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INFLUENCE OF THE SMALL HYDROPOWER STATIONS ON THE HYDROLOGIC PROCESSES IN THE SERET RIVER (LEFT TRIBUTARY OF THE DNISTER RIVER)

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Abstract. Sources of the Seret River are located near Ratyshchi village in Ternopil region. The river has the length of 248 km, the catchment area is about 3,900 km^2. During the last 15 years seven small hydropower stations (SHPS) have been constructed in the Seret riverbed (Zahidhydroenergo, Velykohaivs'ka, Lux-2, Yanivs'ka, Chortkivs'ka, Bilche-Zolotets'ka, Bilche-Zolotets'ka-2, and Kasperivs'ka). Since all the SHPS are situated in the Seret riverbed and have a dam which decelerate water flow velocity, they influence the water runoff, sediments runoff, and water quality. After their building the cases of flooding of villages, overgrowing of the river bed reservoirs by algae plants became more often, and the long-term dynamics of the water and sediments runoff changed. To assess the water and sediments runoff changes in the catchment and to ascertain correlation between these changes and the SHPS the monitoring data sets of the Hydro-Meteorological Survey of Ukraine and the Carpathian Hydrological Observatory were analyzed. Recently the observations on the water runoff are implemented at two gauging stations: Velyka Berezovytsia village and Chortkiv city. The sediments runoff data are collected by the Chortkiv gauging station. The assessment of the water and sediments runoff changes in the Seret River in the period 1948–2022 and ascertaining of the role of water regulating by dams and reservoirs of small hydropower stations in the riverbed have been carried out. We also carried out a comparison of the sediments runoff module for the Seret River and the neighbouring Koropets River.

Keywords: river, small hydropower station, water runoff, sediments runoff.

1. Introduction

Under the conditions of the global climate change and high intensity of manmade transformation of the river systems the topic of amount and quality of water resources has very high priority. Water quality and water runoff of the big rivers in Ukraine directly depend on the state of their tributaries. Tributaries in the catchment system form the river network structure and hydrologic regime and determine the overall hydroecological state of the main river. That is why it is important to study the small and medium rivers, like the Seret. The Seret catchment is affected by the significant manmade influences and is characterized by the high indexes of transformation, especially since the second half of the 20th century. Only during the last 15 years seven small hydropower stations (SHPS) have been constructed in the Seret riverbed. Due to the necessary of dam building a water reservoir is formed upstream. Such reservoir catches up the noticeable part of sediments and lowers the water flow velocity. In its turn the decrease in water flow velocity causes worsening of self-purification abilities of the river. In case of high amounts of organic matter in the water the intensification of overgrowing by water plants and eutrofication processes are observed.

The main goal of this research is assessment of the water and sediments runoff changes in the Seret River for the period of 1948–2022 and ascertaining of the role of water regulating by dams and reservoirs of small hydropower stations in the riverbed. The object of research is the river system of Seret and small hydropower stations with their dams and reservoirs. The subject matter is parameters of the water and sediments runoff, and precipitation for the studied period.

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The topic of the manmade activities influence on the water and sediments runoff in the rivers of the Upper Dnister and Podillia Highland is reviewed in recent scientific papers of I. Kovalchuk, L. Tsaryk, O. Pylypovych, A. Mykhnovych, Y. Andreychuk and others (Kovalchuk, 2013; Kovalchuk et al., 2018; Tsaryk et al., 2023; Pylypovych, Kovalchuk, 2017; V. Khilchevskyi et al., 2013; Pylypovych, Morozovs'ka, 2023; Morozovs'ka, Pylypovych, 2021; Mykhnovych, 2019; Andreychuk, Kovalchuk, 2004).

