Probabilistic Assessment of Low Flows in the Upper Ipeľ River Basin (Slovakia)

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Abstract

Over the past decade, significant decreases in river discharges and more frequent occurrences of hydrological drought have been documented across Slovakia, including the transboundary Ipeľ River basin. This trend, primarily driven by rising air temperatures and increased evapotranspiration, presents severe challenges for sustainable water resource management and ecosystem preservation in the region. The primary objectives of this study were to analyze low-flow characteristics across the Upper Ipeľ River basin at four key gauging stations – Holiša (1931–2022), Kalinovo (1971–2022), and upstream/downstream of the Málinec Reservoir (1995–2022) – and to develop robust T-year 7-day minimum specific runoff estimates specifically for the Ipeľ: Málinec upstream station. Long-term mean daily discharge series were processed using the three-parameter Log-Pearson Type III (LP3) theoretical distribution, with non-exceedance curves constructed accounting for extreme low-flow outliers through skewness adjustment. The critically short observational record at Málinec upstream was successfully extended from 28 to ~75 years using the hydrological analogy method, leveraging strong correlation (r = 0.909) with the neighboring unregulated Rimavica basin. Analysis confirmed multi-decadal drought variability and declining discharge trends. The extended series produced substantially lower design values than the short record, yielding a 100-year 7-day minimum specific runoff of 0.89 $l.s^{-1}.km^{-2}$ (90% confidence interval: 0.75–1.03 $l.s^{-1}.km^{-2}$) at Ipeľ: Málinec upstream. These T-year design values provide essential parameters for reservoir yield analysis, environmental flow allocation, drought contingency planning, and climate change adaptation strategies throughout the Upper Ipeľ basin.

Keywords: *Low flows, Ipeľ River, Málinec WR, Log-Pearson Type III distribution, Hydrological analogy, Design values*

1. Introduction

Given its size, Slovakia is a highly diverse country with rugged relief, varied geological subsoil, numerous soil types, rich landscape cover, and a high proportion of forestation. In addition to these factors, climatic conditions, primarily precipitation, are also highly variable in both time and space. Because of this variability, it is difficult to find regions with analogous runoff regimes. Therefore, it is necessary to analyze runoff changes separately across a large number of streams.

As early as the 1960s in former Czechoslovakia, a number of water managers dedicated themselves to analyzing the development of hydrological series [1–3]. In his works, Bratránek expressed the hypothesis that natural, approximately 90-year fluctuations occur within the hydrosphere. At the end of the last century, this topic was addressed in connection with climate change by researchers such as [4–12].

In the 21st century, hydrologists primarily focus on analyzing long-term discharge trends. Poórová et al. [13] investigated the trends of minimum annual and monthly discharges for the period 1961–2012 in Slovak river basins. According to their results, annual minima are decreasing in the Morava, lower Váh, Nitra, Hron, Ipeľ, Slaná, and Bodva basins. Conversely, increasing trends in annual minima were observed in the upper Váh, Poprad, Hornád, and Bodrog basins. Pekárová [14] compared the trends of annual minimum and maximum discharges across ten major Slovak rivers over two periods (1931–1972 and 1973–2014). They found that minimum annual discharges have an increasing trend, except for the Váh and Krupinica rivers, with 3- and 7-day minima also rising. In contrast, maximum annual discharges, as well as 3- and 7-day maxima, are decreasing. Ďurigová et al. [15] analyzed mean monthly discharges on 14 selected Slovak rivers using basic descriptive statistics and trend analysis. They found that the most significant changes in the trend and periodic components occur on the Hron River. Among smaller basins, the Kysuca, Bystrica, and Čierny Váh rivers exhibit statistically significant decreasing trends. Ďurigová and Hlavčová [16] detected changes in decadal hydro-meteorological series on the upper Váh River, and Pavelková et al. [17] observed similar changes in Eastern Slovakia. A detailed analysis of discharge developments for the most significant rivers in the Danube basin was elaborated through the cooperation of Danube countries in the monograph Flood regime of rivers in the Danube River basin. Over the last two decades, changes in the hydrological balance of Slovak basins have also been recorded [18] and [19]. In the last decade after 2010, several dry years occurred throughout the Danube basin [20].

Recent studies (e.g. [21]) show that drought assessment is increasingly supported by multi-source remote sensing data and machine-learning approaches, which enable more detailed spatiotemporal monitoring of drought development and provide useful support for water management under changing climate conditions.

Consequently, the main objectives of the presented paper are:

- a comprehensive statistical analysis of low flows and hydrological drought occurrence in the Upper Ipeľ River basin at four gauging stations: Holiša, Kalinovo, and upstream and downstream of the Málinec Reservoir, based on mean daily discharges;

- cross-correlation analysis and extension of the series of 7-day minimum discharges at the Ipeľ: Málinec upstream station for the period 1931–1994 by hydrological analogy based on measured discharges from the neighboring Rimavica and Čierny Hron basins;
- estimation of *T*-year 7-day minimum specific runoff using the Log-Pearson Type III (LP3) theoretical distribution in the Upper Ipeľ basin above the Málinec Reservoir.

