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CONDITIONS FOR THE FORMATION OF OUTFLOW AND ITS CHARACTERISTICS IN RIVER BASINS OF THE LUBLIN REGION

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A b s t r a c t. The Lublin region is the area situated in-between the two rivers: the Bug and the Wisła, and between the Tanew in the south and the Krzna in the North. This area is characterised by very varied terrain and climate conditions of water circulation. In the present study the conditions of the outflow formation were discussed and characteristic parameters of the outflow level that reflect water reserves of the region were given.

K e y w o r d s: surface outflow, river basin, Lublin region, water reserves

CONDITIONS FOR OUTFLOW FORMATION

Rainfall water in the initial phase of the rain is retained by tree leaves, in terrain cavities, in the soil and supplies moisture to the ground. After the initial water capacity of the ground has been exceeded, surface outflow starts to reach rivers after a certain time lag. The process of surface outflow is created when the intensity of rainfall or snow thawing exceeds water infiltration capacity into the bedrock. However, not the whole amount of rainfall reaches the earth surface, part of the rainfall water is utilised by interception, part is retained in the water basins, and part flows directly via rivers. The part of the rainfall that flows into the rivers by surface outflow, is called effective rainfall. The intensity of the process of surface outflow depends both on the climatic factors and on the terrain properties.

Rainfall water that reaches the surface can flow directly into rivers, return to atmosphere in the process of evaporation and transpiration, or can be retained in the soil cover - retained in the ground. Soil plays a decisive role in the distribution of rainfall water into the individual phases of water circulation since intensity of infiltration, surface outflow, and the level of soil retention depend on the type of soil. Distribution into individual phases of water circulation depends first of all on the granulometric composition of the soil, methods of soil utilisation, level and schedule of agrotechnical treatments, as well as on the depth of bedrock occurrence. The granulometric composition of the soil, type of rock and its origin, decide on its water capacity and permeability. In the regions with high soil water permeability the density of permanent river net is low, since rainfall water can easily penetrate into underground water system. Whereas the soils with high water capacity, keep part of the moisture in the soil profile, which limits the supply to underground waters and favours surface outflow along saturated ground. It should be noted, that even though every region soils constitute a constant factor, conditions of infiltration change with air and ground temperature, plant cover and farming routines.

Most often the outflow of rainfall water appears in the areas build up of impermeable formations. Whereas good permeability of the ground decreases surface outflow, as part of the rainfall water is retained underground. Drops of water flow down the surface and join forming water races, which, in turn, join to

form episodic streams that flow into permanent net of rivers. The velocity of water flow depends on the intensity of rainfall, differentiation in the initial conditions of the flow resulting mainly from the terrain inclination and ground permeability.

The higher the ground elevation, the more intense rainfalls. The pattern of the main elements in the terrain relief against the most frequent air masses is also a factor that influences the level of water supply. Terrain inclinations and the character of terrain relief of the place with the highest elevation considerably influence water circulation, mainly the structure of outflow. Moreover, terrain relief decides on the pattern of water net, course of water divisions, shape of the basins, which also strongly influence the time of concentration of water outflow. The Lublin region is the area situated in-between the two rivers: the Bug and the Wisła, and between the Tanew in the south and the Krzna in the North (Fig. 1). It covers two whole geographic regions - the Lublin Upland and Polesie Lubelskie, together with Roztocze within the Polish borders. It also covers small parts of the Mazowsze Lowland and Podlasie in the north, and some fragments of Sandomierz and Pobuże Dales in the south. This area is characterised by very varied terrain and climate conditions of water circulation. In the present study the conditions of the outflow formation were discussed and characteristic parameters of the outflow level that reflect water reserves of the region were given.

The main elements of the terrain relief in the Lublin Upland and Roztocze are summit levellings formed on several levels, denudation monadnocks, steep slopes falling with their edges into depressions and deeply cut river valleys, together with big amount of dry valleys and young erosion cuts. Live terrain relief is visible at high relative altitudes reaching up to 80-120 m. Steep slopes with inclination of 15-20^{o} are also characteristic. This live relief favours surface outflow, even though it is effectively counteracted by high water capacity of the soil and good ground permeability.