2. Experimental part

2.1. Study sites

The Seret River starts near Ratyshchi village in Ternopil region where several rivers, namely the Seret Pravyi, the Seret Livyi, the Vyatyna and the Hrabarka, are joined together. The length of the Seret is 248 km, the catchment area is about 3,900 km^2. The river catchment is located within the two administrative regions, i.e. Lviv and Ternopil, and three administrative districts, i.e. Zolochiv (Lviv region), Ternopil and Chortkiv (Ternopil region).

Geologically the river basin is situated on the Ternopil Plateau, which is a part of the Volyn-Podillia plate within the Eastern-European platform. In the upper part the Seret flows on the flat and bogged terrains. Downstream Ternopil city the Seret has a mountain character and V-shape river valley. Concerning the relief, in the northern part the valley has lower cutting in the mother rocks and is characterized by the slight slopes and opens sediments of Upper Cretaceous and Neogene. The bottom of the valley is bogged with pit lands. The floodplain is relatively wide. In the south the river valley is deeply cut in the Podillia Plateau surface and opens sediments of Silurian, Devonian, Jurassic, Cretaceous and Neogene periods (Kostiuk, 2013).

Within the Seret river bed there are eight small hydropower stations (Fig. 1): Zahidhydroenergo, Velykohaivs'ka, Lux-2, Yanivs'ka, Chortkivs'ka, Bilche-Zolotets'ka, Bilche-Zolotets'ka-2, and Kasperivs'ka. Most of them are newly constructed during 2009–2021. The Kasperivs'ka SHPS has been functioning for more than 60 years. According to the classification, most of them belong to the Micro type. Their capacity is less then 1 Megawatt, and only the Kasperivs'ka one has the capacity of 9.38 Megawatt (Table 1). All SHPS function according to green tariff amounting to 11–15 eurocents in UAH equivalent.

Table 1

The main parameters of SHPS in the Seret river basin

Number	Name of the SHPS	Type	Capacity, megawatt	Localisation	Year of construction
1	Zahidhydroenergo,	Riverbed	0.18	Horischiy Ivachiv village	2021
2	Velykohaivs'ka	Riverbed	0.15	Dychkiv village, Hnizna River (left tributary of the Seret)	2019
3	Lux-2	Riverbed	0.08	Myshkovychi village	2019
4	Yanivs'ka	Riverbed	0.66	Dolyna village	2012
5	Chortkivs'ka	Riverbed	0.2	Chortkiv town	2018
6	Bilche-Zolotets'ka	Riverbed	0.63	Bilche-Zolote village	2009
7	Bilche-Zolotets'ka-2	Riverbed	1.44	Bilche-Zolote village	2014
8	Kasperivs'ka	Riverbed	9.38	Kasperivtsi village	1963

Since all SHPS are situated in the Seret riverbed and have a dam which decelerate water flow velocity, they influence the water runoff, sediments runoff, and water quality. For example, the zone of the impact on the water flow velocity is thirty times larger than the river bed width (Afanasyev et al., 2019). In its turn the velocity deceleration can affect the hydrological conditions during 50 % of the time along the thirty river bed widths downstream. Also the velocity deceleration can change the ecological conditions of the river – thermal and oxygenic regimes as well as the biodiversity. By the river bank strengthening the zone of impact on the erosion-accumulation regime amounts the distance equal to two riverbed widths (Afanasyev, et al., 2019). Besides that, the water reservoir by the dam affects the water runoff due to increasing of evaporation and catches up the sediments runoff and causes their accumulation on the bottom.

Sometimes the SHPS constructing can reinforce the flooding processes during the floods, enhance the river water pollution and eutrophication, affects the water and sediments runoff and other. For instance, the Zakhidhydroenergo hydropower station, upon being reconstructed, replaced the old hydro-engineering objects. But even during building works, in 2020 some emergency was observed, which was caused by unsatisfactory state of the dam and inability of water runoff regulation. So during the flood of 29.09.2020–01.10.2020, which was caused by heavy rains, some terrains, private economies and houses on the floodplain in Ivachiv Horishniy village were flooded. After the incident the Zakhidhydroenergo Company has set the lifting mechanism in the dam body of the Horishnio-Ivachivs'kyi water reservoir.

