How to cite: Nagy P., Kubiak-Wójcicka K., Zeleňáková M., Purcz P. (2025) Deficit Water Volume in Hnilec River in Slovakia *"Air and Water – Components of the Environment" Conference Proceedings*, Cluj-Napoca, Romania, p. 157-166, https://doi.org/10.24193/AWC2025_15 .

DEFICIT WATER VOLUME IN HNILEC RIVER IN SLOVAKIA

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ABSTRACT. Deficit Water Volume in Hnilec River in Slovakia. In this study, water deficit volumes were determined in the Hnilec River catchment in selected hydrological stations in the period 1961-2020, divided into three twenty-year periods (1961-1980, 1981-2000 and 2001-2020). From the perspective of climate change and its impact on water management and use, it is very important to determine the volume of the water deficit in the Hnilec River catchment. The study used parameters characterizing water scarcity (deficit), i.e. the volume of water deficit, as well as the duration of water deficit during the year. The assessed deficit volumes for the 3 analyzed hydrological stations lasted on average 60-75 days a year in the period 1961-2020. The volumes that were missing in a given period in the assessed stations constituted about 5% of the surplus volumes. The largest water deficit was recorded at all hydrological stations in the period 1981-2000.

Keywords: flow, deficit volume, Hnilec, Slovakia

1. INTRODUCTION

Studies conducted by many authors indicate that there is increasing evidence of climate change, which will contribute to changing water availability in Europe (Ionita et al., 2020; Bevacqua, et al. 2024). The main cause of changes is the increase in air temperature, which causes, among others, floods, droughts, heat waves and other climate-related hazards, which are becoming more intense, longer and more frequent. Some communities and regions are more exposed, but overall Europe is not prepared for rapidly increasing climate hazards (https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation). Increasingly frequent droughts cause restrictions in the availability of water resources Hisdal and Tallaksen (2000). The concept of drought itself is a phenomenon difficult to define unambiguously. Droughts are most often defined as a long-term lack or significant deficiency of precipitation (International Glossary of Hydrogeology). Many authors emphasize that drought is a natural phenomenon resulting from lower than normal rainfall for a longer period of time. Several types

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of drought can be defined: meteorological, atmospheric, agricultural, hydrological and socio-economic (Wilhite and Glantz, 1985, Crocetti et al., 2020). From the point of view of water resource availability, hydrological drought is of great importance for society. Hydrological drought is characterized by a reduction in lake capacity, a decrease in groundwater levels and a decrease in stream flow, which can occur for a year or for several consecutive years and often affect large areas. Climatic fluctuations are therefore the main natural physical factor determining the severity of drought, but human activity can also contribute to it. Drought is usually associated with the resource implications of water availability and can be defined in terms of different streamflow uses and the sum of the minimum low-flow requirements for each of them (Aron and Emmanuel, 1982). The International Dictionary of Hydrology (WMO, 1974) defines low flow as "the flow of water in a stream during a prolonged drought". This definition does not clearly distinguish between low flows and droughts. Low flows are a seasonal phenomenon and an integral component of the flow regime of any river (Smakhtin 2001). Drought is therefore a more general phenomenon and can be characterized by more than just low flows. Droughts include periods of low flows, but a continuous seasonal event of low flow does not necessarily constitute a drought, although some researchers refer to a continuous period of low flow during one year as an annual drought (Zelenhasic and Salvai, 1987, Tallaksen et al., 1997). The results show that the signal of low flow change is strengthened with increasing levels of warming. Low flows decrease in the Mediterranean region, while they increase in the Alpine and northern regions (Marx et al., 2018). The analyzed region is sensitive to climate change because it covers a small mountain catchment located in the eastern part of Slovakia. The aim of this study was to construct, analyze and interpret the duration of low flow and deficit volumes at 3 hydrological stations in the Hnilec river catchment in eastern Slovakia.