2. Catchment Description and Data Used

The Ipeľ River is the last direct right-bank tributary of the Danube River within Slovakia. Its basin extends across Slovakia and Hungary, with the Slovak portion covering 3,650 km², or 7.4% of Slovakia's total area. With a total length of 233 km, the Ipeľ River flows predominantly southward, draining the southwestern Slovak Ore Mountains (Slovenské rudohorie), the Javorie Mountains, and the entire Ipeľ Plateau (Ipeľská planina). The basin's highest elevation is Mount Drahová (1,118 m a.s.l.) in the Vepor Mountains (Veporské vrchy), with a mean basin elevation of 380 m a.s.l. and an average slope along the gradient curve of 6.5°. The river and its tributaries form a pinnate drainage network with a density of 1.8 km/km² across both the Slovak and Hungarian portions of the basin. The Upper Ipeľ Basin lies within a highland-lowland transition zone and exhibits a rain-snow runoff regime, with peak water yields typically occurring in spring.

Construction of the Málinec raw water reservoir began above the village of Málinec in 1989 and it entered permanent operation in 1994. Located on the Ipeľ River, the dam rises 48.5 m above the valley floor and spans 684.5 m at the crest [23]. The reservoir has a total volume of approximately 26.6 million m^3, of which the active storage volume exceeds 23.7 million m^3. At maximum water level, it covers a surface area of nearly 1.54 km^2. The primary purpose of this water structure is to accumulate raw water for the Málinec water treatment plant, which supplies drinking water to surrounding districts and serves tens of thousands of residents. A significant secondary function—directly relevant to *T*-year minimum flow analysis—involves flow regulation and augmentation in the Ipeľ River downstream of the reservoir during periods of critically low precipitation.

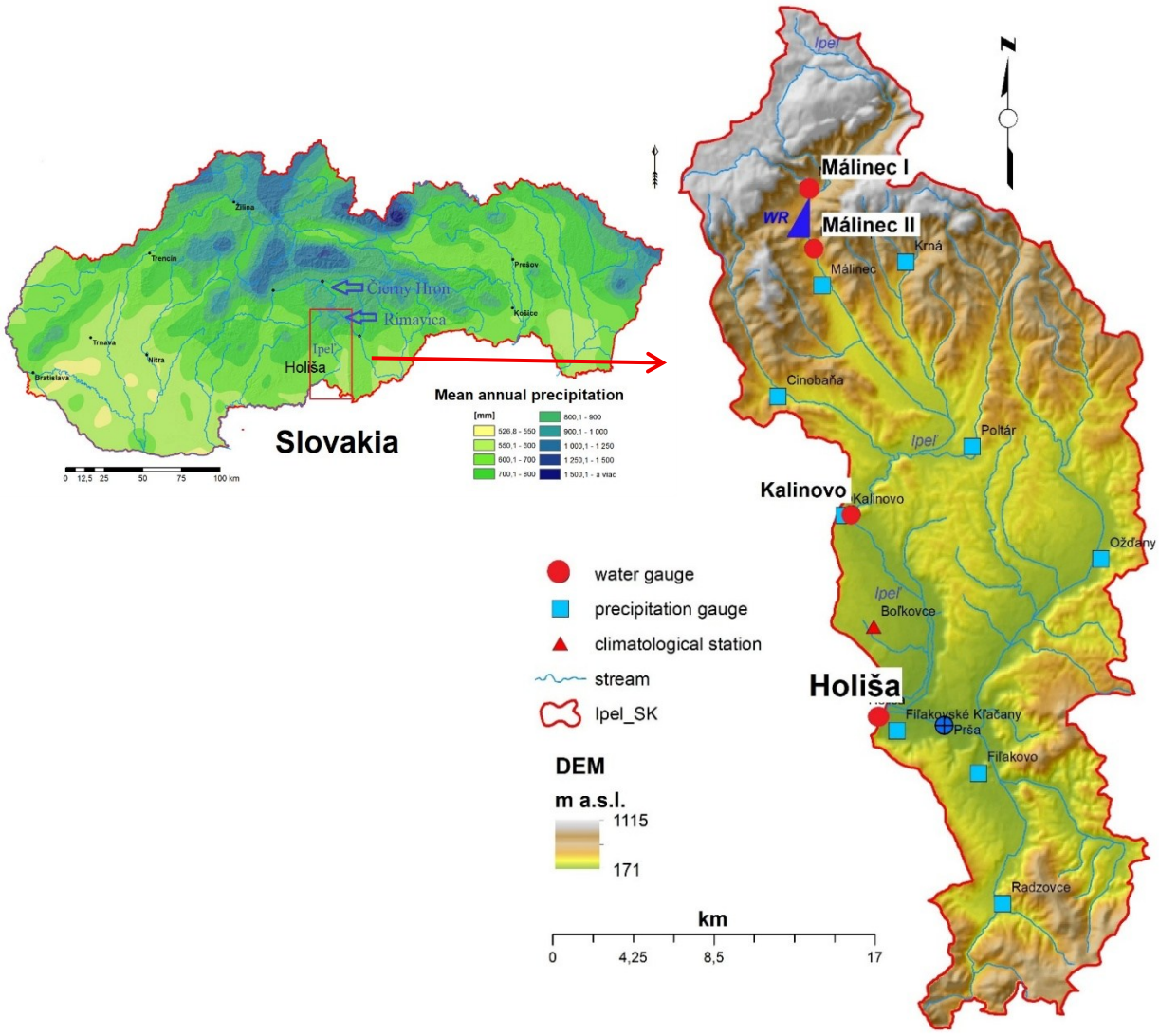


Fig. 1. Topographical map of the Upper Ipeľ River basin up to the Holiša gauging station, showing the locations of the analyzed hydrological, precipitation, and climatological stations. The inset map displays the spatial distribution of mean annual precipitation across Slovakia for the reference period 1991–2015.