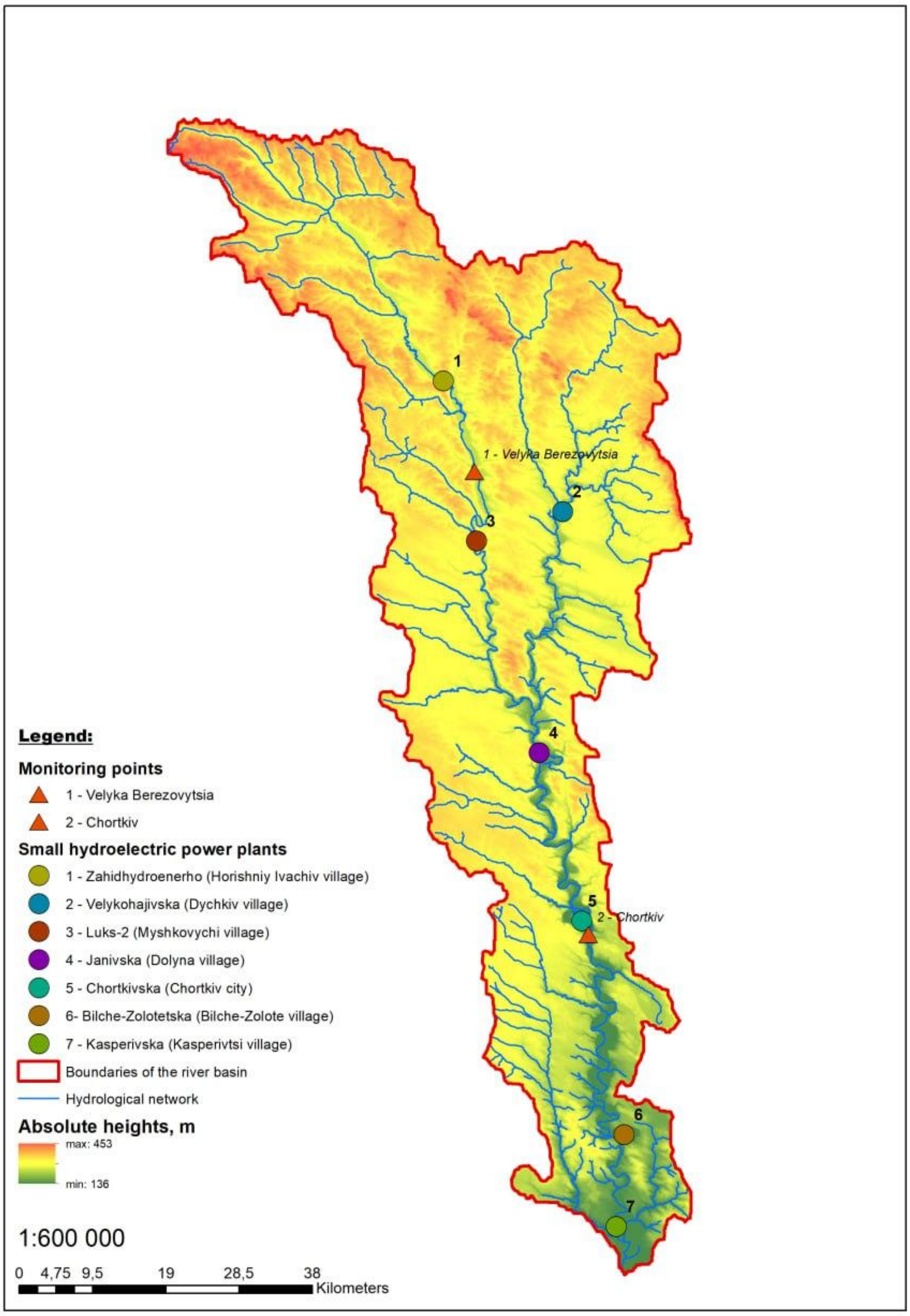

Fig. 1. The SHPS and the gauging stations localization in the Seret river basin (SHPS: 1 – Zahidhydroenergo; 2 – Velykohaivs'ka; 3 – Lux-2; 4 – Yanivs'ka; 5 – Chortkivs'k; 6 – Bilche-Zolotets'ka and Bilche-Zolotets'ka-2; 7 – Kasperivs'ka)