In the Lublin Upland and Roztocze about 55% of the area is occupied by the soils formed of loess and loess like formations. They are characterised by medium or low water conductivity. General water capacity, despite poor permeability, is high. In order to enable the transfer of rainfall water into the ground, there must be rainfall supply for a longer period of time. Slow movement of water decides on the levelling of underground supply and on the time lag between supply and outflow. High susceptibility of soils to erosion is their unfavourable feature.

An important feature of this region that manifests its geographical differentiation is points to the characteristic features of water circulation, is density of the river net. The Lublin region belongs to the areas with the strongest differentiation in Poland as far as the density of occurrence of surface water forms. The water net is the least frequent in the Lublin Upland, which results mainly from the permeability of surface formations. Whereas in the lowland areas, and especially in the Lublin Polesie the net of surface water is very dense. It has been very strongly transformed during melioration work.

MEAN OUTFLOW

The mean unit outflow from the Lublin Region in the period 1951-1990 was 3.92 l/s km^2. In the lowland part of the region it was 3.47 l/s km^2, and in the highland part it was 4.08 l/s km^2. In the above region mean unit outflows vary from 3.3 l/s km^2 in the Huczwa basin and regions close to the Bug to 7.0 l/s km^2 in the area of south Roztocze slopes. High values of about 6.0 l/s km^2 were noted in the Tanew basin and a little lower, of about 5.0 l/s km^2 at the north Roztocze slope (the upper Wieprz, the Por). In the central part of the Lublin Upland unit outflows exceed 4.0 l/s km^2, whereas at the peripheral part of the region, especially in its eastern parts and in the lowland areas, unit outflows are lower than 4.0 l/s km^2.

