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LONG-TERM TRENDS OF GROUNDWATER RUNOFF CHANGES OF THE VOLYN POLISSIA RIVERS (UKRAINE)

WIELOLETNIE TENDENCJE ZMIAN ODPŁYWU PODZIEMNEGO DO RZEK POLESIA WOŁYŃSKIEGO (UKRAINA)

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Abstract. In this study the contribution of individual sources of river flow Volyn Polissia (Ukraine) by base flow separation techniques for two specific periods: 1961–1990, and 1991–2010, the multiplicity of 1961–1990 was considered as representative to obtain reliable values climate standards. The calculations indicate significant changes in the structure of river outflow. The share of power in the downstream river snow fell from 47 to 28%, and has increased the role of groundwater. Average annual runoff into rivers Polesie groundwater runoff in the Volyn Ukraine for the period 1961–1990 was approximately 38% of the total outflow. Today (1990–2010 onwards) component supply groundwater runoff rose about 1.4 times and is 53%.

Key words: climate changes, groundwater runoff, hydrograph, characteristics of stream flow, Volyn Polissia (Ukraine).

Abstrakt. W pracy określono udział poszczególnych źródeł w zasilaniu rzek Polesia Wołyńskiego (Ukraina) za pomocą metody genetycznego podziału hydrogramu odpływu dla dwóch charakterystycznych okresów: 1961–1990 i 1991–2010. Wielolecie 1961–1990 uznano za reprezentatywne do uzyskania miarodajnych wartości normy klimatycznej. Przeprowadzone obliczenia świadczą o istotnych zmianach w strukturze odpływu rzecznego. Udział zasilania śnieżnego w odpływie rzecznym zmniejszył się z 47 do 28%, natomiast została wzmożona rola wód podziemnych. Średni roczny odpływ podziemny do rzek Polesia Wołyńskiego na obszarze Ukrainy dla okresu 1961–1990 wynosił około 38% odpływu całkowitego. Współcześnie (1990–2010) składowa zasilania podziemnego rzek wzrosła około 1,4 razy i wynosi 53%.

Słowa kluczowe: zmiany klimatyczne, odpływ podziemny do rzek, hydrogram, przepływy charakterystyczne, Polesie Wołyńskie.

PROBLEM STATEMENT

Methodology of hydrological calculation bases on statistic data processing of a previous long-term research when hydrological characteristics spread for the particular time of operation or planning measures which are under projection (Galuszczenko, 1987). Such approach is followed from the conception about the stationary (quasi-stationary) of the pro-

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cess of long-term climate changes of stream flow forming. Validity of such approach nowadays stimulates a lot of doubts due to climate changes which happen at last decades.

The climate changes inside the research area have become apparent in the average annual temperature rise of air by 1.0°C relative to normal for last 20 years (1990–2010). The greatest change of air annual temperature is fixed in winter and spring seasons. Their annual temperature has risen by 1.6 °C (winter) and 1.3°C (spring). The amount of precipitations rose in all the seasons (except winter) – substantially in spring and autumn (by 12 and 8%). The sum of summer season precipitations is practically stable. The winter season characterizes by the decrease of the amount of precipitations, particularly during December and January (by 15–18%) (Grebin, 2010).

The changing of water-thermal balance components which happened during two decades caused some changes of the stream flow regime in the Area Rivers (Dobrowolskij, 2007). For study of the change of river runoff regularity is necessary to learn the power source and modern changes of them (Dżamalow, 2008). It was the main goal of our research.

STATEMENT OF RESULTS

Volyn Polissia is located between the rivers Zakhidnii Buh in the West and Sluch in the East (Fig. 1). The territory is covered by lakes, by swamps and woodland.