2. MATERIALS AND METHODS

2.1. Study area

The study area includes the catchment area of the Hnilec River, which is located in the eastern part of Slovakia. The Hnilec River is a right tributary of the Hornád River, and its source is in the Low Tatras. Hydrological observations of the Hnilec River are carried out at 3 hydrological stations. These are: Stratena – a hydrological station located in the upper reaches of the river, Svedlar – a station in the middle reaches of the river and Jaklovce located in the mouth section. The Palcmanská máša reservoir, which is located in the upper reaches of the river, below the Stratena station, has an influence on the flow regime of the Hnilec River (Fig. 1). The Palcmanská Maša reservoir is located at an altitude of 786.1 m above sea level and its surface is about 0.9 km2. The maximum volume of the reservoir is 10.4 x 106 m3 and the average depth is 13.0 m. Palcmanská Maša is a multifunctional reservoir, the retention time of the reservoir is 88 days (Fidlerová and Hlúbiková, 2016). The

Hnilec River catchment is a mountain catchment, which is used as 73.8% by forests, 11.2% by shrub and herbaceous vegetation, heterogeneous agricultural area is 6.1%, pastures 4.6%, while agricultural areas and urban tissue each account for 1.9% of the total catchment area (CLC 2018; Kubiak-Wójcicka et al., 2023).

Table 1. ***Characteristics flows of the Hnilec River in the years 1961-2020***

No.	River	Hydrological station	Catchment area km^2	Flow ($m^3 \cdot s^{-1}$)		
				maximum	average	minimum
1.	Hnilec	Stratená	64.67475	19.3	1.077	0.08
2.	Hnilec	Švedlár	352.0132	110.0	3.509	0.230
3.	Hnilec	Jaklovce	604.018	178.0	5.942	0.621

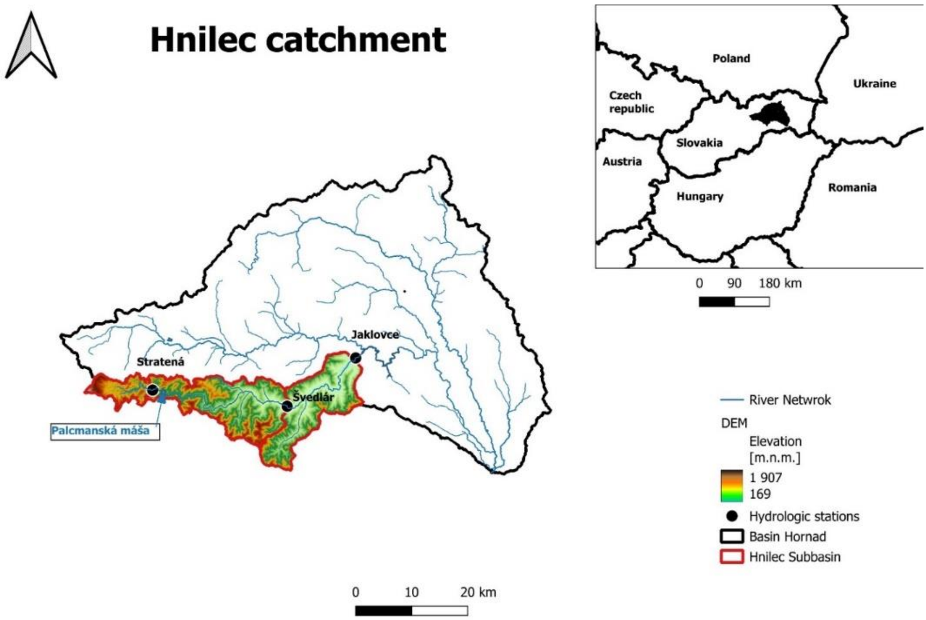

Fig. 1. ***The Hnilec River catchment***

2.2. Data and methods

This study uses daily flows data for a 60-year observation period for 3 hydrological stations located in the Hnilec River catchment. The data were provided by the Slovak Hydrometeorological Institute and covered the research period 1961-2020. Different thresholds are used in the literature to define periods of low and high flows. For periods of low flow, thresholds of Q30%, Q25%, Q10%, Q5%, Q1% and Q0.5% are usually adopted. The choice of an appropriate threshold largely depends on the region and significance (Kubiak-Wójcicka et al. 2021, Tomaszewski and

Kubiak-Wójcicka, 2021). For the purposes of this study, a threshold of 10% was adopted to define periods of low flows. The research period 1961-2020 was divided into 20-year periods. The use of 20-year periods is an appropriate sample size for this study. Deficit volumes are volumes that are missing the minimum flow value. First, the minimum value of surface runoff was chosen - quantile Q10. Fig. 1 shows the deficit surface runoff graphically.