This study utilized time series of mean daily discharges from four gauging stations within the Upper Ipeľ River basin up to the Holiša gauge, along with two ~90-year series of daily discharges from the Rimavica and Čierny Hron basins (Fig. 1). Table 1 presents the basic hydrological characteristics of the evaluated stations.

It is evident that discharge measurements downstream of the Málinec Reservoir are influenced by reservoir regulation. To assess long-term trends and *T*-year 7-day minimum flows reliably, analysis must rely on data unaffected by anthropogenic influences (i.e., the reservoir). Discharge measurements for the Ipeľ River upstream of the reservoir are available only from 1995 onward [22]. This record length is insufficient for evaluating long-term trends or reliably estimating *100*-year 7-day minimum flows. Therefore, to extend the series of 7-day minimum discharges at the Ipeľ: Málinec upstream station, we employed measured daily discharge data from the neighboring Rimavica River at the Lehota nad Rimavicou station (Fig. 1).

Tab. 1. Basic hydrological and geographical characteristics of the analyzed gauging stations in the Upper Ipeľ River basin and the neighboring Rimavica and Čierny Hron reference catchments.

No.	Station	River	discharge since	A [km^2]	River km [km]	Gauge zero [m a.s.l.]	Mean Altitude [m a.s.l.]	Q 1995–2020 [m^3.s^{-1}]
7398	Málinec upstream WR	Ipeľ	1995	54.24	197.6	348.96	810	0.52
7402	Málinec downstream WR	Ipeľ	1995	85.21	193.5	291.35	760	0.69
7420	Kalinovo	Ipeľ	1971	287.6	171.6	200.28	510	1.51
7440	Holiša	Ipeľ	1931	685.26	157.2	172.41	380	2.59
7045	Hronec	Č. Hron	1931	239.41	2.4	480.48		2.49
7860	Lehota above Rimavica	Rimavica	1931	148.95	2.9	264.07	660	1.31

3. Methods

When assessing hydrological drought, the following indicators are evaluated:

- Discharge characteristics: minimum mean daily discharges (evaluated at monthly or annual steps over the entire period), flow-duration curves of mean daily discharges (M-day discharges), minimum monthly and annual discharges, and *T*-year minimum discharges.
- Non-discharge characteristics: temporal occurrence of dry periods (date of occurrence, number of days with low-flow periods, the longest drought episode), and deficit volumes.

This study focused on discharge characteristics. Individual runoff characteristics were calculated from time series of mean daily discharges. The following variables were derived:

- Mean annual discharge (Qa): calculated from mean daily discharges over a calendar year.
- Annual 7-day minimum ($Q_{d7,min}$): the lowest average discharge sustained over seven consecutive days within a calendar year. This parameter more reliably reflects the real impact of drought on ecosystems than absolute daily minima, as it eliminates short-term fluctuations and measurement errors.

In Slovakia, the determination and evaluation of *T*-year minimum discharges and low-flow conditions at gauging stations were previously governed by the standard OTN 3113-1 (2007) and are currently regulated by the proposed standard OTN ŽP 3113-1:04. According to this standard, minimum discharge selection is based on the hydrological year (starting April 1).

Hydrological Analogy Method

To extend the short record of 7-day minimum discharges at the Ipeľ: Málinec upstream station (1995–2022), a hydrological analogy approach was applied. Pearson correlation coefficients were calculated between the available 7-day minimum specific runoff series at Málinec upstream and long-term series (>90 years) from neighboring unregulated basins with similar physiographic and climatic characteristics. The basin exhibiting the strongest correlation was selected as the donor catchment. Daily mean discharges from this donor basin were then used to estimate missing 7-day minima at Málinec upstream, yielding an extended series suitable for long-term trend analysis and LP3 fitting.

Probabilistic Assessment

In the probabilistic assessment of minimum discharges at gauging stations, the most crucial step is selecting appropriate theoretical non-exceedance probability curves, i.e., the most suitable distribution function type and parameter estimation method. Commonly – in hydrology – used distributions include the Gumbel (E1), Generalized Extreme Value (GEV, AE), Rossi (ME), 3-parameter log-normal (LN3), 3-parameter Pearson (P3, PE3), 3-parameter log-Pearson (LP3), and 3-parameter Weibull (WB3). Parameter estimation typically employs the method of moments, quantiles, or maximum likelihood.

For *T*-year 7-day minimum discharges, this study applied the Log-Pearson Type III (LP3) distribution. Adjusting the skewness coefficient within LP3 improves estimates in the lower tail (minima). Given the potential for regionalizing distribution parameters, using a single distribution type across all data—followed by parameter regionalization—is recommended over mixing distribution types.

4. Results

4.1 Statistical Analysis of Flow Regime Changes

Given the long observation record at the Ipeľ: Holiša station (1931–2022), particular attention was devoted to identifying historical droughts in this series [22]. Since downstream regulation by the Málinec Reservoir began in 1994, long-term trends were also statistically evaluated using daily mean discharge series from neighboring unregulated basins: Rimavica at Lehota nad Rimavicou and Čierny Hron at Hronec. Figures 2a–b present mean daily discharges (Qd; dark blue) and 4-year moving averages ($Qd_{4year,ma}$; light blue) for these three stations, with linear (polynomial) trends shown as green dashed lines. The first decade was exceptionally wet in both catchments, particularly 1936–1940, while the driest decadal period occurred in 1981–1990. The wettest year at Ipeľ: Holiša was 1937, and the driest was 1943. Both series exhibit multi-year oscillations in discharge with an approximate 14-year cycle.

