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METHODOLOGY FOR ASSESSING PROBABILITY OF EXTREME HYDROLOGIC EVENTS COINCIDENCE

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Abstract: *The aim of the presented research is improvement of methodology for probability calculation of coinciding occurrence of historic floods and droughts in the same year. The original procedure was developed in order to determine the occurrence probability of such an extreme historic event.*
There are two phases in calculation procedure for assessment of both extreme drought and flood occurrence probability in the same year. In the first phase outliers are detected as indicators of extreme events, their return periods are calculated and series' statistics adjusted. In the second phase conditional probabilities are calculated: empirical points are plotted, and both extreme drought and flood occurrence probability in the same year is assessed based on the plot.
Outlier detection is performed for the territory of Serbia. Results are shown as maps of regions (basins) prone to floods, hydrologic drought, or both. Step-by-step numeric example is given for assessing conditional probability of occurrence of flood and drought for GS Raska on the river Raska. Results of assessment of conditional probability in two more cases are given for combination of extreme flood and 30 day minimum flow.

Keywords: *Conditional probability, outlier detection, extreme hydrologic events coincidence*

1. INTRODUCTION

Defining occurrence possibility of floods and droughts in the same year is important from the standpoint of water resources management. This possibility can be described and quantified through conditional probability. Calculation procedure of conditional probabilities assumes defining the occurrence coincidence of both extreme drought and flood for one year discretization period. Extreme droughts and floods are defined within series of absolute maximum and absolute minimum annual flows. A combined graphical and analytical procedure for conditional probabilities assessment is developed and applied using the results of accepted variables constellations coincidences.

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2. INPUT DATA

The analyzed territory is the Republic of Serbia without the Province of Kosovo and Metohija. Flow records from Hydro-Meteorological Service of Serbia surface water observation network are used for analysis. Series of annual maxima, annual minima and the 30-day minima are taken in consideration. Processing period is equal to the observation period. Series with less than 25 data are excluded from the analysis, being considered unreliable. Also, the gauge stations with zero-flow in annual minima data sets were not taken into consideration.

Figure 1 shows the network of 144 analyzed hydrological gauge stations and 11 major river basins.

3. METHODOLOGY

There are two phases in calculation procedure for assessment of both extreme drought and flood occurrence probability in the same year. In the first phase outliers are detected as indicators of extreme events, their return periods are calculated and series' statistics adjusted. In the second phase conditional probabilities are calculated, plotted, and both extreme drought and flood occurrence probability in the same year is assessed.

3.1. The first phase

3.1.1. *Extreme events detection*

In hydrological practice, historic events are those which, in an uninterrupted time series, considerably exceed or deviate from the neighboring values for the variable under consideration. On the other hand, historic events are those which did not happen during the observation or gauge period, but are still remembered or recorded in some way, due to their severity. This definition mainly refers to historic floods. This research deals with extreme flows that happened within gauge period, perceived historic events due to their magnitude.

Hydro-Meteorological Service of Serbia recommended the Pilot and Harvey test for outlier detection. These outliers are considered historic events (*HE*).

The Pilot and Harvey test is generally used to obtain realistic assessments of historic events (outliers) under extreme hydrologic conditions (floods and droughts). The assumption is that quantitative characteristics of these conditions have the Log-Pearson III (*LPT3*) probability distribution. Under such assumption, the upper and lower limits for the outliers are computed using the following formulas (1), (2):

Upper limit

$$Y_H = Y_{av} + K_N S_y \quad (1)$$

Lower limit

$$Y_L = Y_{av} - K_N S_y \quad (2)$$

(these equations apply if -0.4> C_{sy} > 0.4)

where:

Y_H – logarithm of the value of the outlier upper limit;
Y_L – logarithm of the value of the outlier lower limit;

Y_{av} – average value of the time series Y;
$Y = \log X$
X - observed time series;
S_y – standard deviation of the time series Y;
C_{sy} –skew coefficient of the time series Y;
K_N – frequency factor (critical value) for the risk coefficient ά=10%
N – sample size of Y series for which statistical parameters will be calculated.

The frequency factor, K_N, is computed using the formula (3):

$$K_N = -3{,}6220 + 6{,}2844\, N^{0.25} - 2{,}49835\, N^{0.5} + 0{,}491436\, N^{0.75} - 0{,}037911\, N \quad (3)$$

The historic flood detection procedure itself involves a comparison of empirical distribution functions with defined outlier limits. If any empirical point falls outside the range defined by upper and lower limit, then such a point is deemed to represent a historic event with probability 1- ά = 0.90.