First, it was necessary to calculate the quantile value for all hydrological stations on the Hnilec River. To calculate the quantile, daily surface runoff for the period 1961-2020 was used, and then quantiles were calculated for each 20-year period. Then, the quantile value Q10 was subtracted from the daily surface runoff. If the difference between daily surface runoff and surface runoff, which is equal to the Q10 quantile, was negative, it meant a water deficit, and positive values meant a water surplus. Then, all negative values were summed for individual years and periods. In addition to the runoff deficits, the total duration was determined, i.e. the total number of days with water deficits and the beginning and end of the water deficit occurrence. In a similar way, the quantiles were summed, which represented the deficit period (Fig. 2).

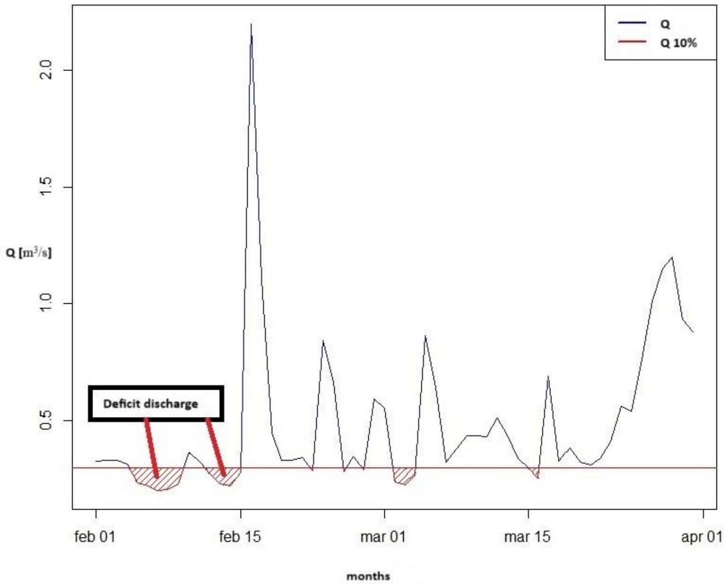

Fig. 2. ***Deficit flow***

3. RESULTS

3.1 . Characteristic flows

The analysis of the average annual flow values in the period 1961-2020 showed the variability of flows in individual years. The results show that the greatest flow fluctuations occurred in the multi-year period 1961-1980, while the smallest difference between maximum and minimum flows was recorded in the period 1981-2020. The large difference in flows resulted from the maximum flow values that occurred in the period 1961-1980. The maximum values in this period were higher than 31% at the Stratena station, 67% at the Svedlar station and up to 96% at the Jaklovce station compared to the maximum values from the period 1981-2000. The average flows from the multi-year period 2001-2010 were comparable to the average flows from the years 1961-2020 (Table 2).

Table 2. Characteristics and quantile Q10%

period		Stratena	Švedlar	Jaklovce
1961-2020	min	0.080	0.230	0.621
	max	19.300	110.00	178.000
	average	1.070	3.740	5.940
	Q 10%	0.314	0.840	1.530
1961-1980	min	0.080	0.230	0.621
	max	19.300	110.000	178.00
	average	1.240	3.510	6.690
	Q 10%	0.332	0.868	1.750
1981-2000	min	0.113	0.412	0.684
	max	14.670	65.78	90.67
	average	0.893	3.07	5.024
	Q 10%	0.283	0.805	1.380
2001-2020	min	0.150	0.39	0.690
	max	18.970	89.40	143.280
	average	1.090	3.71	6.100
	Q 10%	0.353	0.853	1.510

3.2 Characteristics of annual low flows 1961-2020

From the point of view of defining the hydrological regime and water availability, annual low flows are important. The results show that the lowest low flows were in the period 1981-2000 in all 3 hydrological stations, the highest flows were observed in the period 1961-1980, slightly lower flows were in the period 2001-2020 (Fig. 3-5). Noteworthy are the years 2010, 2014, 2020, where low flows were the highest in the analyzed period 1961-2020. The values of low flows exceeded the Q10% values determined for all 3 sub-periods. In the other years, the values of low flows were much lower than the Q10% values determined for the sub-periods, which means that years with water deficits during the year predominate.

3.3. Water deficit

The analysis of daily flows allowed us to distinguish low-flow periods and determine the volume of water deficit during the year and in individual periods. At all analyzed hydrological stations, the highest water deficit and the number of days with water deficit were recorded in the years 1981-2000, while the lowest in the years 2001-2020 (Fig. 6-8).

