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Water flow distribution changes for characteristic sections of Pripyat River basin (Ukraine)

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SUMMARY

Water discharge is the main quantitative characteristic of river water runoff, which is directly measured at the hydrological stations, in contrast to other runoff characteristics that flow from it.

The study of the total potential of hydropower, which involves the allocation of characteristic sections of rivers by the subdivision method, includes one of the intermediate steps - determine the average water discharge for these sections using existing water runoff maps. Thus, the determined data allowed us to estimate changes in the water flow distribution of rivers downstream and to create a map based on the results of the study.

To assess the reliability of the created map, a comparative assessment was conducted between water discharge for characteristic sections of rivers: determined by the map and the actual values determined by long-term data of hydrological stations located within these sections.

As the studied basin is transboundary, so with the help of the obtained results, it is possible to estimate the water flow for the sections of rivers near the border, where there are no stationary observations at the hydrological stations.

Introduction

During the study of river water regimes and their forecasting, an important step is to assess the water flow of rivers. Usually in hydrology, mainly in operational hydrology, the water flow of rivers is estimated using water discharge values, which are measured at stationary hydrological stations or temporary hydrological observation points. Thus, water discharge is the main quantitative characteristic of river water runoff, which is directly measured at hydrological observation stations, in contrast to other runoff characteristics that are derived from it (*Obodovsky et al.,* 2020 a).

As part of the study of the hydropower potential of rivers of the Pripyat basin within Ukraine, the calculation algorithm of which establishes the need to determine the average annual water discharge for the characteristic sections of rivers, which are selected by the subdivision method (*Korniienko et al*., 2020). We assessed changes in water flow distribution for these sections of the studied basin rivers.

Since cartographic images have scientific value for practical use, one of the tasks of our study was to create a map of water flow distribution changes for characteristic sections of the Pripyat basin rivers within Ukraine. For this purpose, the data of average water discharge, which are characteristic of the selected characteristic sections of rivers, were used.

However, in contrast to the maps of runoff modules, where interpolation was performed within the calculated values and izolines of runoff modules were obtained, the water flow distribution map for characteristic river sections was based on actually calculated data witch change along the river and have a discrete distribution of values.

Almost for the first time, such a cartographic image of the increase of river flow for Ukraine was presented in the works (*National Atlas of Ukraine,* 2007), (*Kalinin and Obodovskyi*, 2003). But it was quite generalized and a small number of river water bodies were used for the Pripyat basin. Our approach allows us to obtain information about the current spatial distribution of runoff, as well as quantitative characteristics of runoff in the border areas of Ukraine.

Method and Theory

The map creation of the water discharge distribution for characteristic sections of rivers was carried out in the following stages.

According to the algorithm for calculating the hydropower potential of the rivers of the studied basin, the characteristic sections of rivers were identified by the subdivision method, which involves the use of longitudinal profiles of each river of the studied basin.

With the help of GIS tools within the Ukrainian part of the basin, 396 characteristic sections on 259 rivers were identified (*Korniienko et al.,* 2020). During the calculation of characteristic sections of rivers, also were determined such characteristics as the length and absolute height of the terrain, which necessary for further calculations.

For further mapping, which was carried out with the help of open modern GIS, the necessary step was to transfer the selected characteristic sections in a linear layer corresponding to the rivers of the study region. To do this, a network of rivers was created based on the data of the digital terrain model. For this purpose, the main tools of the Hydrology group of the Spatial Analyst unit and the basic functional tools of GIS were used. (*Obodovskyi et al.,* 2020 b), (*Samoilenko et al.,* 2018).

Using data on the length of the selected characteristic sections of rivers, two new layers were created: a linear layer corresponding to the characteristic sections of the studied region rivers and a point layer corresponding to the beginning and endpoints of the characteristic sections.

To determine the indicators of average water discharge for characteristic sections of rivers within the study region, a modern map of water runoff modules is involved (*Obodovskyi and Korniienko*, 2020). Because the determination of runoff modules is carried out for the centers of gravity of catchments, the boundaries of catchments were constructed for outlet points of the basin corresponding to the points of beginning and end of sections. Gravity centers and runoff modules are defined for the created

catchments. The next step was to recalculate the determined values of runoff modules in water discharge. The catchment squares were determined for this purpose. To calculate the average water discharge for each characteristic section of the rivers of the study basin, two values were averaged, which corresponded to the water discharge at the beginning and end of the section, respectively.

Results of investigations

As a result of the research, a linear layer of the Pripyat basin rivers within Ukraine was obtained with the relevant attributive information, which includes the main characteristics of selected sections of rivers, including the value of the average annual water discharge. For the cartographic image, the determined values of the average annual water discharge of the studied region rivers were classified into 8 intervals, which were assigned the appropriate colors (Fig. 1).