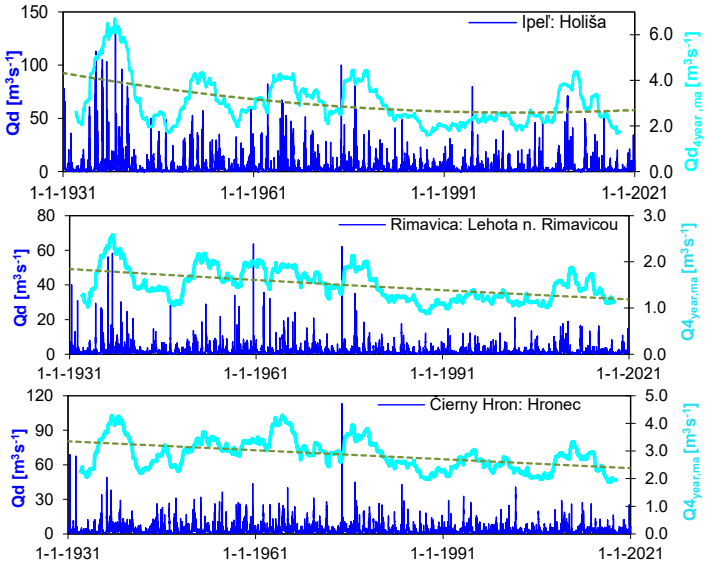


Fig. 2. Long-term time series of mean daily discharges at the Ipeľ: Holiša and Rimavica: Lehota nad Rimavicou gauging stations for the period 1931–2020. The plots include 4-year moving averages to highlight multi-year oscillations and fitted polynomial trend lines indicating long-term changes in runoff.

Occurrences of historical droughts in these basins are highlighted graphically in Figures 3a–c, where the y-axis uses a logarithmic scale to emphasize minima. Extreme droughts in the Ipeľ basin occurred in 1947 and 1993.

In the Rimavica basin, extreme summer droughts were recorded in September 1947, June 1964, August 1993, August 2003, September 2012, and August 2018. The Čierny Hron basin, located farther north with higher elevations than the Ipeľ basin, exhibits minima predominantly in winter. Consequently, this basin was excluded from subsequent analyses.

The Ipeľ and Rimavica rivers are characterized by peak discharges occurring in March and April, while minimum flows typically occur in August and September. Changes in long-term mean daily flows, low flows (the 7.5th percentile), and high flows (the 90th percentile) across different reference periods, including three 30-year sub-periods and the overall long-term period, are illustrated in Figure 4.

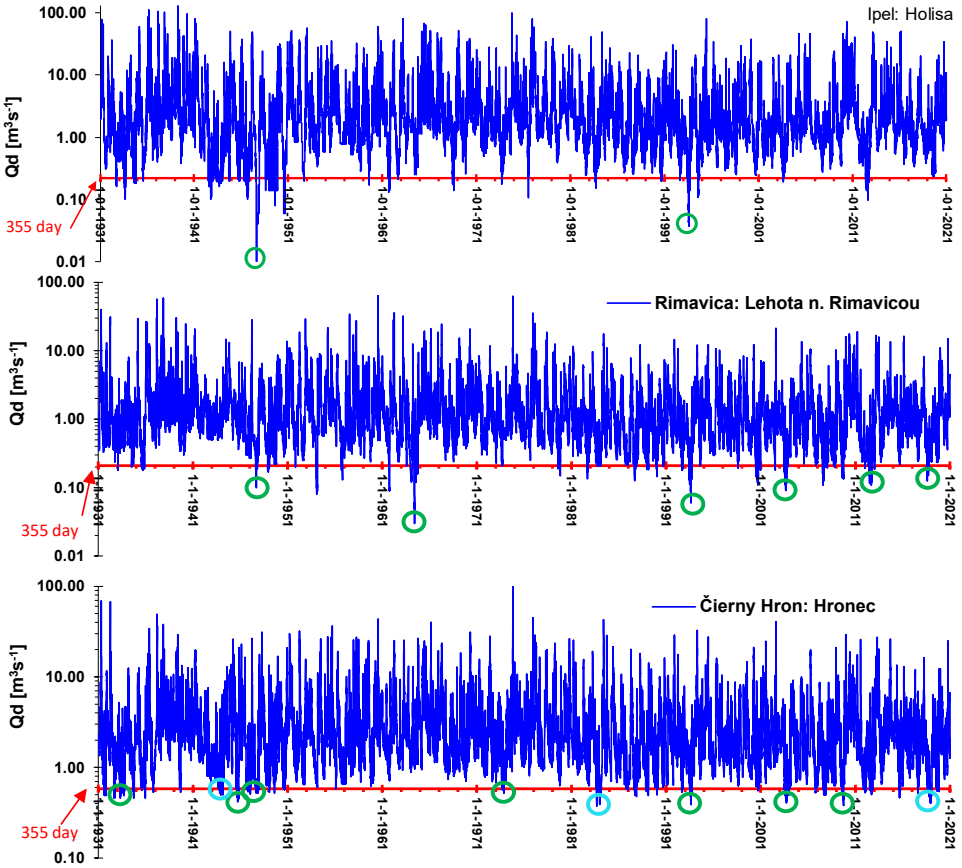


Fig. 3. Hydrographs of mean daily discharges (blue lines) plotted on a logarithmic scale for the period 1931–2020. The graphs highlight low-flow periods, emphasizing values that fall below the Q355d threshold discharge. Occurrences of extreme summer historical droughts are highlighted with green circles.