At the foot of the basin there is Precambrian crystal rock (mainly granite and gneiss). It is usually covered with shale and cracked clay/ on the clay stratum lie carbon sediments: sent, limestone. The carbon layer in the upper and middle part of the basin is covered with Neogene rock (grey send) on which limestone and quartz sent lie. The surface layer consists of Quaternary Age stuff which is characterized by the developing of moraine sediments, fluvial-glacial send, loam and loess. The soil in the upper part of the basin is clay-sandy and large dusty loamy, and in some places it is dust heavy-loamy in the lower part – mostly sandy or clay-sandy. The annual fluctuations of the levels on the rivers of the indicated territory which refers to the area with high and sufficient moisture is characterized by high spring-flood and rather low-water which interrupts by floods caused by rain and snow-melting. Spring-flood replaces by summer-autumn low–water which is characterized by significant changeability. The summer low-water is lower than in winter. Rain floods during the summer-autumn period happen almost every year. The autumn floods are the highest and the longest. The winter low-water is often interrupted by the thaw and is a result of winter-floods in some years are higher than the spring-floods. The annual value overriding of maximum spring level comparing the minimal summer level is 1.0–2.5 m.

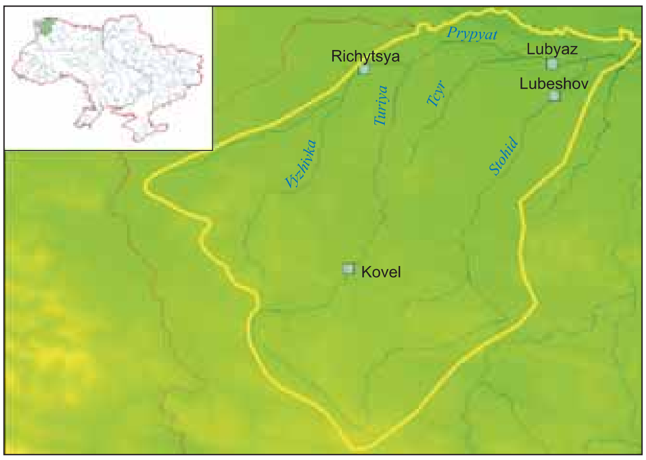

Fig. 1. Location of the research area within Ukrainian boundaries

Lokalizacja obszaru badań na terenie Ukrainy

The river stream flow regime of the indicated territory is determined by their river alimentation which, depending on the season could be snow-melting or rainfall or groundwater. The river alimentation is has mixed type with the predominance of a particular kind. So, in spring the river have the mixed river alimentation that includes snow-melting, rain and groundwater; in the low-flow period they have (summer-autumn and winter) – mostly groundwater runoff, during rain floods – rainy and groundwater runoff (Vasylenko, 2010).

The most common method of determining the types of hydrological power source of the river is runoff hydrograph separation into parts that characterize the surface and groundwater runoff. So hydrograph separation is to allocate the groundwater components, which are determined by the dynamic of the degree of hydraulic communication channel and groundwater.

To take in to consideration the river alimentation is mainly due to the groundwater zone of intense water exchange it seems appropriate to allocate of two components groundwater runoff – subsurface (short-term variability) and the base or main (long volatility). The later one is the most important from the point of view of regular supplies of the river water (Vasylenko, Grebin, 2010).

Using the daily discharge water data in some selected gagging stations, average stream discharge hydrographs for each gagging stations were plotted for two character periods: before 1990 and 1990–2010 (Figs. 2, 3).

The analysis of these hydrographs proves the changes in runoff distribution. As human impact during this period has not changed dramatically, the reasons of the annual distribution of stream flow distribution that occurred should be searched in changes in the conditions of rivers alimentation, caused changes in climate.