In compliance with the test conditions, only the data sets that satisfied -0.4> Csy > 0.4 were taken into consideration for further investigation.

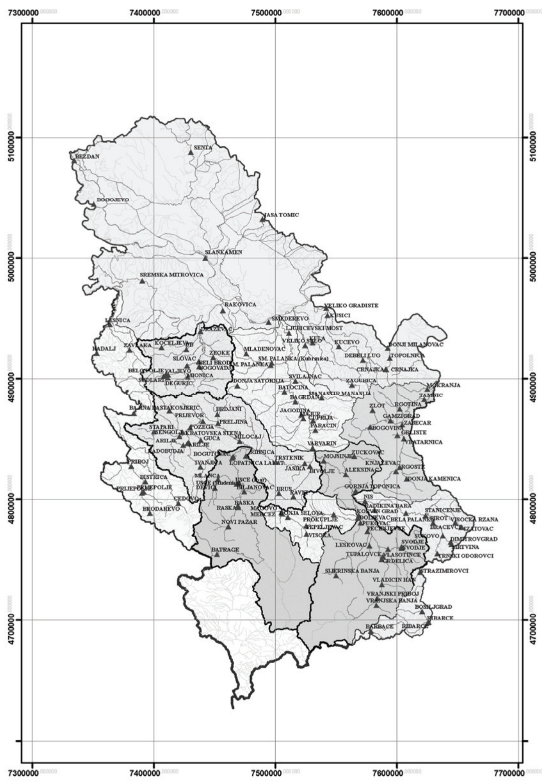

Fig. 1 Hydro-Meteorological Service of Serbia surface water observation network-analyzed hydrological stations and major river basins.

3.1.2. *Calculations of statistical parameters and return periods of outliers*

In order to estimate return period of detected outliers by Pilot and Harvey test, procedure shown below is preformed because calculated statistical parameters do not reflect the actual characteristics of the analyzed processes.

When outliers are detected, they have to be adjusted based on whether they have occurred during a monitoring (gauge) period or not, assuming that the random variable X follows the Pearson 3 ($PT3$) or $LPT3$ distribution. If an outlier does not occur in the observation period, n, and if it is not exceeded during a longer period of time, N, then the empirical probabilities of a tested series P_i (i=1,2,3,......, n+1) are computed using the formula (4):

$$P_1 = 1/(N+1),\ P_2 = 1/(n+1),\ P_3 = 2/(n+1)\ ,\ P_4 = 3/(n+1),\ ......,\ P_{n+1} = n/(n+1) \qquad (4)$$

If two outliers have occurred, one during the monitoring period n, and the other not in that period, and neither have been exceeded during the longer period of time N, then empirical probabilities of series P_i are computed based on the formula (5):

$$P_1 = 1/(N+1),\ P_2 = 2/(N+1),\ P_3 = 3/(n+1)\ ,\ P_4 = 4/(n+1),\ ...,\ P_{n+1} = n/(n+1) \qquad (5)$$

If the random variable X has the $PT3$ or $LPT3$ distribution, adjusted statistical parameters for a single outlier outside the monitoring period are computed using the formulas (6), (7), (8):

Average value – $X_{av,N}$

$$X_{av,N} = \frac{\left[X_N + (N-1)\sum_{i=1}^{n} \frac{X_i}{n} \right]}{N} \qquad (6)$$

where:

X_N is the value of outlier – random variable X, which has not been exceeded during the time period N, and

X_i are values of the members of the basic data series for the monitoring period n.

Coefficient of variation – $C_{v,N}$

$$C_{v,N} = \sqrt{\frac{1}{N-1}\left[(k_N - 1)^2 + \frac{N-1}{n}\sum_{i=1}^{n}(k_i - 1)^2 \right]} \qquad (7)$$

where:

$k_N = \dfrac{X_N}{X_{av,N}}$ is the value of the outlier modulus coefficient,

$k_i = \dfrac{X_i}{X_{av,N}}$ is the modulus coefficient of the random variable X during the monitoring period.

