MAIN HYDROLOGICAL STATISTICAL CHARACTERISTICS OF LOW WATER ON THE BARCĂU/BERETTYÓ STREAM

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ABSTRACT. – Main hydrological statistical characteristics of low water on the Barcău/Berettyó stream. Water deficits in low water periods caused by dry periods leading to droughts often are accompanied by considerable damage in the Tisa/Tisza Basin. Owing to the transboundary character of the river and also communal, industrial and considerable agricultural irrigation water demands assessment of low water conditions is utmost important. The Barcău/Berettyó stream entering into the Crişuri/Körös river network is the secondary left bank tributary of Tisa. The catchment is shared by Romania (56%) and Hungary (44%). Daily streamflow data for the description of low flow conditions are available since 1950, namely 55 and 58 years long series for Sălard (RO) and Berettyóújfalu (HU) consequently. Lower reaches of the river were considerable modified during the 19th century river training and flood protection works including the topology and geometry of channel network, while the hydrological regime of the upper hilly and undulating regions remained nearly natural until 1977. Low water thresholds for the analysis of low water events were set by using different statistical approaches. Temporal changes of hydrological regime and low water events are described by the comparison of nearly equally long periods of observed daily flow series (28 and 30 years). Time independent and time dependent block extreme statistics are used to describe low water distributions.

Keywords: minimum discharge, low flow periods, hydrological statistical analysis, transboundary rivers, water uses, discharge values probabilities.

1. INTRODUCTION

The Tisa Basin is subject to considerable socio-economic and ecological demage caused by long standing droughts and low water periods. Water regime and weather conditions leading to low water and associated risk have been widely investigated by researchers of the region (Újvári et al 1958, Topor 1964, Păduraru et al. 1974, Zelenhasić et al. 1987, Pálfai 2002, Kovács & Domokos 1996, Szalai et al. 2000, Mika et al 2004, Konecsny 2004, Konecsny et al. 2006, Stanciu 2007, Şerban 2008). There is a need for careful attention and profound professional knowledge to manage low flow situations on transboundary rivers where parties, countries need to share available limited water resources. An earlier study targeted low water conditions of the transboundary Romanian-Hungarian section of Mureş/

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Maros stream (Konecsny 2010, Konecsny & Bálint 2010). The present paper deals with a smaller stream: the Barcău/Berettyó.

2. HYDROGRAPHICAL CONDITIONS AND THE IMPACT OF HYDRAULIC ENGINEERING MEASURES ON HYDROLOGICAL REGIME OF THE INVESTIGATED RIVER REACH

The Barcău/Berettyó drainage basin (6095 km2) belongs to the Criş/Körös river network within the Tisa Basin and as such is shared by Romania (56%) and Hungary (44%). From its sources Barcău/Berettyó traverses 120 km in Romania and the downstream 78 km in Hungary before entering into Crişul Repede/Sebes Körös. The river length under natural conditions was considerable longer (364 km) before river training works started in 1858. Barcău flows between flood embankments along its entire Hungarian reach while there is a 244-km long system of dikes on the main stream and tributaries in Romania. In the course of more recent decades a number of small reservoirs were built on smaller tributaries.

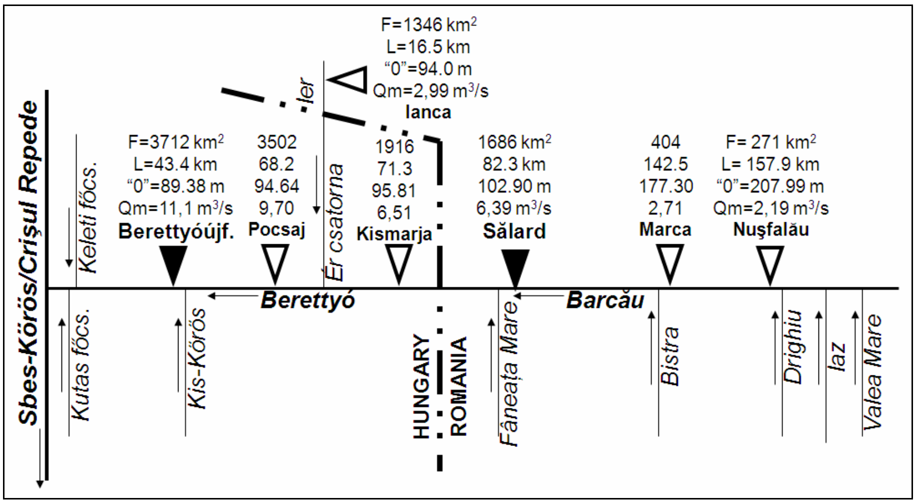

Fig. 1. ***Scheme of the Barcău/Berettyó: tributaries and gauging stations. At each gauge drainage area; river/chainage kilometrage, i.e. distance from the mouth in km; elevation of the gauge „0" above mean sea level; mean flow and gauge name – are given consequently***

Weather conditions and hydrological causes which might be influenced by anthropogenic impact induce low flow events in the Tisa Basin (Konecsny 2004). Periods of low precipitation and hydrological droughts are closely connected with the presence of dry air masses with stabile stratification characteristic for anticyclonic circulation patterns (Stanciu 2007).