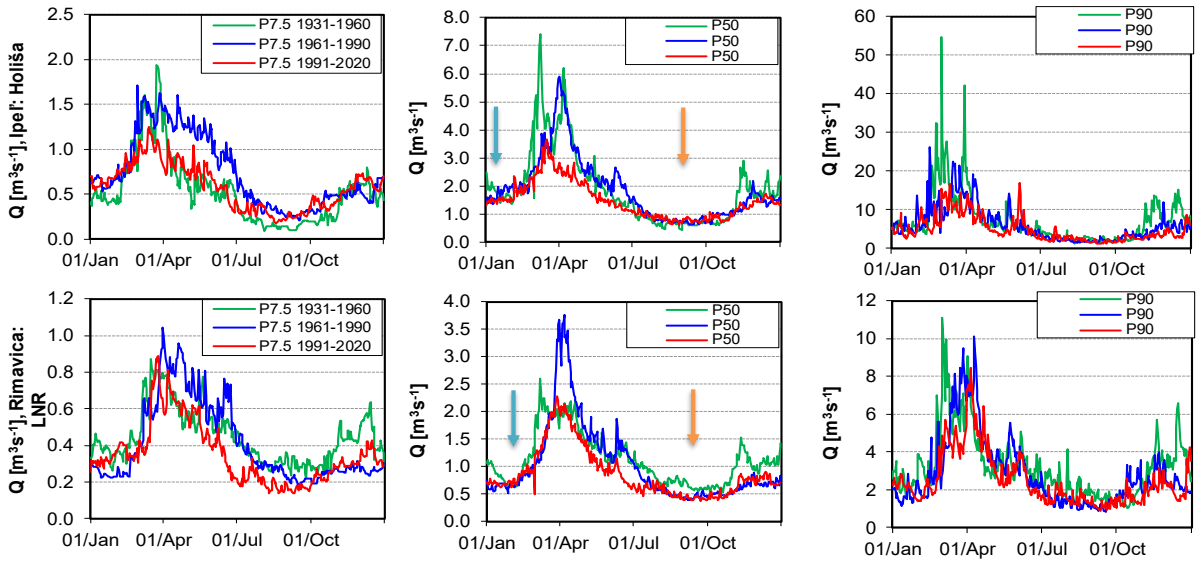


Fig. 4. Long-term mean daily discharge regimes across three 30-year reference periods (1931–1960, 1961–1990, and 1991–2020) at the evaluated stations.

4.2 Extension of the 7-day Minimum Specific Runoff Series at Málinec Upstream Station

From the mean daily discharge series, 1-, 3-, 7-, 30-, and 90-day average minimum and maximum flows were derived. To enable the comparison of *T*-year minimum values across different locations, subsequent analyses utilized series of minimum specific runoff (q_{dmin}), expressed in liters per second per square kilometer.

The extension of the 7-day minimum specific runoff ($q_{7d,min}$) series at the Ipeľ: Málinec upstream station was performed using cross-correlation analysis. During the observation period, the strongest correlation between specific runoff values was found between the Málinec upstream station and the Rimavica: Lehota nad Rimavicou station, with a correlation coefficient of 0.909 (Table 2). Both the measured and extended series of minimum 7-day specific runoffs are illustrated in Figure 5.

Tab. 2. Pearson correlation matrix of the 7-day minimum specific runoff between the evaluated stations

Variables	Ipeľ: Holiša	Rimavica: Lehota	Ipeľ: Kalinovo	Ipeľ: Málinec D	Ipeľ: Málinec U
Ipel: Holiša	1	0.775	0.959	0.507	0.844
Rimavica: Lehota	0.775	1	0.669	0.185	**0.909**
Ipeľ: Kalinovo	0.959	0.669	1	0.542	0.799
Ipeľ: Málinec D	0.507	0.185	0.542	1	0.204
Ipeľ: Málinec U	0.844	**0.909**	0.799	0.204	1