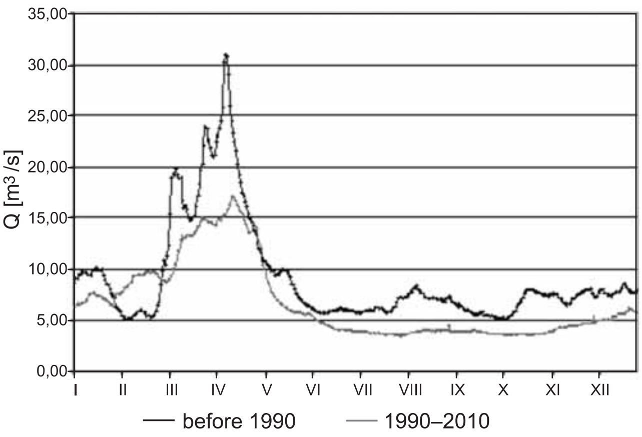

Fig. 2. Averaged runoff hydrograph by g/ n river Prypyat (Richytsya) for two periods (before 1990 and 1990–2010)

Uśredniony hydrogram odpływu rzeki Prypeć (Riczycia) dla dwóch okresów (1961–1990 i 1990–2010)

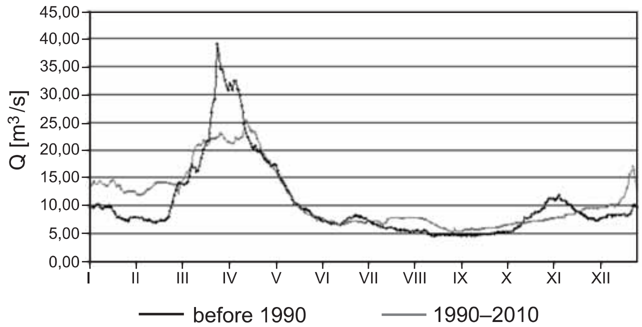

Fig. 3. Averaged runoff hydrograph by g/ n river Stokhid (Lubeshov) for two periods (before 1990 and 1990–2010)

Uśredniony hydrogram odpływu rzeki Stohid (Lubeszіw) dla dwóch okresów (1961–1990 i 1990–2010)

The visual observation of hydrographs shows the decrease in the height and volume of spring flood which is caused by lessening of snow-melting river alimentation for Volyn Polissia rivers. The increase in water content during the winter low- water is caused by the climatic conditions of the season over the past decades. It is shown in frequent thaws, causing melting of snow cover, in reduce the depth of soil freezing and replenishment of groundwater. Some decreasing water content of summer-autumn period low-water in the rivers of the region due to the fact that with increasing the temperature and maintaining rainfall in this period, the increasing volume of evaporation on catchments and reduce the river runoff happened.

The most common method of hydrological determining the types of river alimentation is hydrograph separation into parts, which describes surface and groundwater runoff, the dynamics is determined by the degree of hydraulic communication of stream flow and groundwater.

The method involves the separation of groundwater runoff through a straight line or a smooth curve that combines the latest winter water discharge and discharge of summer low-water. Later it was proposed to separate an groundwater runoff into two components – the deep groundwater and subsurface flow. Excretion of a deep groundwater is carried out by determining of a horizontal line, which is held on the hydrograph through the point of the minimum discharge. Further, this method stripping of groundwater runoff without significant changes adopted by the most researchers.

Researches conducted earlier have concluded that the value of the minimum average runoff for a certain long period corresponds to the full river alimentation of the groundwater, and the value of the minimum annual runoff to the size of base groundwater runoff. Using data on daily water discharge, the averaged runoff hydrographs have been built for each of the gauging stations for two specific periods: before 1990 and 1990–2010.

The getting results of a particular type of river alimentation for each of the two characteristic periods were summarized in table 1.

Analysis of the table shows that the rivers in the region have mixed river alimentation with snow-melting, rain and groundwater. From the prevalence of certain types of river alimentation and changes throughout the year annual distribution of stream flow fluctuations depend. During the first billing period (before 1990) River basin was characterized by mixed river alimentation dominated by snow-melting, which part was almost 47%. Because of changes in climatic characteristics listed above, the part of snow river alimentation significantly decreased and now is only 28%. Significant for this region is the part of groundwater runoff. Changes in components of water –thermal- balance that occurred over the past decades have led to the growth of this component of the rive alimentation in this region and now it reaches 53%. This is almost twice the share of groundwater runoff base. Changes rainy component in the river alimentation in this region are relatively minor.