Annual precipitation shows an increase from 550 mm to 750 mm as moving from the West to the eastern hilly region on Barcău catchment. Extremely dry years appeared in 1986, 1973, 2000, 1961 (Şerban 2008), and also in 1946-1953.

Annual flood volumes on the river are 69 10^6 m^3 at Nuşfalau, 201 10^6 m^3 at Sălard and 351 10^6 m^3 at Berettyóújfalu consequently. These values are reduced to their third and forth in extreme low flow years.

There is no reservoir in operation along the Romanian reach of Barcău, while one is under construction at Suplacu de Barcău. The 15 10^6 m^3 capacity emergency detention basin (polder) at Sălard was completed in 1987-ben. Several emergency and permanent reservoirs are in operation along the Romanian section of Ier canal, the largest one at Andrid with capacity 17.5 10^6 m^3. The number of smaller reservoirs within the Barcău drainage basin are accounted as 13 with storage capacity in the range of 1 to 4 10^6 m^3, and 41 reservoirs with capacity less than 1.00 10^6 m^3. Part of those are out of operation. The emergency reservoir, polders constructed at the mouth of Ier/Ér in Hungary has the capacity of 12.2 10^6 m^3, while along Berettyó near Szeghalom the Kutas and Halaspuszta detention basins are capable to store 36.5 10^6 m^3 and 35.5 10^6 m^3flood water consequently. The reservoir on Ier at Andrid is the only significant structure which has influence on low flow.

3. HYDROLOGICAL DATA FOR STATISTICAL ANALYSES, DEFINITIONS OF LOW WATER PERIODS AND METHODS OF ANALYSES

Long observed flow series are available at four Romanian and three Hungarian hydrometric stations along the river (figure 1). Uninterrupted daily flow rates have the length of 55 and 58 years at Sălard and Berettyóújfalu consequently, while other stations have observations less than 50 years. Observed low waters are close to natural conditions for the period 1950-1977, while anthropogenic impact on the hydrological regime is somewhat significant for the period 1978-2007.

A low flow period is defined within the hydrological or calendar year and considered as a period with decreased runoff when ‚low flow' discharges are observed. The low flow event is defined as function of time, while values remain below a discharge threshold (Kovács & Domokos 1996). The given discharge value is a threshold related to groundwater supply originated base flow and possible interflow or surface flow component, also referred as a reference discharge value, critical or threshold low flow value. Low flow periods might be continuous or are sometimes interrupted by episodes of higher flow events. When the limiting period of slightly higher flow was less than three-day long then the two low flow periods were considered as one single event on Barcău. Whenever a low flow event continued at the end of the calendar year the given event was assigned to the year it started.

The Generalised Extreme Value Distribution (GEV) uniting Gumbel, Weibull and Frechet types of distributions was used to describe probability distributions the annual minima of discharges and the number of days below the low water threshold was also analysed. At the first step the entire length of observation period was investigated followed by a time-dependent analyses for detecting temporal changes throughout the years.

4. RESULTS OF STATISTICAL ANALYSES

Extremes of Barcău hydrological regime are demonstrated by the selected high water year (1970) and low water years (1959, 1953) when daily flow series differ significantly (figure 2). The observed lowest minimum flows definitely occurred during the 1950(53)-1977 period with undisturbed natural flow conditions, while values are higher during decades influenced regime (1978-2007). Time series show steep increase of minimum flows (figure 3) related mostly to climatic variability however partly the impact of reservoirs and sewage outflow originating from groundwater utilisation explains the observed rise. Annual minima of daily mean flow values vary between 0.141 m^3s^{-1} (23/01/1964) and 2.97 m^3s^{-1} (10/02/2005) at Barcău-Sălard and between 0.181 m^3s^{-1} (12/08/1972) and 7.44 m^3s^{-1} (9/06/1998) at Berettyó-Berettyóújfalu.