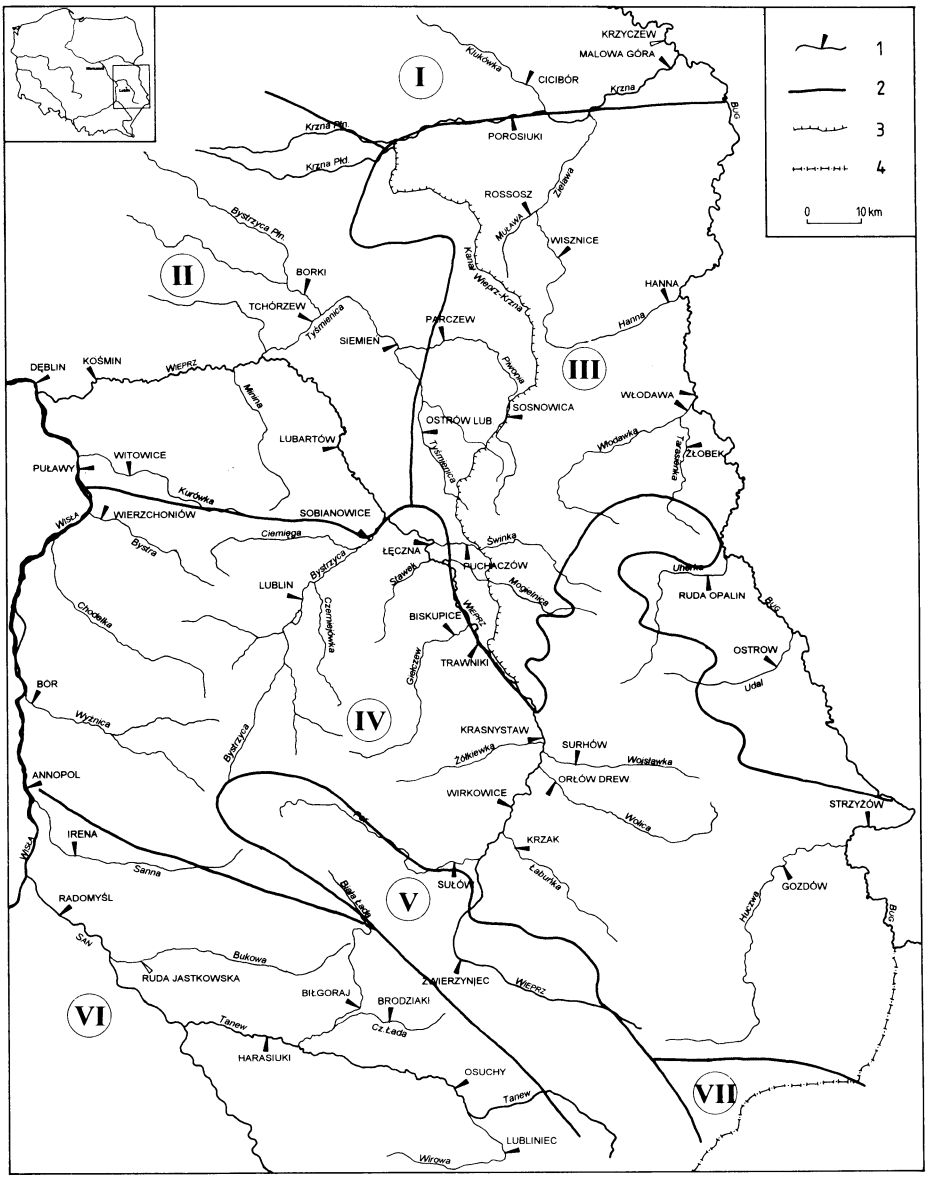

Fig. 1. River net and physiographic regions in the Lublin region. 1. River net and water-gauge. 2. Borders of physiographic regions. 3. The Wieprz-Krzna Canal. 4. Borders of the country. Physiographic regions: I. Podlasie, II. Mazowsze, II. Lublin Polesie, IV. Lublin Upland, V. Roztocze, V.I Sandomierz Basin, VII. Bug Basin.

Changes in the outflow levels from year to year are not identical, but their rhythm is similar. It follows from the fact that outflow depends mainly on the climatic conditions, i.e., precipitation and evapotranspiration that are not very differentiated in the area in-between rivers. Studies on the irregularity of the annual outflow showed that the lowest variability was noted in the rivers of the Roztocze region where high underground retention considerably levels the outflow [8]. In the 40-year period from 1951 to 1990 the mean annual flow in the Wieprz in Kośmin varied from 70.0 m^3/s in 1967 to 21.2 m^3/s in 1990. It means that the coefficient of irregularity is 3.30. A similar annual variation in the flow was noticed in the upper part of the Wieprz basin (Krasnystaw - 2.76) and in other upland rivers: the Tanew in Harasiuki - 2.99, the Por in Nawóz - 2.34. These levels are typical for the plain rivers with snow-rainfall water feed. Higher irregularity of the annual outflow occurred in the lowland part of the region, and especially in the Polesie Lubelskie in which shallow reserves of underground waters that feed the rivers are very poor. The coefficient of irregularity of the Tyśmienica in Tchórzew was 4.24, and the Krzna in Malowa Góra - 4.39 [9].

The amount of outflowing water showed seasonal rhythm which depends mainly on the climatic conditions. In all the rivers underground waters, together with melting snow and rainfall are the source of feeding. Annual course of air temperature makes the highest monthly outflow occur in the period of spring thawing. Summer outflow is low since precipitation of the warm summer months is utilised to a large extend for evapotranspiration. The minimum outflow appears in late summer of early autumn sine the reserves of underground waters are slowly being used up, evaporation is still high, and the period of autumnal rains has not come yet. In autumn precipitation increases, but decreases slightly again in winter which results from the inhibition of surface feeding caused by the temperatures below zero. This secondary outflow minimum (only slight due to the unstable winter conditions) distinguishes the rivers of the Lublin region from other rivers of western Poland [9].

Underground retention plays a very significant role in the generation of outflow size and its variability. In the Roztocze and in the western and central part of the Lublin upland good conditions for water retention underground favour levelling of river outflow. Thanks to that seasonal outflow rhythm, no matter how significant, is characterised by a low amplitude of changes. A monthly coefficient of flow in the rivers is lower than 2, whereas in the lowland rivers is exceeds 3. It is related to the low retention abilities of the substrate and quick exhaustion of underground reserves.