These changes in river alimentations that have occurred in recent decades in the region, caused some redistribution of annual stream flow distribution. There was some reduction

Table 1

Part certain types of river alimentation for river for rivers Polesie Volhynian

Udział głównych źródeł w zasilaniu rzek Polesia Wołyńskiego

Time	Type of river alimentation by [%]			
	snowmelt	rain	groundwater	base groundwater
Before 1990	46.4	15.8	25.9	11.9
1990–2010	27.9	19.1	31.5	21.5

in the volume of runoff summer-autumn low-water (mainly due to the fall season), with increasing the volume of winter low-water runoff at the same time (Fig. 4). Most of these changes occur on reclaimed areas (upper reaches Prypyat basin and the river Turia), they are smaller in the Stokhid basin.

Changes in components of water-thermal balance that occurred over the last twenty years, led primarily to changes of the mean water flow, which is caused mainly by groundwater runoff.

For Volyn Polissia rivers more pronounced is the summer-autumn low-water flow (when there is depletion of groundwater) that is interrupted by certain rises caused by rain -floods and winter time, which interrupted the level rise due to melting snow during thaws. Winter low-water is higher as groundwater runoff is formed due to autumn moisture, and due to groundwater river alimentation and melt-water during the thaw.

The beginning of the summer-autumn low water in the rivers of the Upper Prypyat basin, on average, is observed in the third week of May - early June. The average duration of the summer-autumn low-water is 120–140 days, the average length of the most low-water period of summer-autumn low-water is 20–30 days. The beginning of the winter low -water in the rivers basin occurs mainly in the third week of November – the first half of December. The average length of low water is 60–80 days. The end of winter low- water time comes mainly in the first half of March.

Components of the seasonal changes of water-thermal balance depended on corresponding changes in temperature and precipitation during the year, coasted in a significant increase in the mean water runoff (Fig. 5)

The increase of the minimum annual water discharge in the rivers basin were started to fix in the 70-ies of the last century. It is shown by constructed for selected gauging different integral curves fluctuation minimum annual discharge of water (Fig. 6).

Differential integral curve minimum annual discharge on water for rivers is a curve of minimum flows totaled deviations from the annual arithmetic mean of all the minimum annual flow:

$$K_i = Q_i / Q_{śr.}$$

where:

K_i – coefficient of variation of the test values from the arithmetic mean,

Q_i – the size of the minimum annual flow in a given year,

$Q_{śr.}$ – the arithmetic mean of all the minimum annual flow (Wladimirow, 1990).

The process of the growth of the minimum discharge increased significantly from the end of 80-s of XX century, which also associated with climate change.

Minimum winter average monthly discharge increased during 1990–2010 years in all rivers Volyn Polissia. The value of growth ranged from 13% (r. Prypyat – s.Richytsya) to 58% (r. Prypyat – s. Lyubyaz). Previously, the minimum winter average monthly discharge within the region was mostly in the month of January, during the last decades they are fixed in the month of December.

Essential for the past two decades, the above changes and the period of summer-autumn low-water are important. Almost for all the gauging states they have increased from 24%

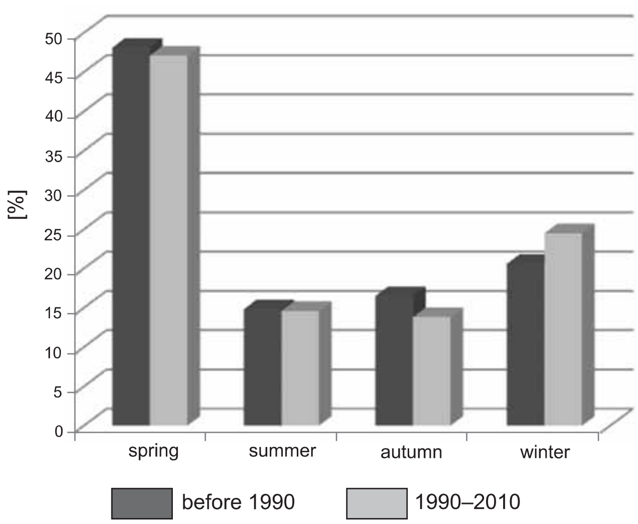

Fig. 4. The annual stream flow distribution basin Upper Prypyat for two periods (before 1990 and 1990–2010)