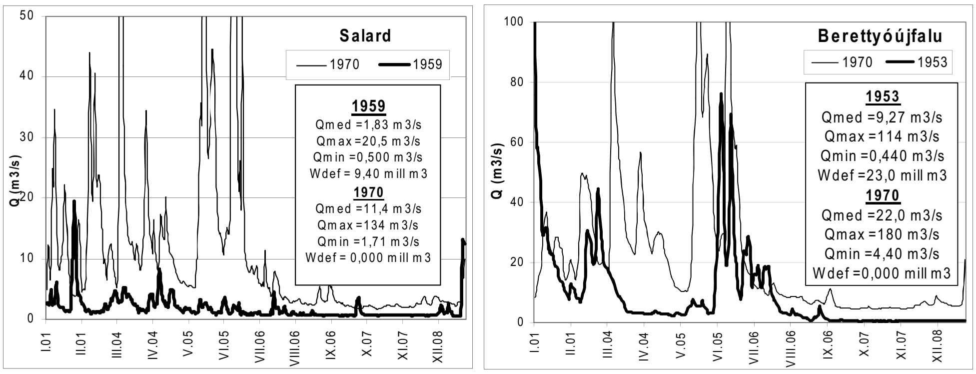

Fig. 2. ***Hydrographs of daily discharges and characteristic annual values for the high water year – 1970, and low water years – 1953, 1959 at stations Sălard (Romania) and Berettyóújfalu (Hungary)***

Table 1. ***Annual minima of daily mean flow rates on River Barcău***

Period	Years number	$Q_{m\ min\ d}$ -Year	$Q_{m\ min\ d\ aa}$	C_v	Low flow values of different probability $[m^3s^{-1}]$			
					80%	90%	95%	97%
Barcău Sălard								
1953/1977	25	0.100-53	0.674	0.74	0.358	0.216	1.80	0.130
1978/2007	30	0.415-03	1.25	0.44	0.850	0.640	0.480	0.420
1953/2007	55	0.100-53	0.989	0.59	0.489	0.351	0.211	0.185
Berettyó Berettyóújfalu								
1951/1977	27	0.181-72	1.43	0.79	0.490	0.287	0.200	0.170
1978/2007	30	0.680-94	2.54	0.58	1.28	0.955	0.720	0.670
1951/2007	57	0.181-72	2.00	0.72	0.722	0.492	0.287	0.180

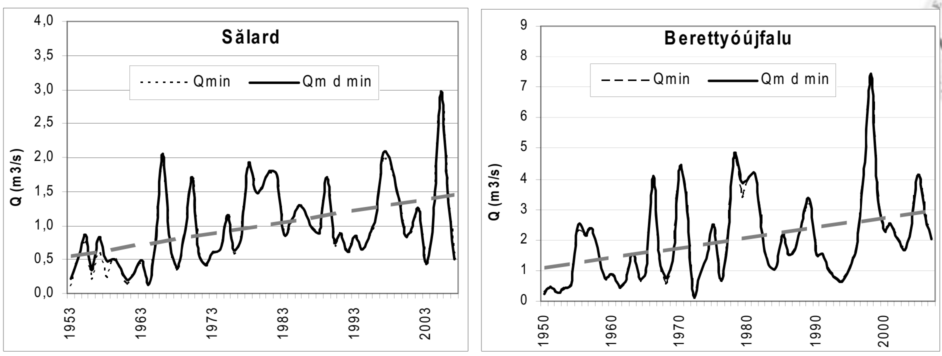

Fig. 3. ***Annual minima of daily mean discharges (continuous lines) and instantaneous minima (dashed lines) with linear trends at stations Barcău-Sălard and Berettyó-Berettyóújfalu (1950-2007)***

These values are almost identical with annual instantaneous flow minima (0.100 m^3s^{-1} and 2.90 m^3s^{-1}; 0.165 m^3s^{-1} and 7.40 m^3s^{-1}consequently).

Time dependent analyses of annual minimum flows underline the increase of the minima. Distributions are clearly shifted two higher values when 30-year periods at the beginning and at the end of the observations are compared (figure 4).