Despite general similarities in the outflow variability caused mainly by the climatic conditions (precipitation and evapotranspiration), a regional differentiation of the outflow rhythm in the rivers of the Lublin region have been found. Differences in the sizes of the spring maximum are most noticeable. The lowest spring flow increase is observed in the rivers that flow from the Roztocze, i.e., the upper Wieprz, the Wyżnica, the Por, the Biała Łada, and the Bystra that drains the western part of the Lublin Upland. In all the above rivers the coefficient of monthly flow does not exceed 1.4, i.e., the flow does not reach 140% of the mean flow. The highest monthly coefficients of flow variation (2 and more) are observed in the rivers of the eastern part of the Lublin region, both in the upland - the Uherka, Huczwa, Wolica, and in the lowland - the Krzna, Włodawka [9].

MAXIMUM OUTFLOWS

Analyses of 24 h flows point to the occurrence of extreme annual maximum and minimum values in each of the seasons. For example, in the period 1951-1990 maximum flows in the Wieprz at Kośmin appeared most often in spring (13 times in April and 11 times in March). However, in 8 years they were observed in winter, and it 4 cases in autumn. Only once the yearly maximum of flow was observed in the summer months - July [9]. Similarly in other rivers of the Lublin region high flows

were recorded most often in spring, and far less frequently in the summer months. The highest swells are generated during thawing, when rain falls onto the snow cover. The level of swells depends mainly on the reserves of water gathered in snow and amount of rain water as well as on the conditions of ground freezing.

Comparison of swell water outflows in various basins and evaluation of their mean and episodic (maximum) levels is possible after the amount of water outflow from 1 km^2 has been evaluated. The level of maximum annual flows of the biggest river in the Lublin region - the Wieprz at Kośmin - ranged from 591 m^3/s to 40.0 m^3/s in the period 1951-1995. The unit outflows related to these flows were, respectively, 50.7 l/s km^2 and 3.91 l/s km^2; and the coefficient of irregularity is 13.0. A similar variation in the maximum flows occurs in other big rivers of the Lublin region, i.e., the Tyśmienica and the Krzna in which the coefficient of irregularity exceeded 13, and the maximum unit outflows were 48.7 l/s km^2 in the Tchórzew profile, and 58.2 l/s km^2 in the Malowa Góra profile. Higher variation in the maximum flows occurred in the upland rivers where terrain configuration favours quick outflows and generation of big swells. Maximum unit outflow from the Bystrzyca basin was 88.5 l/s km^2 in the Sobianowice profile, and 100.0 l/s km^2 from the Wieprz basin in Krasnystaw. Out of the big rivers, the highest unit outflow of 112.1 l/s km^2 was recorded for the Tanew in Harasiuki [9]. On the basis of the materials collected spatial differentiation of the maximum unit outflows from the biggest basins of the rivers in the Lublin region that ranged from 46 to 108 l/s km^2. Most of the data show unit outflows at the level of 70-100 l/s km^2. The recorded levels of outflow were located at the probability level of maximum flows of 2-3%. Unit outflows with probability of exceeding 50% are several l/s km^2 in the case of the rivers of Lublin Upland. The recorded values of maximum unit outflows belong to the lowest in this country.

The level of maximum outflows increases with the decreasing area of the basin. For example, the maximum unit outflow from the Wieprz basin to Krasnystaw is 120 l/s km^2, and in the Bystrzyca basin to Sobianowice - 267 l/s km^2 [3]. Unit outflows from other basins with the areas of 300-400 km^2 can even exceed 300 l/s km^2. In the smaller basins of up to 100 km^2 - unit outflows can considerably exceed 500 l/s km^2. Culmination unit outflows form the uplands can reach 20 m^3/s km^2. Outflows at the level of several m^3/s km^2 appear only in the basins with small areas.