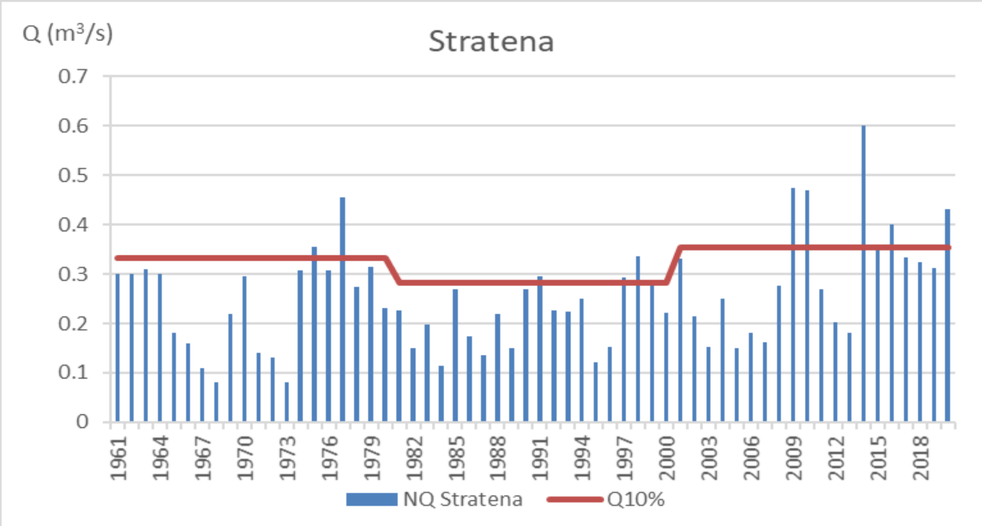

Fig. 3. Annual low flows of the Hnilec River at the Stratena hydrological station from 1961 to 2020.

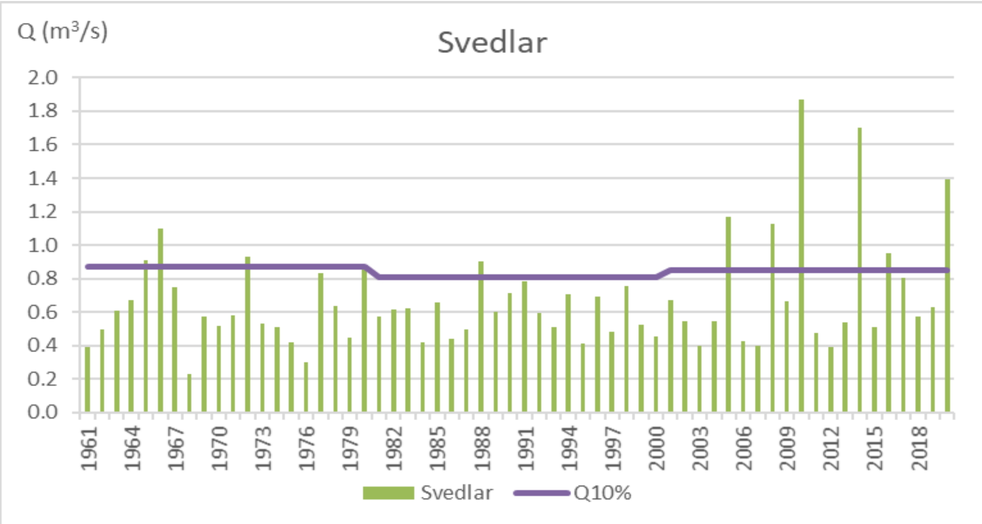

Fig. 4. Annual low flows of the Hnilec River at the Svedlar hydrological station from 1961 to 2020.

At the Jaklovce hydrological station, the minimum difference in deficit values occurred in the period 2001-2020, the average flow rates and Q10 were most consistent with the period 1961-2020. The period 1981-2000 was a dry period and the lowest flow rates were recorded in this period. If we compare Q10% calculated for the period 1961-2020 and Q10% calculated for the period 1981-2000, it was smaller, and therefore smaller deficit volumes occurred. The period 1961-1980 recorded the highest flow rates, but the greatest difference in deficit volumes.