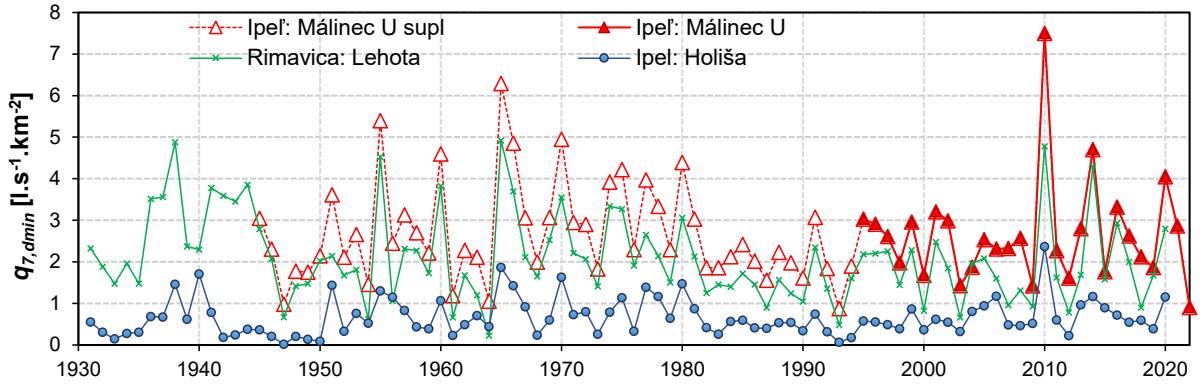
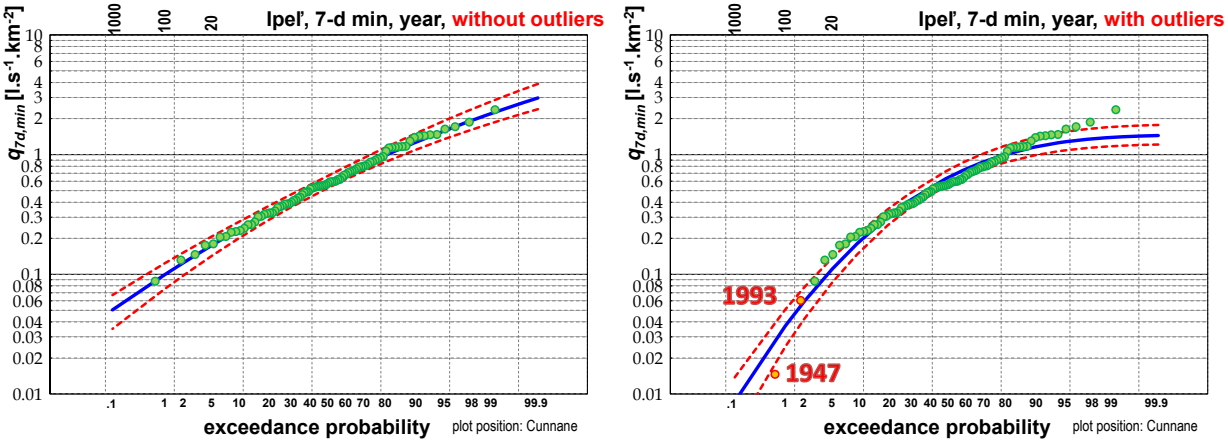


Fig. 5. Series of measured 7-day minimum specific runoff ($q_{7d,min}$) from the Ipeľ: Holiša, Ipeľ: Málinec upstream, and Rimavica: Lehota nad Rimavicou stations. The plot also includes the extended 7-day minimum specific runoff values for the Ipeľ: Málinec upstream station, estimated for the unobserved period of 1945–1994.

4.3 T-year 7-day Minimum Specific Runoff

Theoretical LP3 non-exceedance probability curves for the 7-day minimum specific runoff ($q_{7d,min}$) at the Ipeľ: Holiša station are plotted in Figures 6a and 6b. Figure 6a displays the curve without accounting for outliers, while Figure 6b incorporates extreme low-flow outliers. The graphs clearly demonstrate that when estimating *T*-year low-flow design values, it is crucial to include the extreme minimum outliers in the calculations to accurately capture the behavior of the lower tail of the distribution. Conversely, the upper tail representing the highest minimum values is of lesser importance for drought assessment.



a) b)

Fig. 6. Theoretical non-exceedance probability curves for the *T*-year 7-day minimum specific runoff ($q_{7d,min}$) at the Ipeľ: Holiša station, fitted using the Log-Pearson Type III (LP3) distribution: (a) calculated without the inclusion of extreme low-flow outliers (1995–2020), and (b) calculated with extreme outliers included to better capture the lower tail of the distribution (1945–2020).

The *T*-year 7-day minimum specific runoff design values for the Ipeľ: Málinec upstream station, calculated using the LP3 theoretical distribution for both the observed (1995–2020) and the extended (1945–2020) periods, are visually presented in Figure 7 and summarized in Table 3. The estimation derived from the extended long-term series yielded notably lower design values, better reflecting the historical drought severity. Specifically, the *100*-year 7-day minimum specific runoff ($q_{7d,min}$) was estimated at 0.89 (l.s^{-1}.km^{-2}), with a 90% confidence interval ranging from 0.75 to 1.03 (l.s^{-1}.km^{-2}).

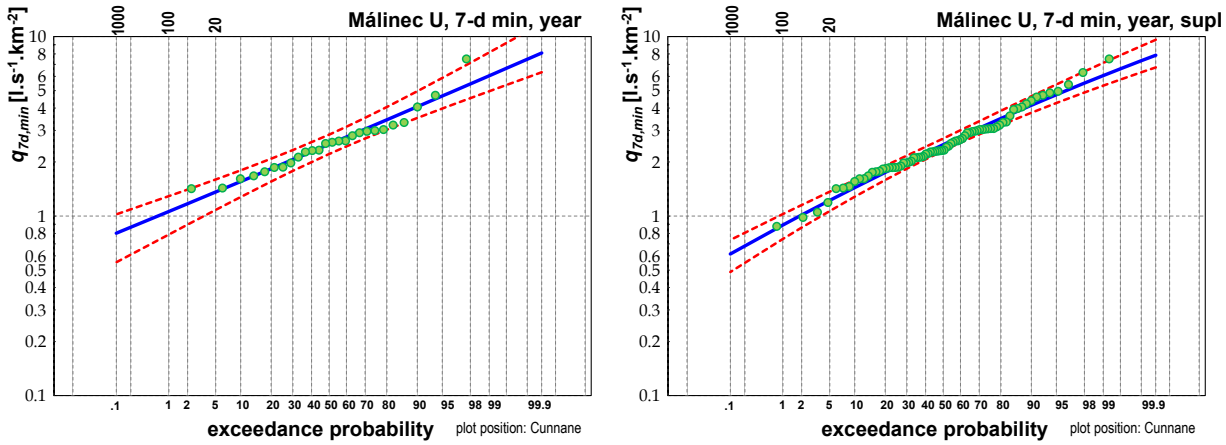


Fig. 7. Theoretical non-exceedance probability curves of the T-year *7*-day minimum specific runoff (l.s^{-1}.km^{-2}) at the Ipeľ: Málinec upstream station, fitted using the LP3 theoretical distribution: for the short-observed period 1995–2020 (left), and for the extended long-term period 1945–2020 (right).