A noticeable difference between the created map and the involved map of runoff modules is the inverse distribution of these characteristics over the territory.

According to the map of water flow distribution changes for characteristic sections: water discharge increases downstream (with increasing catchment area), in contrast to the map of water runoff modules, where the largest runoff modules are observed in river headwaters and areas with significant slopes. Therefore, in general, these values decrease with increasing areas (*Obodovsky et al.,* 2020 a).

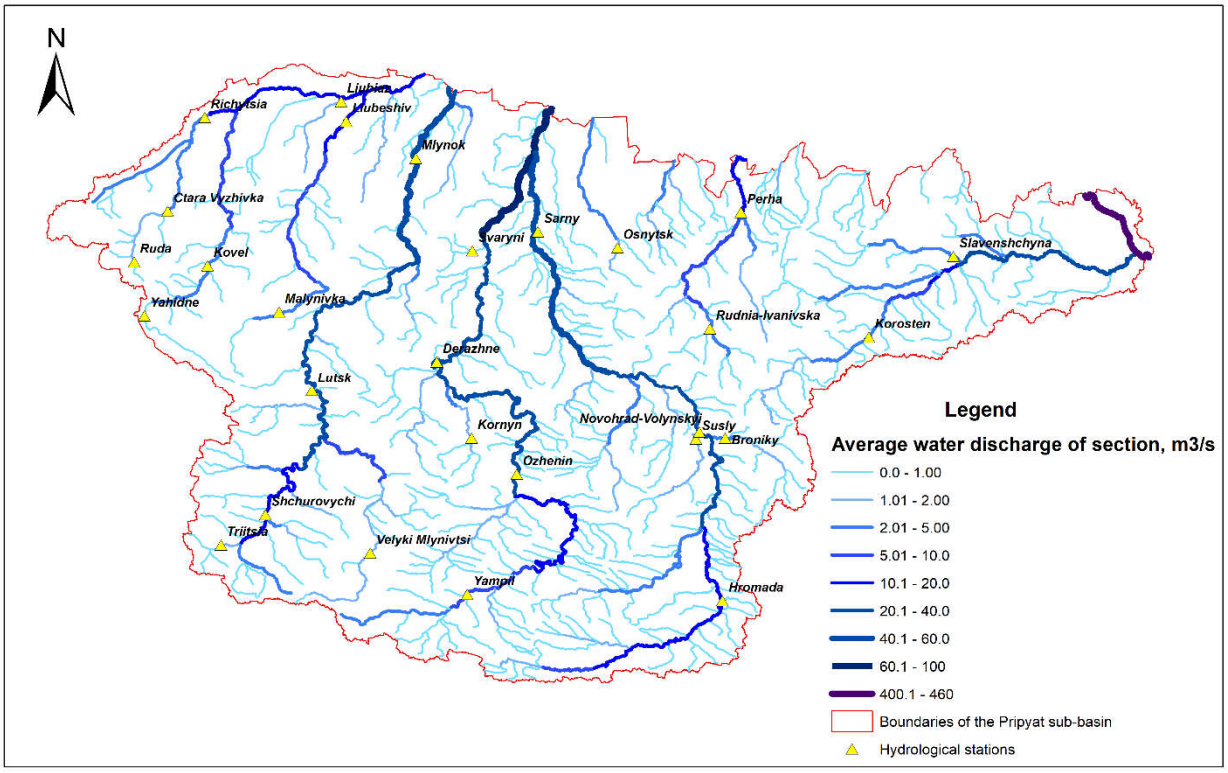

Figure 1 *Water discharge distribution changes for characteristic sections of Pripyat river basin (Ukraine).*

Analyzing the obtained cartographic image of the distribution of average water discharge of the Pripyat basin rivers within Ukraine, it can be determined that in a large area, including the basins of the rivers Vyzhivka, Turia, Stokhid, the middle and lower reaches of the rivers Styr, Goryn, Sluch (central part of the basin). The average annual water discharge is in the range from 1,0-4,0 m^3/s, which corresponds to water runoff modules in the range of 3,2 to 4,0 $l/s*km^2$.

Instead, the center of the largest average annual modulus of water runoff in the Pripyat basin is observed in the upper reaches of the Styr and Horyn river basins – 5,0-5,8 $l/s*km^2$and in the upper reaches of the

tributaries of the Ubort, Noryn, Zherev rivers. – 4,2-5,4 l/s*km^2, but water discharge in these areas does not exceed 3,0 m^3/s.
To assess the reliability of the constructed map (Fig. 1), a comparative assessment was made between water discharges, which was calculated with the help of a study map and which actually determined at hydrological stations on the materials of stationary observations located within these areas. For this purpose, data from 28 hydrological stations within the Ukrainian part of the Pripyat basin were used.
The result is a dependence (Fig. 2) with a high degree of correlation (r = 0.96). Accordingly, it should be noted that the determined water flows within the river sections, in general, are close to the actual values of the average annual water flow, which are measured at hydrological stations.