Skewness coefficient – $C_{s,N}$

$$C_{s,N} = \frac{N}{(N-1)(N-2)C_{v,N}^3}\left[(k_N - 1)^3 + \frac{N-1}{n}\sum_{i=1}^{n}(k_i - 1)^3 \right] \qquad (8)$$

If there are two outliers, one in and the other not in the monitoring period, then statistical parameters are computed using the following formulas (9), (10), (11):

Average value – $X_{av,N}$

$$X_{av,N} = \frac{\left[X_N + X_{N-1} + (N-2)\sum_{i=2}^{n}\frac{X_i}{n}\right]}{N} \tag{9}$$

Coefficient of variation – $C_{v,N}$

$$C_{v,N} = \sqrt{\frac{1}{N-1}\left[(k_N-1)^2 + (k_{N-1}-1)^2 + \frac{N-2}{n-1}\sum_{i=2}^{n}(k_i-1)^2\right]} \tag{10}$$

Skewness coefficient – $C_{s,N}$

$$C_{s,N} = \frac{N}{(N-1)(N-2)C_{v,N}^3}\left[(k_N-1)^3 + (k_{N-1}-1)^3 + \frac{N-2}{n-1}\sum_{i=2}^{n}(k_i-1)^3\right] \tag{11}$$

The following procedure is used to adjust the statistical parameters:

The weight coefficient – W is determined based on the number of events that are not within outlier limits, using the formula (12):

$$W = \frac{N-Z}{n+L} \tag{12}$$

where:
Z is the number of high outliers, which are above high outlier limit,
L is the number of low outliers, which are lower than low outlier limit.

In the case of detection of both high and low outliers, the adjusted values of the statistical parameters are calculated using the logarithmic values of the observed random variable X (i.e. using the random variable Y), as follows

Average value - $\overline{Y_L^*}$

$$\overline{Y_L^*} = \frac{W\sum_{i=1}^{n}Y_{i,L} + \sum_{j=1}^{Z}Y_{j,L}}{N - W\cdot L} \tag{13}$$

Variance – $(S_L^*)^2$

$$(S_L^*)^2 = \frac{W\sum_{i=1}^{n}(Y_{i,L} - \overline{Y_L^*}) + \sum_{j=1}^{Z}(Y_{j;L} - \overline{Y_L^*})^2}{N - W\cdot L - 1} \tag{14}$$

Skewness coefficient - G_L^*

$$G_L^* = \frac{N - W\cdot L}{(N - W\cdot L - 1)(N - W\cdot L - 2)}\left[\frac{W\sum_{i=1}^{n}(Y_{i,L} - \overline{Y_L^*})^3 + \sum_{j=1}^{Z}(Y_{j,L} - \overline{Y_L^*})^3}{(S_L^*)^3}\right] \tag{15}$$

Empirical probabilities are calculated using the expression (16)

$$P = \frac{m^*}{N+1} \tag{16}$$

where:

$m^* = m$ for $1 \le m \le Z$

$m^* = W \cdot m - (W-1)(Z+0.5)$ for $(Z+1) \le m \le (Z+n+L)$

here, m^* is the weighted order, m is the order of the data point in the ascending or descending series, depending on the studied process.

The adjusted values of the statistical parameters, as defined above, are used to calculate the theoretical probabilities (or return periods) of recorded outliers, based on *PT3* - $P(X_N)$ or *LPT3* – $P(X_N = 10^{(YL)})$ distribution:

$$T(X_N) = \frac{1}{P(X_N)} \quad \text{(in years).}$$

3.2 The second phase

3.2.1. *Conditional probability*

The procedure for defining the conditional occurrence probabilities of floods and droughts is based on the given coincidence definition. The term 'coincidence' implies probability of the simultaneous occurrence of two random variables Y=Qann,max and X=Qmin, being annual minimum or 30 days minimum for one year discretization period. Assuming that both random variables have Normal Distribution, density function of two-dimensional random variable (X,Y) is:

$$f(x,y) = \frac{1}{2\pi\sigma_x\sigma_y\sqrt{1-R^2}} e^{-\frac{1}{2(1-R^2)}\left[\frac{(x-\overline{X})^2}{\sigma_x} - \frac{2R(x-\overline{X})(y-\overline{Y})}{\sigma_x\sigma_y} + \frac{(y-\overline{Y})^2}{\sigma_y}\right]} \tag{17}$$

where

x, y - values of random variables X, Y

$\overline{X}$, $\overline{Y}$ - means of X, Y

σ_x , σ_y – standard deviations of X, Y

R – correlation coefficient between X and Y.