Tab. 3. Design values of *T*-year 7-day minimum specific runoff (l.s^{-1}.km^{-2}) for the Ipeľ: Málinec upstream station, estimated using the LP3 theoretical distribution for the observed (1995–2020) and extended (1945–2020) periods.

	T	***p***	***q***	***q(5)***	***q(95)***	***q***	***q(5)***	***q(95)***
0.999	1000	0.001	0.80	1.02	0.55	0.62	0.74	0.49
0.99	100	0.01	1.06	1.29	0.79	0.89	1.03	0.75
0.98	50	0.02	1.17	1.41	0.90	1.01	1.15	0.86
0.95	20	0.05	1.36	1.60	1.08	1.22	1.37	1.07

5. Conclusion

This study provided a comprehensive probabilistic assessment of low-flow conditions in the Upper Ipeľ River basin, analyzing long-term discharge series from four key gauging stations (Holiša, Kalinovo, and upstream/downstream of the Málinec Reservoir) and focusing specifically on *T*-year 7-day minimum specific runoff estimation at the Ipeľ: Málinec upstream station using the Log-Pearson Type III (LP3) distribution.

Historical analysis at Holiša (1931–2022) revealed pronounced multi-decadal variability, with an exceptionally water-rich period in 1936–1940 contrasting severe drought episodes in 1981–1990 and extreme minima in 1947 and 1993. Long-term declining trends were confirmed across both mean daily and maximum discharges. The LP3 analysis yielded critically low design values, including a *100*-year 7-day minimum specific runoff of 0.06 l.s^{-1}.km^{-2}, confirming the basin's extreme low-flow vulnerability.

Methodological innovation addressed the critical limitation of the short observational record (1995–2022) at Ipeľ: Málinec upstream. The hydrological analogy approach, utilizing strong correlation (r = 0.909) with the neighboring unregulated Rimavica basin (Lehota nad Rimavicou), successfully extended this series to ~75 years. This extension was essential, as LP3 fitting of the short record substantially underestimated historical drought severity.

Primary results for the target Ipeľ: Málinec upstream station demonstrate that the extended series produced significantly lower

and more realistic design values than the short-observed record. Key findings include:

- *100*-year 7-day minimum specific runoff: 0.89 $l.s^{-1}.km^{-2}$ (90% confidence interval: 0.75–1.03 $l.s^{-1}.km^{-2}$).
- Demonstrated need to include extreme low-flow outliers in LP3 fitting for accurate lower-tail estimation.
- Validation of the Rimavica basin as a suitable hydrological analogue for regional low-flow extrapolation.

Reservoir impact analysis showed that Málinec Reservoir regulation substantially alters downstream flow conditions, weakening correlations (r = 0.204) between upstream and downstream stations and masking natural low-flow variability. This underscores the necessity of unregulated reference catchments for robust *T*-year estimation.

According to [22], the baseflow index at the Mlálinec above WR station (54.24 km^2) is 0.702. Furthermore, according to [22], the long-term mean of 7-day minimum flows was 2.426 $l.s^{-1}.km^{-2}$ (i.e., 0.1316 $m^3.s^{-1}$) and Q99 was 1.512 $l.s^{-1}.km^{-2}$ (0.082 $m^3.s^{-1}$). These values are naturally higher than our estimates of *100*-year minima.

An important methodological finding of this study concerns the application of the Log-Pearson Type III (LP3) distribution for low-flow estimation. By carefully adjusting the skewness coefficient, the LP3 fitting could be optimized specifically for the lower tail of the distribution – the region most relevant for *T*-year minimum flow design values. This targeted adjustment significantly improved the accuracy of extreme low-flow estimates compared to standard parameter fitting.

The upper tail of minimum flow values (representing relatively "wetter" low-flow conditions) was intentionally de-emphasized, as it has limited practical relevance for water management applications. Our focus remained on achieving precise characterization of the lowest 1-5% quantile range, where design values for *20*-, *50*-, and *100*-year return periods reside. This selective optimization demonstrates that LP3 parameter regionalization should prioritize lower-tail performance when applied to hydrological drought assessment across similar Carpathian basins.

The derived design values provide essential parameters for water management practice, including reservoir yield assessment, minimum environmental flow guarantees, drought contingency planning, and climate change adaptation strategies for the Upper Ipeľ basin and the broader Danube catchment. The demonstrated efficacy of the hydrological analogy method offers a transferable approach for low-flow assessment in data-scarce regions worldwide.