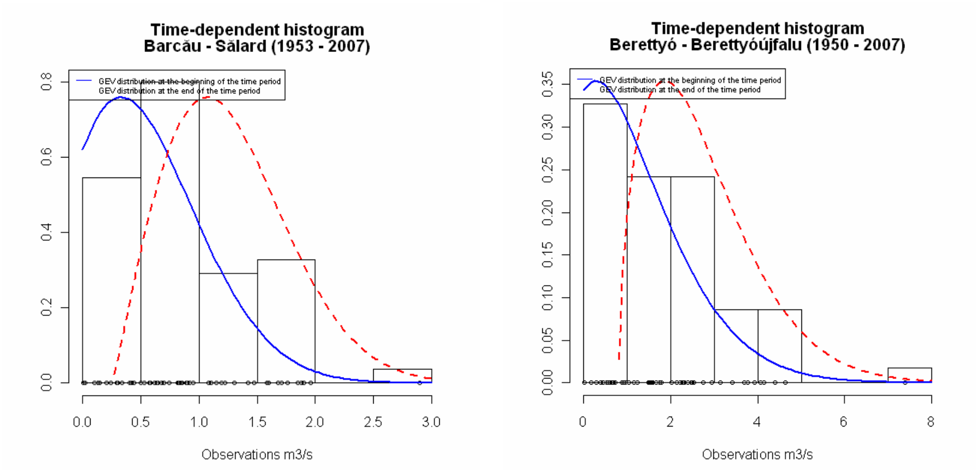

Fig. 4. ***Distribution of annual minima of daily mean discharges at the beginning (continuous lines) and at the end of the observation period (dashed lines) at stations Barcău-Sălard and Berettyó-Berettyóújfalu (1950-2007)***

Minima related to winter half year (September–March) are 0.141 m^3s^{-1}/ 1964 and 0,453 m^3s^{-1}/1954 and to summer half year (April-September) 0,200 m^3s^{-1}/ 1961 and 0,181 m^3s^{-1}/1972 consequently at Sălard and Berettyóújfalu. Winter minima at Berettyóújfalu are more that three times higher than at Sălard, while summer half year minima are 10% less. The significantly higher winter half year difference probably can be explained by differences in methods of observations and data processing in the two countries, especially when ice is present (no reduction factor is used for ice phenomena during winter in Hungary).

Annual minima never occurred in March and June at Sălard and in February and March at Berettyóújfalu station (figure 5). Annual minima are most frequent during August-September 44.4% and 58.4% of cases, and generally in the summer half year 53.9%, and 76.8% consequently at Sălard and Berettyóújfalu.

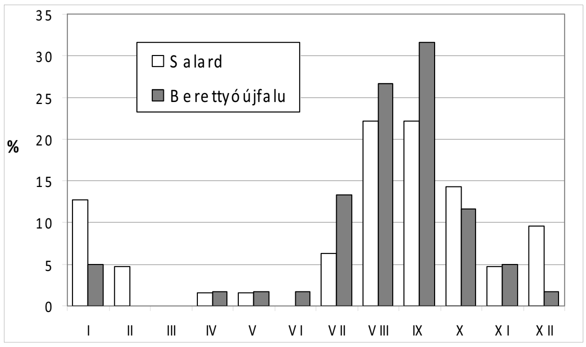

Fig. 5. ***Seasonal frequencies of annual minima of daily mean flow***

The number of days with flow values **below the low flow threshold** accounted total 3528 for 1950-2007, the annual average being 64.1 days resulting from values varying within the range of 0-215 days (1959 with longest low flow) at Sălard. Identical values at Berettyóújfalu are total 4911 days for the 58 years, annual average 84.7 days, range 0-284 days (1950 with the longest low flow). Annual duration of low water events exceeded 200 days once at Sălard and 7 times at Berettyóújfalu, while durations in the range 100-200 days 15 and 13 times consequently. Annual values show a definite decreasing trend (figure 6).

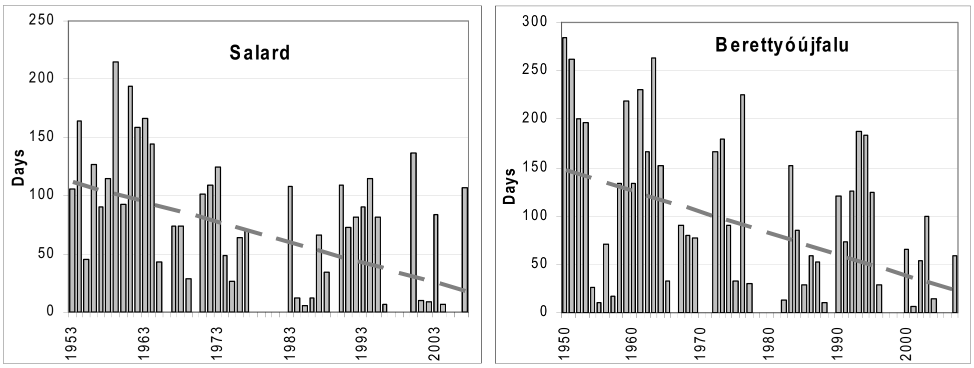

Fig. 6. ***Day number of low water events, days below the threshold (Q_0)***

The longest continuous low flow events were 179 days 17/06-12/12/1961 (Sălard) and 230 days 22/04-7/12/1950 (Berettyóújfalu). The durations of annual longest low flow events show also a decreasing trend.