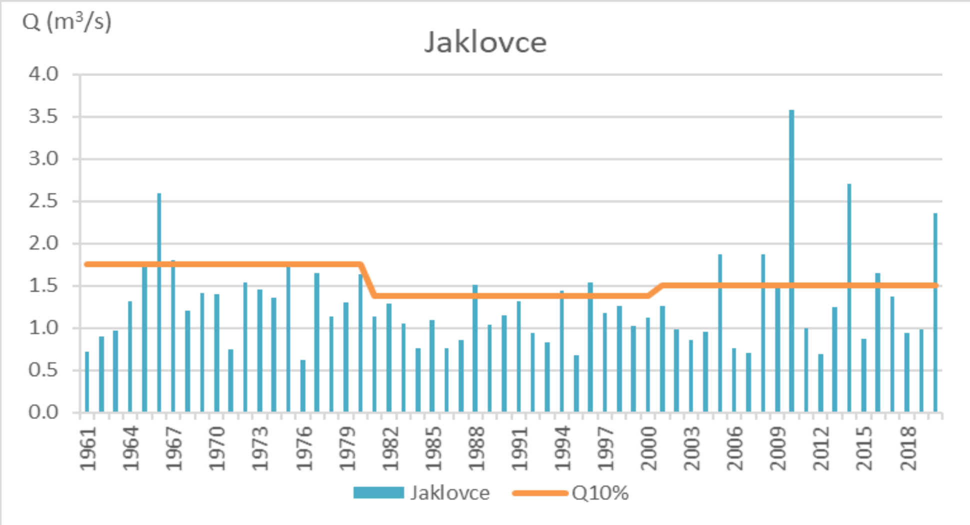

Fig. 5. Annual low flows of the Hnilec River at the Jaklovce hydrological station from 1961 to 2020.

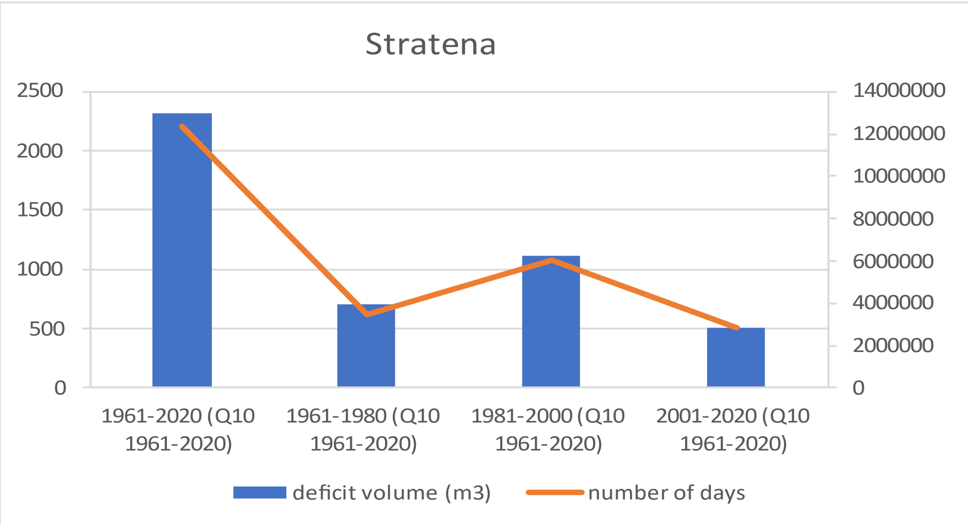

Fig. 6. ***Deficit volume station Stratena***

At the Stratená station, there is a difference in deficit volumes in the period 2001-2020 and in the period 1981-2000. There are differences in deficit volumes in all three periods.