Acknowledgments

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References

1. L. Křivský, “Climate fluctuations in our country and climatological prognosis for the next few decades (Kolísání podnebí u nás a klimatologická prognosa pro nejbližších několik desetiletí)”, Meteorologické zprávy 10, 71–72 (1957).
2. A. Bratránek, “Occurrence of extreme water regimes periods in Central Europe and their significance from the water management point of view (Výskyt období extrémních vodností ve střední Evropě a jejich význam z vodohospodářského hlediska)”, J. Hydrol. Hydromech. 8, 3–14 (1960).
3. J. Balek, “Linear extrapolation of average annual discharges of selected rivers of four continents (Lineární extrapolace průměrných ročních průtoků vybraných řek čtyř kontinentů)”, J. Hydrol. Hydromech. 16, 402–428 (1968).
4. R. K. Klige, A. O. Selivanov, and A. M. Voronov, “Changes in the water regime of the territory of the USSR over the last millennium (Izmenenia vodnogo režima territorii SSSR za poslednye tysjačiletie)”, Vodnye resursy 5, 28–40 (1989).
5. R. S. Bradley, “Reconstruction of Climate from A.D. 1000 to the Present,” in Contemporary Climatology, edited by R. Brázdil and M. Kolář (Brno, 1994), pp. 12–21.
6. O. Majerčáková and P. Škoda, “Development of precipitation and runoff in the territory of Slovakia and its possible influence by climate changes (Vývoj zrážok a odtokov na území Slovenska a jeho možné ovplyvnenie klimatickými zmenami)”, Meteorologické zprávy 46, 164–168 (1993).
7. R. Brázdil and M. Kolář, Contemporary Climatology (Brno, 1994).
8. M. Lapin, P. Faško, and V. Zeman, “Contribution to analysis of possible global warming impacts upon climate change in Slovakia”, in National Climate Programme of the Slovak Republic, Vol. 2 (Bratislava, 1994), pp. 39–77.
9. E. Přenosilová, K. Nacházel, and A. Patera, “Estimating the impact of climate change on utilisation of surface water resources”, in XVIIth Conference of the Danube Countries on Hydrological Forecasting and Hydrological Bases of Water Management (HNC IHP, Budapest, 1994).
10. J. Hladný, Impacts of a potential climate change on hydrology and water resources in the Czech Republic (Praha, 1997).
11. P. Petrovič, “Climate change impact on the water management in the Nitra basin (Slovakia)”, Annales Geophysicae 15, Supplement II (1997).
12. O. Lukjanetz and M. Sossedko, “Runoff estimate for the next years in the Carpathians with regard to multi-annual fluctuations”, in XIX Conference of the Danube Countries (Osijek, Croatia, 1998), pp. 393–401.
13. J. Poórová, L. Blaškovičová, P. Škoda, and V. Šimor, “Trends of minimum annual and monthly discharges on Slovak rivers (Trendy minimálnych ročných a mesačných prietokov na slovenských tokoch)”, in Seminar Sucho a jak mu čelit (Prague, 2013), pp. 20–23.
14. P. Pekárová, P. Miklánek, J. Pekár, and B. Pramuk, “Identification of changes in the daily discharge regime of Slovak rivers. Part II: Comparison of two periods (Identifikácia zmien režimu denných prietokov slovenských riek. II. Časť: Porovnanie dvoch období)”, Acta Hydrologica Slovaca 18, 183–192 (2017).

References

15. M. Ďurigová and K. Hlavčová, "The detection of changes in the upper Váh river basin according to decadal analysis", Acta Hydrologica Slovaca 21, 39–47 (2020).
16. M. Ďurigová, D. Ballová, and K. Hlavčová, "Analyses of Monthly Discharges in Slovakia Using Hydrological Exploratory Methods and Statistical Methods", Slovak J. Civ. Eng. 27, 36–43 (2019).
17. D. Pavelková, B. Kandra, A. Tall, M. Gomboš, and H. Hlavatá, "Comparison of the trend development of basic hydrometeorological elements with their trend development in normal periods (Porovnanie trendového vývoja základných hydrometeorologických prvkov s ich trendovým vývojom v normálových obdobiach)", in Hydrological Processes in the Soil–Plant–Atmosphere System (Institute of Hydrology, Slovak Academy of Sciences, Bratislava, 2021), pp. 274–285.
18. L. Blaškovičová, K. Jeneiová, K. Melová, J. Poórová, S. Liová, K. Slivková, and B. Síčová, "Changes in Selected Low-Flow Characteristics in the 2001–2015 Period Compared to the 1961–2000 Reference Period in Slovakia", Climate 10, 81 (2022).
19. D. Halmová, P. Pekárová, J. Podolinská, and K. Jeneiová, "The assessment of changes in the long-term water balance in the Krupinica River basin for the period 1931–2020", Acta Hydrologica Slovaca 23, 21–31 (2022).
20. D. Halmová, P. Pekárová, J. Mészáros, P. Miklánek, and V. Bačová Mitková, "Identification of the occurrence of historical droughts on the Danube and its tributaries (Identifikácia výskytu historických súch na Dunaji a jeho prítokoch)", in Hydrological Days 2021: IX. National Conference of Czech and Slovak Hydrologists and Water Managers (Hydrologické dny 2021) Český hydrometeorologický ústav, Praha, (2021), pp. 33–34.
21. T. T. Trang, T. P. Thao, T. T. Ha, and T. Lan, "Drought Monitoring Method Using Remote Sensing Data and Artificial Intelligence," J. Pol. Miner. Eng. Soc. 2, 889–902 (2025).
22. Z. Bajtek, I. Leščešen, and K. Jeneiová, "Analysis of trends of low flow in river stations in Ipeľ with respect to Málinec reservoir", Acta Hydrologica Slovaca 26, 123–131 (2025).
23. A. Kasana, "Priehrady a nádrže: vodárenská nádrž Málinec a horná nádrž Látky v rámci prevádzky prečerpávacej vodnej elektrárne [Dams and Reservoirs: Málinec Water-Supply Reservoir and the Látky Upper Reservoir within the Operation of a Pumped-Storage Hydroelectric Power Plant]," Vodohospodársky spravodajca 9–10, 5–11 (2025).