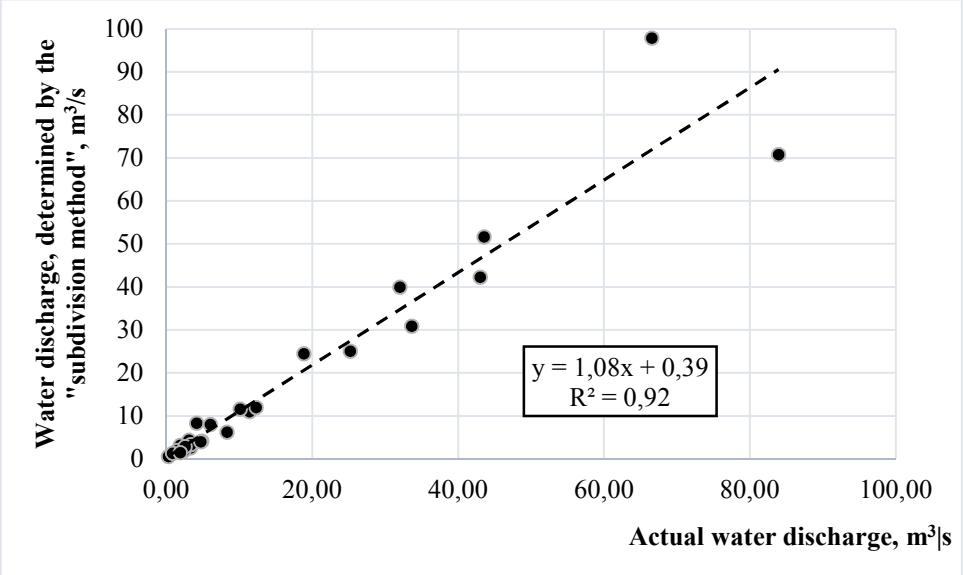

Figure 2 *Dependence of water discharges determined with the help of a map for selected sections and water discharges calculated according to stationary observations at hydrological stations within the Pripyat river basin of Ukraine.*

It should also be noted that the studied basin is transboundary, within which most of the main tributaries of the Ukrainian part of the Pripyat basin carry their flow to the territory of the Republic of Belarus, and the lower part of Pripyat river reach return to the territory of Ukraine with total runoff from both Belarus and Ukraine. Thus, the water flow distribution (values of water discharge) of rivers bordering the state border and are transboundary were determined (Table 1).

Table 1 *The main characteristics of transboundary river sections on the border of Ukraine and the Republic of Belarus*

Section	River	Where it flows	Catchment area, km^2	Water runoff modulus, l/s*km^2	Water discharge at the border, m^3/s	Average Water discharge at the section, m^3/s
Ukraine → Republic of Belarus						
Pripyat - state border	Pripyat	Dnieper	8590	3,42	29,4	18,8
Styr- state border	Styr	Pripyat	12684	3,78	47,9	45,1
Horyn - state border	Horyn	Pripyat	26606	3,48	92,7	66,5
Stvyga - state border	Stvyga	Pripyat	1000	3,8	3,80	3,89
Ubort - state border	Ubort	Pripyat	2994	4,20	12,6	12,3
Slovechna - state border	Slovechna	Pripyat	292,6	4,88	1,43	0,88
Republic of Belarus → Ukraine						
State border - Pripyat	Pripyat	Dnieper	116739	3,89	409	431

Thus, the highest water discharge at the border of Ukraine and the Republic of Belarus has the right-bank tributary of the Pripyat, the Goryn River, with a water discharge at the border of 92,7 m^3/s (according to the calculated values). This judgment is confirmed by long-term data of the station on Goryn river - Richitsa (currently inactive), which is located in the Republic of Belarus, the average annual water consumption was 96,8 m^3/s (*Kalinin and Obodovskyi*, *2003*).

According to Table 1, about 190 m^3/s of river water flows to the territory of the Republic of Belarus, at the same time about 400 m^3/s returns to Ukraine. Thus, the existing information was confirmed that the Ukrainian part of Pripyat and its main tributaries form about 46% of the runoff of Pripyat versus data of hydrological station - Mozyr. (*Kalinin and Obodovskyi*, *2003*; *Volchek*, *2017*).

Conclusions

The obtained map allows to estimate and analyze the water discharge values of the Pripyat basin rivers within Ukraine the studied region rivers. In particular, to determine the average annual water discharge for the selected sections of the studied region rivers.

Such values are first of all necessary for the establishment of the general hydropower potential of the rivers. Since the main variable characteristic in determining the total hydropower potential is water flow distribution at the section, the obtained map acquires additional scientific and practical value.

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