Fig. 2. The dam of the Lux-2 SHPS and the water reservoir with the marks of the growing up and possible eutrophication (Butsniv village, Ternopil district, Ternopil region)

There were also some problems during building of Lux-2 SHPS. In 2020 local community activists declared some breaches of the law during the construction and the station was commissioned without the required Commission of the Regional authority on the environment report on the environmental impact. The documented some problems. On the satellite image from the Google service some processes of overgrowing by water plants in the lower part of the dam reservoir can be observed. Obviously the overgrowing can be caused by the water flow velocity deceleration and organic matter accumulation in the water body (Fig. 2).

2.2. Materials and Methods

To investigate the changes of the water and sediments runoff the methods of observation, expedition, map analysis, GIS-modelling, statistical analysis were used. The Hydro-Meteorological Survey of Ukraine provided the observation data sets on the water discharge, sediments runoff, and precipitation. Daily parameters of water discharge and precipitation as well as yearly parameters of water discharge, sediments discharge and runoff modules were analyzed. The topographical, thematic maps and satellite images were used. Also in the summer of 2022 the field investigations of the riverbed and floodplains in the zones of the SHPS impacts was carried out.

Recently the observations on the water runoff are have been implemented at two gauging stations: Velyka Berezovytsia and Chortkiv (Fig. 1). The sediments runoff data are collected by the Chortkiv gauging station. The analyzed hydro-meteorological data sets for the period of 1948–2022 were provided by the Lviv Regional Centre of Hydrometeorology and the Carpathian Hydrological Observatory.

3. Results and Discussion

The changes in annual water and sediments dynamics for the long period in the Seret river basin have been assessed concerning the SHPS impacts on the hydrological regime.

The water discharges in the Seret river near Velyka Berezovytsia village usually fluctuate between 1.37 and 9.8 m^3/s, and near Chorkiv town — between 2.5 m^3/s and 20.1 m^3/s in the years with low water runoff. During the years with medium water runoff the water discharge amount 60–90 m^3/s. Maximal moment water discharge of the extreme flood was observed on 5.04.1956 – 313 m^3/s, minimal moment discharge was observed on 2.07.1960 – 0,23 m^3/s.

The curve of daily water discharge in Chortkiv quite often does not correlate with the daily precipitation. This fact can be explained by the water regulation effects of the SHPS dams and reservoirs in the riverbed. For example, during heavy rains in August and

September 2020 we do not observe peaks on the water discharge graph (Fig. 3). In the other case in the middle of July 2020 we can see significant peaks on the water discharge graph without heavy rains. Such peaks can be caused by the water discharge from the reservoir of the Chortkiv SHPS. The hydrograph, which was built for the Velyka Berezovytsia gauging station confirms that. Here, the daily water discharges correlate much more with the daily precipitation (Fig. 4). Only one SHPS is located 18.5 km upstream from the gauging station (Zakhidhydroenergo in Horishniy Ivachiv village).

The average annual water discharge for the long-time period in the Seret (Chortkiv) is 14.8 m^3/s. The maximal average annual water discharge in this period amounts to 23.6 m^3/s (1980), the minimal – 6.3 m^3/s (2020). The average annual water discharges are characterized by the trend-line of decreasing after 2009 (Fig. 5).