If studied random variables do not have Normal Distribution, it is necessary to perform the following transformations:

$$u = \log X \qquad w = \log Y$$

$$\Psi = u - \overline{u}\,, \qquad \xi = w - \overline{w} \tag{18}$$

Consequently, density function of transformed variables becomes

$$f(\psi,\xi) = \frac{1}{2\pi(1-\rho^2)} \exp\left\{-\frac{1}{2(1-\rho^2)}[\psi^2 - 2\rho\psi\xi + \xi^2]\right\} \tag{19}$$

Variances σ_ξ and σ_ψ and correlation coefficient ρ are calculated from the observed series.

Solution of equation (19) is a pair of values $\xi_{1,2}$ for any ψ. In other words, for each standardized variable $\psi = \log X - \overline{\log X}$ there are two standardized values $\xi_{1,2} = \log Y - \overline{\log Y}$.

A correlation ellipse f(λ) for probability λ is obtained in the (ψ, ξ) (i.e. (x,y)) plane for values of ψ set in advance. Each of the ψ values is impaired with its ξ_1 and ξ_2 values, and

$$\lambda^2 = \psi^2 - 2\rho\psi\xi + \xi^2 \quad (20)$$

The correlation ellipses for probabilities under consideration represent cross section of horizontal plane and the surface that defines two-dimensional Normal distribution. In order to calculate original values of historic flows: $Y = Q_{\max,annual}$ and $X = Q_{\min,annual}$ or $X = Q_{\min,30\ days}$, an inverse procedure is applied.

The aim of this paper is to present exceedance probability assesment for a unique historic event which imples exceedance probability of two separate historic events:

$$P(Q_{\max,annual} \geq Q_{\max,outlier} \mid Q_{\min,annual} \leq Q_{\min,outlier}) \quad (21)$$

3.2.2. *Graphic procedure*

The explanation is easier to follow on the Figure 5.

According to the procedure given above, for several characteristic probabilities, correlation ellipses are drawn in the (*x*,*y*) plane - $Y = Q_{\max,annual}$, $X = Q_{\min,annual.}$ Gravity center (*GC*) coordinate for correlation ellipses is ($\overline{Q}_{\min,annual}, \overline{Q}_{\max,annual}$). Empirical points should fall within correlation field. They are pairs of observed values ($Q_{\min,annual}$, $Q_{\max,annual}$) for each year in the gauge period. Detected outliers: $Q_{\max,outlier}$ and $Q_{\min,outlier}$ are mapped as two separate points. In order to bring them into one point (achieve coinciding event), from the empirical point of historic maximum - $Q_{\max,outlier}$, a horizontal line is drawn, while a vertical line is drawn from empirical point of historic minimum - $Q_{\min,outlier.}$ The intersection of these two straight lines is point of historic event (*HE*) of interest, with coordinates ($Q_{\min,outlier}$; $Q_{\max,outlier}$). Now, an assisting straight line that joins *HE* and GC points, and cuts through the probability ellipses is drawn. This assisting line defines density function of two-dimensional conditional distribution.

The assumption is that exceedance probability of historic events represents exceedance probability of *HE* point density function of conditional probabilities along the defined assisting line:

$$P(Q_{\max,annual} \geq Q_{\max,outlier}; Q_{\min,annual} \leq Q_{\min,outlier}) =$$
$$= P(Q_{\max,annual} | Q_{\min,annual} \geq HE(Q_{\min,outlie}; Q_{\max,outlier})$$

Obtained ellipses correlation field quantiles are used on the y axis for defining the conditional probabilities density function. The quantiles are defined for intended probability (λ) as upper ($\overline{\lambda}$) and lower ($\underline{\lambda}$) limits, as well as for gravity center GC ($\overline{Q}_{\min,annual}; \overline{Q}_{\max,annual}$). These quantiles are noted:

$$Q_{\max,annual}(\overline{\lambda})\;;\quad Q_{\max,annual}(\underline{\lambda})\quad \text{and}\quad Q_{\max,annual}(\mathrm{GC}).$$

Statistical parameters of conditional probabilites density function are defined using a standard combination of graphical and analitical procedure. Curtosis coefficient is estimated using the following formula:

$$C_C = \frac{Q_{\max,annual}(\overline{\lambda}) + Q_{\max,annual}(\underline{\lambda}) - 2Q_{\max,annual}(GC)}{Q_{\max,annual}(\overline{\lambda}) - Q_{\max,annual}(\underline{\lambda})} \tag{22}$$