Zmiana w sezonowej strukturze odpływu rzecznego Górnej Prypeci na przykładzie dwóch okresów porównawczych (1961–1990 i 1991–2010)

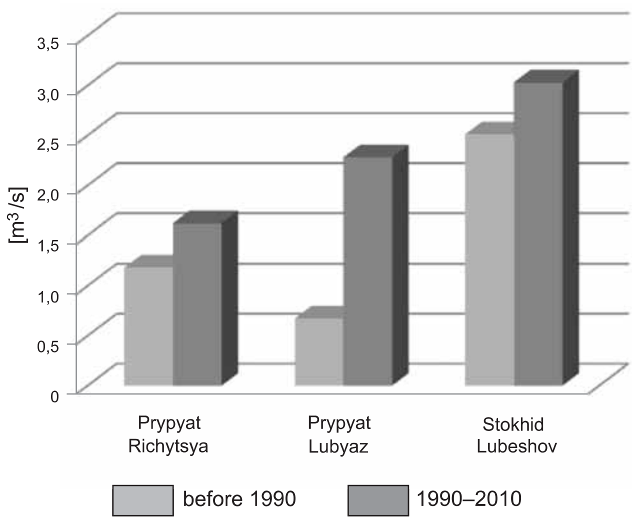

Fig. 5. Minimum annual water discharge in some rivergauging Volyn Polissia two periods (before 1990 and 1990–2010)

Zmiany w minimalnych rocznych przepływach rzek Polesia Wołyńskiego na przykładzie dwóch okresów porównawczych (1961–1990 i 1991–2010)

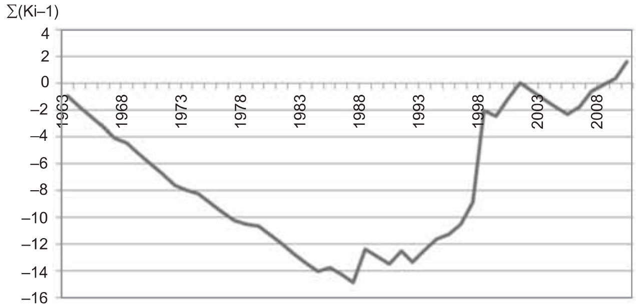

Fig. 6. The integral curve fluctuation minimum annual discharge on water for gauging river Prypyat (Lubyaz)

Różnicowa krzywa całkowania minimalnych rocznych przepływów rzeki Prypeć (Lubiaz)

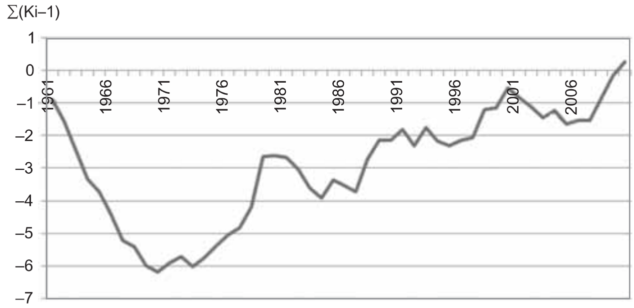

Fig. 7. The integral curve fluctuation minimum annual discharge on water for gauging river Stokhid (Lubeshov)

Różnicowa krzywa całkowania minimalnych rocznych przepływów rzeki Stohid (Lubesziw)

(r. Stokhid – smt Lubeshov) to 41% (r. Turiya – Kovel). Exceptions are gauging r. Prypyat – s. Richytsya. For the recent decades, the average summer minimum water discharge at the site of the gauging states tend to decrease. The later fact is coast by the work of Verhnopryp'yatskoyi drainage-wetting system. Limiting the time intervals for the basin have not changed and are the same therefore, in fall (limiting season) and September (limiting month).