The average sediments runoff in the Seret varies between 0.46 and 2.7 кg/s. The maximal moment parameter during a flood can amount 110 kg/s, for example in April of 1996. During the year with medium water runoff, the graph curve illustrates increasing of the sediments runoff from May till July and decreasing during winter months (Fig. 6).

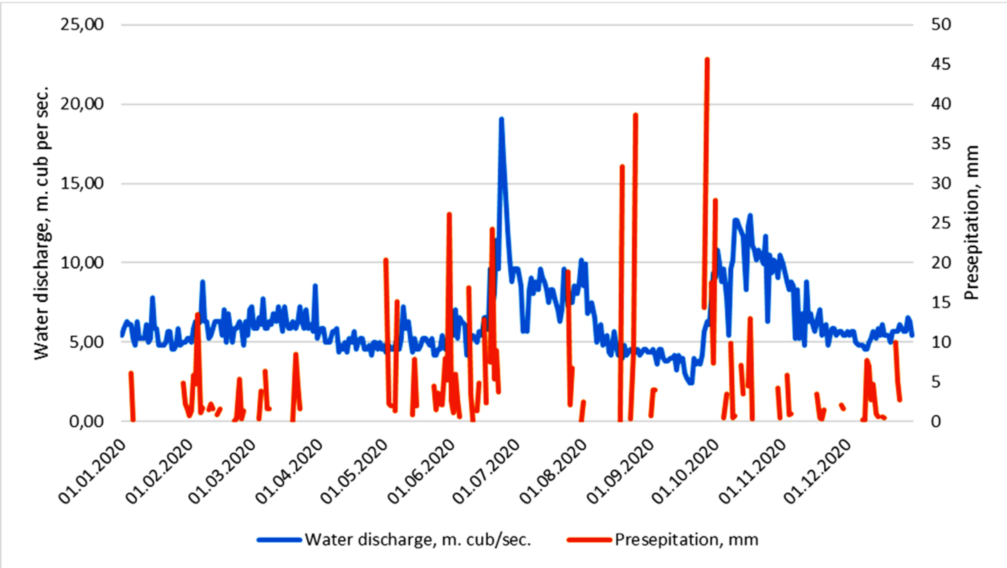

Fig. 3. The daily discharges and daily precipitation curves for the Seret near Chortkiv

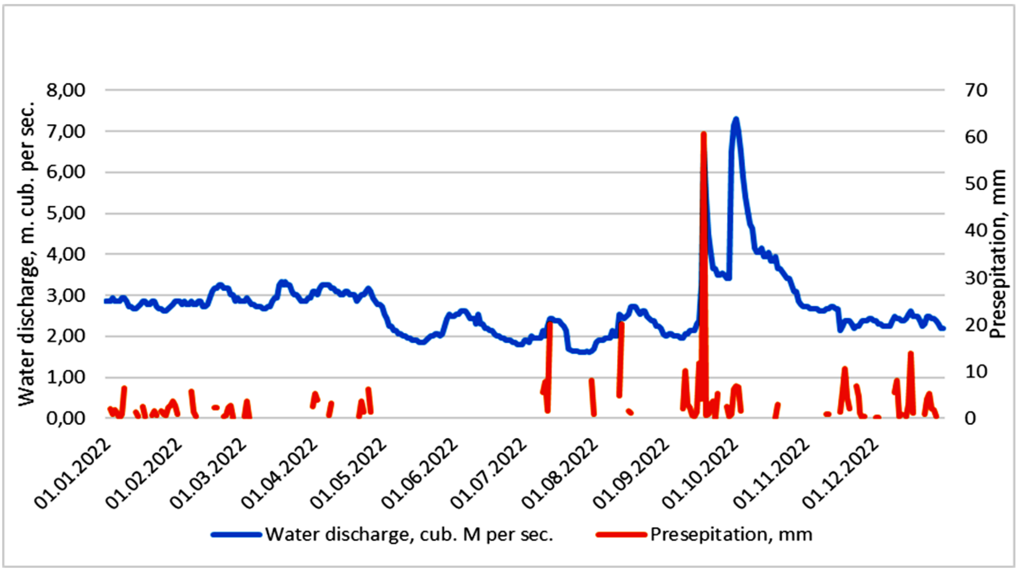

Fig. 4. The daily discharges and daily precipitation curves for the Seret near Velyka Berezovytsia