There is a direct link between curtosis coefficient and skewness coefficient [4]. Frequency factors for intended probability values of λ are obtained from Pearson III table. These are:

$$K(\overline{\lambda});\quad K(\underline{\lambda})\quad \text{and}\quad K(\lambda_{GC}=0.5).$$

For calculating other statistical parameters the following formulas are used:

variance

$$\sigma = \frac{Q_{\max,annual}(\overline{\lambda}) - Q_{\max,annual}(\underline{\lambda})}{K(\overline{\lambda}) - K(\underline{\lambda})} \tag{23}$$

mean

$$\overline{Q}_{\max,annual} = Q_{\max,annual}(GC) - \sigma K(\lambda_{GC} = 0.5) \tag{24}$$

coefficient of variation

$$C_v = \frac{\sigma}{\overline{Q}_{\max,annual}} \tag{25}$$

For assesing exceedance probability of historic event (*HE*), frequency factor of historic event for Pearson III distribution is calculated first:

$$K(p) = \frac{Q_{\max,annual}(HE) - \overline{Q}_{\max,annual}}{\sigma} \tag{26}$$

Then, Pearson III table gives a value for distribution function value $F(x{=}HE)$ and exceeding probability of historic events is:

$$P(X>x=HE) = P(Q_{\max,annual}|Q_{\min,annual} \geq HE(Q_{\min,outlier}\;;Q_{\max,outlier}) =$$
$$= P(Q_{\max,annual} \geq Q_{\max,outlier};\ Q_{\min,annual} \leq Q_{\min,outlier}).$$

4. RESULTS

4.1. Extreme events detected

Detection of outliers was performed by Pilot and Harvey test on data sets at 144 gauge stations in Serbia, as it was described above. For calculation of statistical parameters and return period of outliers for this research, theoretical probability was obtained for non-exceeding period of extreme events, N=80 years. Due to lack of field data on historic events outside of gauge period, adopted period mainly exceeds available series observation and hydrological data gauge period.

There are 14 identified gauge stations found with high outliers in series of annual maxima [1] and 35 gauge stations with low outliers in the series of annual minima and 30-day minima [1].

4.2. Mapping

The delineation of sub-basins prone to flood, drought or both was done in ArcGIS using scanned and geo-referenced topographic maps (1:100.000 and 1: 25.000) and river network, GIS layer (1:300.000). Sub-basins of gauge stations with identified outliers are shaded areas shown on maps below representing areas of the territory of Serbia prone to floods (Figure 2), hydrologic droughts (Figure 3) and both (Figure 4).

Fig. 2 Flood prone areas in Serbia.

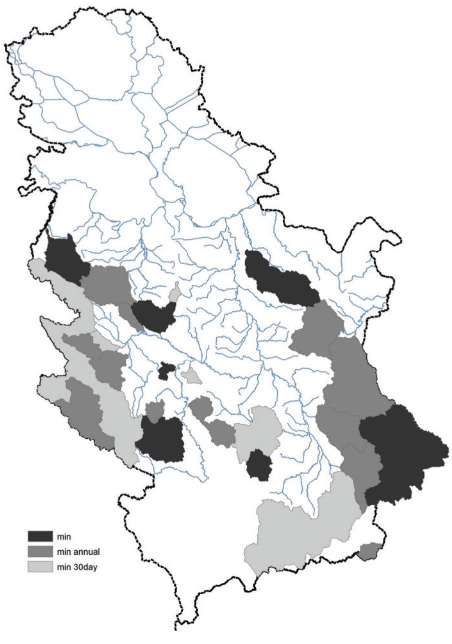

Fig. 3 Hydrologic drought prone areas in Serbia.

Fig. 4 Areas prone to both flood and hydrologic drought in Serbia.

4.3. Extreme events coincidence-conditional probability

Both historic floods and hydrologic droughts occurred at two gauge stations in Serbia.

Application of the developed procedure for evaluation of conditional probabilities for occurrence of historic floods and droughts in the same year is illustrated using the river Raska, gauge station Raska being an example. Series of maximum annual flows are adopted as flood indicators and series of minimum annual flows are accepted as hydrologic drought indicators.

Figure 5 illustrates studied series coincidence and conditional probabilities assessment procedure.