The highest values of unit outflows are recorded in the very small basins. Swells on small rivers can be best characterised by the unit outflow with the level that can considerably exceed outflow from big rivers. The highest values appear during heavy rains in the small basins of the upland part of the inter-river river area. The a.m. swells take place during warm part of the year and are usually limited to small areas and short periods of time. In their peak moments they give unit outflows several times, or even several hundred times higher than the maximum levels in big basins. They often occur in the neighbourhood of Krasnystaw, Kazimierz, and Kraśnik. The highest recorded unit outflow occurred in the region of Izbica, where on 16/17. August, 1949, 19.4 m^3/s km^2 out flowed from the basin with the surface of 0.8 km^2 [5]. Episodic unit outflow from the Łopuszanka stream in Piaski Szlacheckie with the surface of 11.5 km^2 was 16.7 m^3/s km^2 in 1956. Also in the neighbourhood of Piaski Szlacheckie in the basin of Ostrzyca stream with the area of 30.6 km^2 an episodic unit outflow of 5.73 m^3/s km^2 was recorded [5,6]. A slightly lower unit outflow was observed in the Grodarz basin in Kazimierz, where 3.66 m^3/s km^2 outflowed from the area of 29 km^2 in May, 1936 [6], and 1.27 m^3/s km^2 in June of 1981 [7]. From a tiny canyon basin near Dzierzkowice an episodic outflow of 2.68 m^3/s km^2 was observed in June, 1969 [1]. A little lower maximum outflow was recorded in May 1996 in the small basins around Wojsławice - 2.44 m^3/s km^2, and Kukawka - 1.04 m^3/s km^2 [4]. According to Ciepielowski [2] culmination unit outflows of a few to several m^3/s km^2 can appear only in the basins of upland rivers with small areas.

MINIMUM OUTFLOWS

The minimum annual levels of flows occur in various seasons but most often in August, September, and July. Changes in the levels of minimum yearly flows are very small when compared with the maximum levels. For example, the minimum yearly flows in the Wieprz at Kośmin changed from 28.6 m^3/s km^2 to 9.20 m^3/s km^2, i.e., to 0.90 l/s km^2. Very small unit outflows of the big rivers in the Lublin region do not reach 1.0 l/s km^2. The lowest minimum values of outflows occur in the lowland rivers of the Lublin region and are of the level of 0.3 l/s km^2, e.g., the Krzna in Malowa Góra 0.32 l/s km^2, the Tyśmienica at Tchórzewo - 0.34 l/s km^2. The upland rivers show the minimum unit outflows of higher level and they do not fall below the level of 1.0 l/s km^2, for example the Wieprz in Krasnystaw - 1.16 l/s km^2, the Bystrzyca at Sobianowice - 1.16, the Tanew in Harasiuki - 1.43 l/s km^2.

The minimum flows in some small rivers of the Lublin region are reduced to zero after prolonged dry periods or at low temperatures, when water in the flume freezes down to the bottom. In the upland rivers flows are slightly higher and the possibility to observe considerably lower flows than the ones recorded so far in small unlike in the lowland rivers.

CONCLUSIONS

The size of mean outflow and its seasonal variations together with the occurrence of extreme values depends on the climatic and terrain conditions of water circulation, and what is even more important, on the intensity of feeding, air temperature and retention capacity of the ground. Beside the type and intensity of precipitation and terrain configuration, factors such as permeability and absorbability of the soil and underlying rocks under the soil layer or on the topographic surfaces, as well as soil cover and ground utilisation, decide on the water seepage into the bedrock and its surface outflow or retention. Spatial variations in the properties mentioned above create great variety of conditions for the circulation of precipitation water in the Lublin region. At the same time it is possible for man to influence individual directions of water circulation in the way that suits his needs. A desirable direction of changes in the outflow conditions should aim at water retention in the soil and bedrock which, in turn, should lead to a decrease in the surface outflow and an increase in the water resources of the basins that are at our disposal. It can be achieved by changes in the structure of agricultural soil utilisation, mainly by forestation of the terrains with high inclination and application of suitable agrotechnical treatments that would follow strictly the prescribed schedule, as well as construction of correction dams that would slow down outflow and retention reservoirs, also in the upper parts of the basins. It is also necessary to protect the basins from pollution resulting from human activities in order to preserve high quality of the stored water.

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