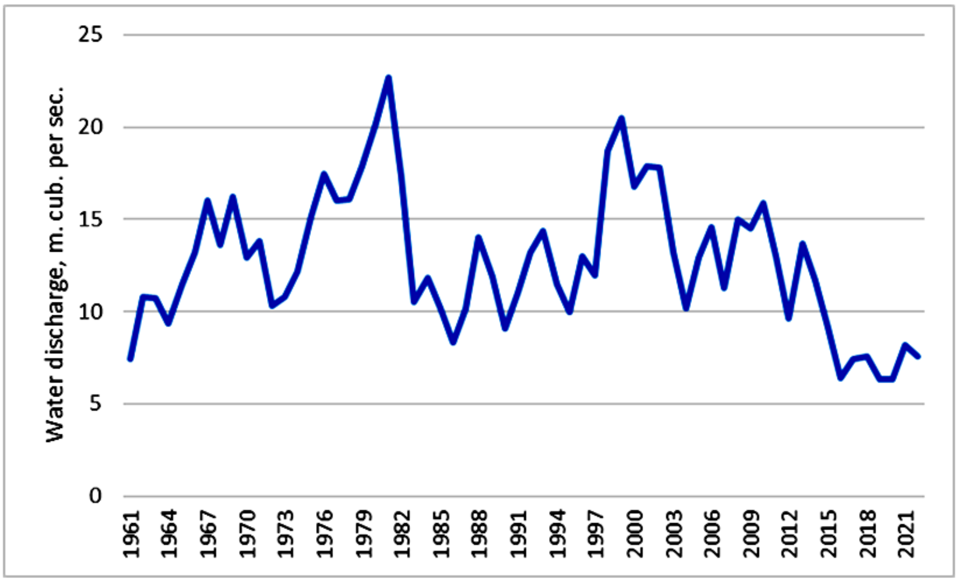

Fig. 5. The average annual water discharge in the Seret river near Chortkiv during the period 1961 – 2022

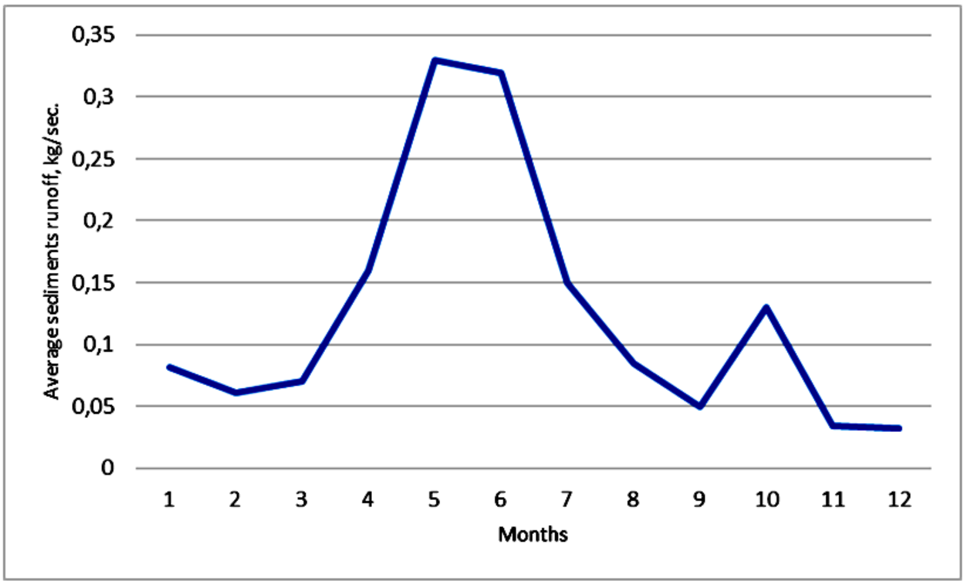

Fig. 6. Monthly sediments runoff distribution in 2019 (low in water runoff) in the Seret (Chortkiv)