All together 210 and 170 **low flow periods** were detected during the 55 years analysed, 4 and 3 events on the average and 11 (1959) and 9 (1984) cases the most, consequently at Sălard and Berettyóújfalu. The number of wet years when discharges remained above the low flow threshold is 13 at both stations, and only less than quarter of the cases appeared before 1977.

The **water deficit** indicates the volume of flow missing relative to the low water threshold during the low flow event. The largest annual deficits appeared 13.7 10^6 m^3 (1961) and 9.40 10^6 m^3 (1959) at Sălard, while the maximum deficits for the period 1978-2007 under anthropogenic impact are below 4 10^6 m^3. The largest annual deficits at Berettyóújfalu are 40.4 10^6 m^3 (1950) and 30.2 10^6 m^3 (1951) and the maximum deficits for the period 1978-2007 remained below 20 10^6 m^3. Annual largest deficits are around three times more at Berettyóújfalu than at Sălard. Recent decades after 1977 are characterised by low water periods of significantly smaller deficits.

Water deficit of the longest low flow periods 13.4 10^6 m^3 (during 179 days, 06/17-12/12/1961) and 37.0 10^6 m^3 (during 230 days, 04/22-07/12/1950) consequently at Sălard and Berettyóújfalu, while the maximum daily deficits are 107,050 m^3 (23/01/1964) and 214,186 m^3 (17/08/1972) consequently.

Naturally water deficit largely depends on the duration of low flow periods demonstrated by relatively close correlation at both Sălard and Berettyóújfalu (figure 7).

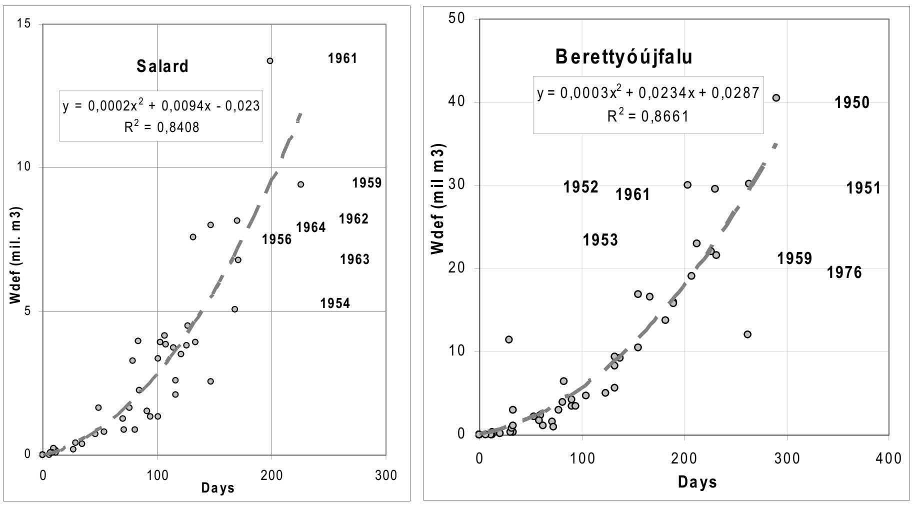

Fig. 7. ***Cumulated annual number of days with streamflow deficit, and cumulated annual streamflow deficit volume***

5 CONCLUDING REMARKS

- Low water events appeared in more than three quarters of the analysed 58 years;
- Low water days on the average consist around one quarter of the entire period although in certain years discharges remained below the low water threshold for more than two third of the annual period;
- Annual minima of daily mean flow values appear most frequently in August-September, while never or very seldom in wet spring and early summer months;
- Annual minima are more frequent in the warmer half year (April-October) than in the winter half year;
- Different types of analyses demonstrate the increase of minimum discharges, decrease of the duration and number of low flow events together with water deficit and also increase of the periods between them are observed after 1978 when anthropogenic impact became significant;
- The longest low flow periods produced water deficit almost 14 10^6 m^3 and more than 40 10^6 m^3 consequently at Sălard and Berettyóújfalu, while the capacity of existing reservoirs is not sufficient to replenish the given deficit;
- Owing to the strong anthropogenic impact on the hydrological regime no climate change related modification of low water conditions can be detected on the Berettyó stream.

ACKNOWLEDGMENT

Research leading to this paper has been supported by the DMCSEE (Drought Management Centre for South East Europe) a cooperation project co-financed by the European Union through South East Europe Transnational Cooperation Programme (Reference Number SEE EoI/A/091/ 2.2/X).

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