CONCLUSIONS

Changes in components of water-thermal balance that occurred over the past two decades have caused some changes of stream flow regime of the rivers in Volyn Polissia. To study these changes in river discharge were considered the sources of their alimentation and their modern changes. Over the past twenty years, the part of snow river alimentation of the region declined from 47 to 28%. The part of groundwater runoff increased to 53%. Changes of the rainwater river alimentation component is insignificant.

These changes in river alimentation that have occurred in recent decades in the region, caused some redistribution of the annual stream flow distribution. There was some reduction in the volume of runoff summer-autumn low water (mainly due to the fall season), with increasing the volume of winter runoff at the same time.

Components of the seasonal changes of water-thermal balance due to corresponding changes in temperature and precipitation during the year, coast to the significant increase in the mean water- flow. Minimum winter average monthly discharge increased during 1990–2010 years in all rivers of the region from 13 to 58%. The above changes for the past two decades and minimum monthly runoff of summer-autumn low-water period increased from 24 to 41% are essential.

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STRESZCZENIE

Współczesne zmiany klimatyczne warunkują przekształcenie składowych cyklu hydrologicznego. Przeprowadzono ocenę wieloletnich zmian odpływu podziemnego do rzek Polesia Wołyńskiego i jego udziału w całkowitym odpływie rzecznym na podstawie analizy przepływów dobowych z lat 1961–2010 dla następujących rzek: Prypeć (stacja w Riczyci i Lubiazi), Wyżiwka (Stara Wyżiwka), Turia (Kowel) i Stohid (Lubesziw). W celu wyjaśnienia przyczyn zmian reżimu hydrologicznego tych rzek analizie poddano także główne charakterystyki meteorologiczne, tj. temperaturę powietrza i opady atmosferyczne. Zmiany klimatyczne na obszarze Polesia Wołyńskiego odzwierciadlają się we wzroście w ciągu ostatnich 50 lat średniej rocznej temperatury powietrza o ok. 1,0°C. Największe ocieplenie obserwuję się w okresach zimowym (o 1,6°C) i wiosennym (o 1,3°C). Ilość opadów atmosferycznych zwiększyła się w okresie wiosennym (12%) i jesiennym (8%). Suma opadów sezonu letniego nie uległa zmianie. Okres zimowy charakteryzuje się zmniejszeniem ilości opadów atmosferycznych, szczególnie w grudniu i styczniu (o 15–18%).

Na podstawie metody genetycznego podziału hydrogramu odpływu rzecznego określono udział poszczególnych źródeł w zasilaniu rzek Polesia Wołyńskiego (Prypeci, Wyżiwki, Turii oraz Stohidu) dla dwóch okresów: 1961–1990 i 1991–2010. Przeprowadzone obliczenia świadczą o istotnych zmianach w zasilaniu podziemnym i śnieżnym wymienionych rzek. W latach 1961–1990 dominującym źródłem zasilania rzek były wody roztopowe. W ciągu ostatnich dwudziestu lat udział zasilania śnieżnego w odpływie rzecznym zmniejszył się z 47 do 28%, natomiast została zwiększona składowa zasilania podziemnego rzek. Współcześnie (1991–2010) średni roczny odpływ podziemny badanych rzek wynosi około 53% odpływu całkowitego i jest w 1,4 razy większy, niż w latach 1961–1990. Udział zasilania deszczowego nie uległ istotnej zmianie. Obserwuje się spadek wielkości odpływu w okresie letnio-jesiennym (głównie jesiennym) oraz wzrost przepływów zimowych. W porównaniu z okresem 1961–1990 w latach 1991–2010 minimalne zimowe średniomiesięczne przepływy rzek Polesia Wołyńskiego zwiększyły się przeciętnie o 13–58%.