The important parameter, which describes the overall denudation intensity in the river basin, is the sediments runoff module. The annual average sediments runoff module is an integral parameter of the erosion-accumulation processes intensity in the river basin. During the long period the wide range fluctuations and significant amplitudes usually characterize this parameter. For the Seret river this parameter changes from 1.1 (1959, 2018) to 73 (1956, 1969) t/km^2 per year.

The long-term fluctuations of the sediments runoff module can be spread across several typical periods. The series of years with low and high sediments runoff form a long-time graph with noticeable tendencies of differently directed changes – decreasing or increasing. We allocated several sub-periods in the sediments runoff graph for the Seret River: 1948–1959; 1960–1972; 1973–1986; 1987–2000; 2001–2019 (Fig. 7). As we can see on Fig. 7, every sub-period lasted for about 11–13 years, and it generally correlates with the Sun activity cycles. Every sub-period also has noticeable maximum and minimum. However, the period of 2001–2019 is a little exceptional. Absence of noticeable maximum, minimum, slight amplitudes and significant decreasing of the sediments runoff characterizes this sub-period of the whole graph. We can assume that such decreasing of the sediments runoff may be related to water runoff regulating by a few dams and reservoirs, which belong to SHPS and were constructed after 2009 (except the Kasperivs'ka one).

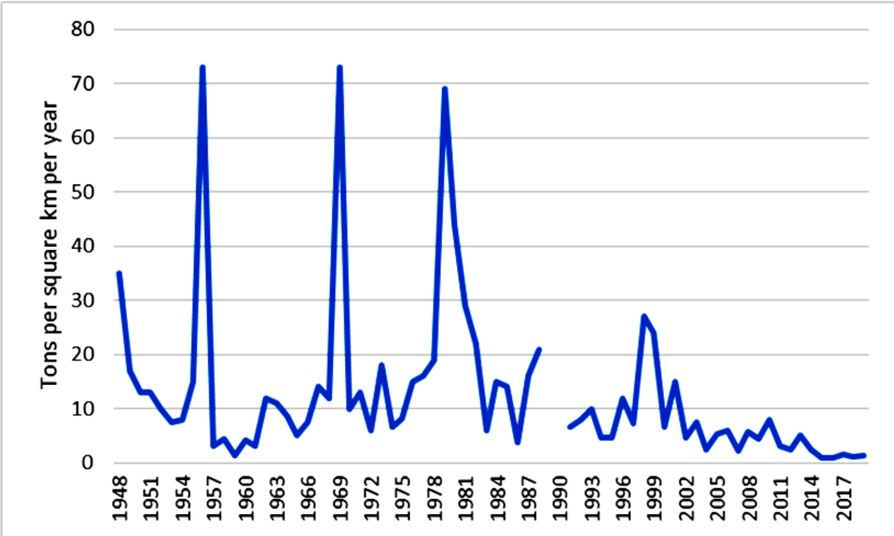

Fig. 7. The long-term dynamics of the sediments runoff module in the Seret River (Chortkiv) during 1948–2019 (according to the data of the Hydro-meteorological Survey of Ukraine)