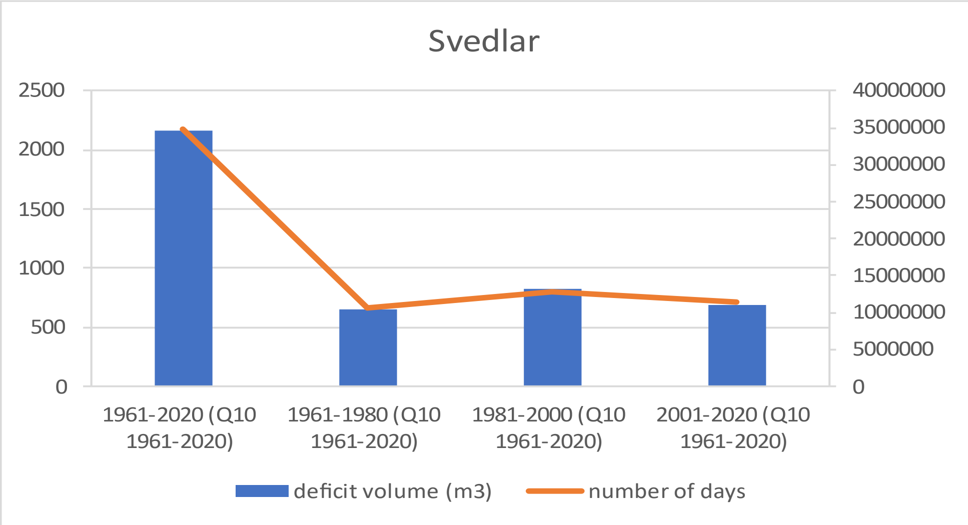

Fig. 7. ***Deficit volume station Švedlár***

At the Švedlár station, the results of the deficit volumes were very similar. This is due to the fact that this station is located below the Palcmanská máša dam and affects the flow rates at the evaluated hydrological station.

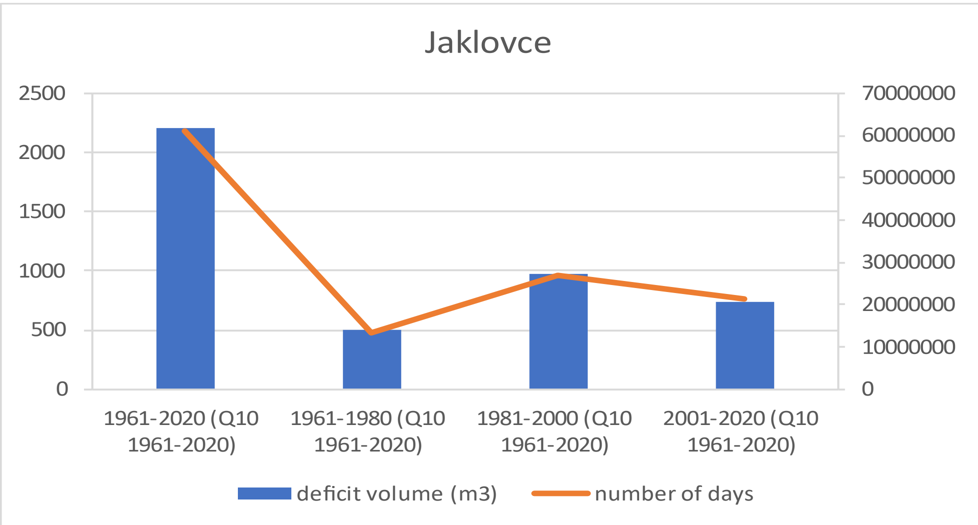

Fig. 8. ***Deficit volume station Švedlár***

The results show that there are differences when Q10 is calculated for different time periods. At the Jaklovce station, a large difference in deficit volumes is seen in the period 1981-2000. The period 1981-2000 can be defined as a dry period. The periods 1961-1980 and 2001-2020 can be defined as wet periods.

2. CONCLUSIONS

The aim of this study was to calculate deficit volumes for three periods and for three hydrological stations in the Hnilec catchment. Low flows were determined by the quantile Q10% and were calculated for the periods 1961-2020, 1961-1980, 1981-2000 and 2001-2020. The aim was to prove the differences in deficit volumes based on the period for which the Q10% were calculated. The conducted studies show that using the threshold for a longer period (1961-2020) and shorter 20-year subperiods (1961-1980, 1981-2000 and 2001-2020) gives different results in the water deficit volume. The results show that the differences in the values defined by the Q10% quantile in the individual subperiods are small, but the variability of low flows from year to year shows high dynamics. There are water shortages in the catchment area, but they can be supplemented with water surpluses. As it results from the multi-year settlement, the Hnilec River catchment area has sufficient water, but unevenly distributed in time. To reduce the water deficit in the catchment area, it is advisable to adapt the excess water in wet periods, which can be used in dry periods. The forms of adaptation should be adapted to the geographical and hydrological conditions of the catchment area.

ACKNOWLEDGEMENT

This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-20-0281. This work was supported by the project of the Ministry of Education of the Slovak Republic VEGA 1/0308/20 Mitigation of hydrological hazards, floods, and droughts by exploring extreme hydroclimatic phenomena in river basins.

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