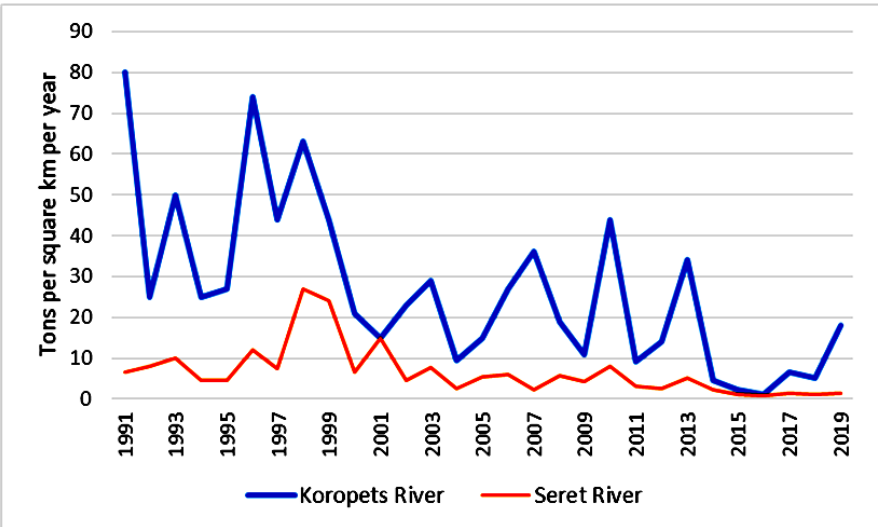

Fig. 8. Comparison of annual average sediments runoff modules in the Seret River (Chortkiv) and the Koropets' River (Koropets' village) during 1991–2019 (according to the data of the Hydro-Meteorological Survey of Ukraine)

If we compare the sediments runoff dynamics of the Seret River with other rivers of Podillia, for example Koropets' River, we can see that in the Koropets' catchment the decreasing after 2001 is less significant, the fluctuations and peaks are more noticeable. That fact can be interpreted as the confirmation of more natural regime of the runoff distribution.

4. Conclusions

During last 15 years, seven SHPS were constructed in the Seret River bed, which produce noticeable impacts on the hydrologic regime. After their building the cases of flooding of villages, overgrowing of the river bed reservoirs by algae plants became more frequent, and the long-term dynamics of the water and sediments runoff was changed. To assess the water and sediments runoff changes in the catchment and to ascertain correlation between these changes and the SHPS functioning we analyzed the monitoring data sets of the Hydro-Meteorological Survey of Ukraine and the Carpathian Hydrological Observatory.

The investigation results have shown that daily water discharges in the Seret River near Velyka Berezovytsia village fluctuates between 1.37 and 9.8 m^3/s, and near Chortkiv town – from 2.5 m^3/s to 20.1 m^3/s during low water runoff years.

The average annual water discharge in the Seret (Chortkiv) is 14.8 m^3/s. Maximum from the average annual water discharge amounts to 58.6 m^3/s (1969), and minimum of this parameter is 6.3 m^3/s (2020). The noticeable tendency of decreasing of the average annual water discharge is observed after 2009.

Daily water discharges in the Seret (Chortkiv) sometimes do not correlate with the daily precipitation. It may be explained by the regulating effects of dams and water reservoirs in the Seret river bed.

In the long-term graph of the sediments runoff module fluctuations in the Seret River we identified the series of sub-periods with noticeable tendencies of differently directed changes – decreasing or increasing: 1948–1959; 1960–1972; 1973–1986; 1987–2000; 2001–2019 (Figure 7). The period of 2001–2019 is a little different. Absence of noticeable maximum, minimum, slight amplitudes and significant decreasing of the sediments runoff characterizes this sub-period. We can assume that such decreasing of graph peaks may be explained by water runoff regulating by SHPS dams and reservoirs, which were constructed after 2009 (except the Kasperivs'ka one).

Comparing the long-term sediments runoff dynamics of the Seret River with the neighboring Koropets' River testifies that decreasing after 2001 in the Koropets' is less significant, the fluctuations and peaks are more noticeable. That fact can be considered as the confirmation of the SHPS influence on the water and sediments runoff regime and distribution.

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