Calculated according to the presented procedure, characteristic values of indicators of floods and droughts on the river Raska are:

$$Q_{max,outlier} = 400\ m^3/s;\ Q_{min,outlier} = 0.75\ m^3/s;$$

$$\overline{Q}_{max,annual} = 69{,}70 m^3/s\ ;\ \overline{Q}_{min,annual} = 2.34 m^3/s$$

$$\lambda = 0.1:\ Q_{max,annual}(\overline{\lambda}) = 250\ m^3/s\ ;\ Q_{min,annual}(\underline{\lambda}) = 19.3\ m^3/s$$

$$C_C = \frac{250 + 19.3 - 2\cdot 69.7}{250 - 19.3} = \frac{129.9}{230.7} = 0.563 \Rightarrow C_s = 1.99 = 2.0$$

$$K(\overline{\lambda}) = 5.91; \quad K(\underline{\lambda}) = -1.00; \quad \sigma = \frac{250 - 19.3}{5.91 + 1.00} = 33.4\ \ m^3/s$$

$$K(p) = \frac{Q_{\max,god}(HE) - \overline{Q}_{\max.god}}{\sigma} = \frac{400 - 69.7}{33.4} = 9.89$$

$$F(x) > 0.9999$$

$$P(X > 400\ m^3/s) = 1 - F(x) < 0.0001$$

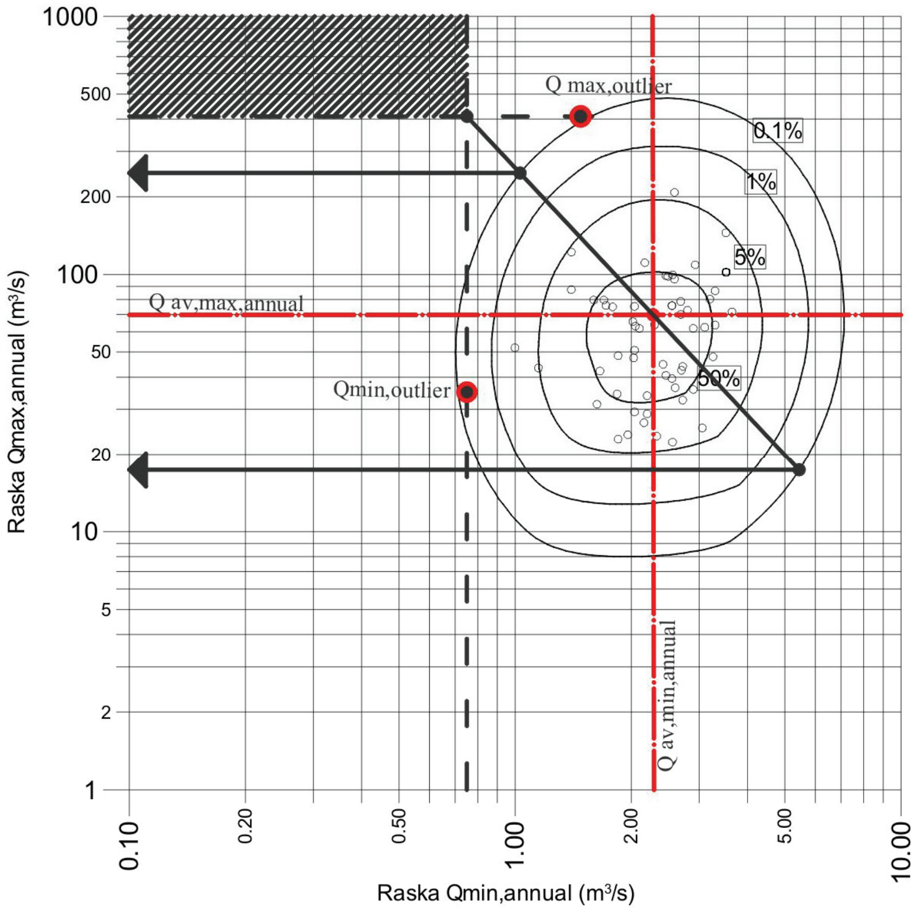

Fig. 5. Conditional probability of occurrence of annual minimum and annual maximum flow on G. S. Raska, graphic part of assessment procedure.

Therefore, probability of exceeding historic floods and droughts in the same year, on the river Raska at Gauge station Raska is:

$$P(X > x = HE) = P(Q_{\max,annual} | Q_{\min,annual} \geq HE(0.75\ ;\ 400)) =$$

$$= P(Q_{\max,annual} \geq 400\ m^3/s;\ Q_{\min,annual} \leq 0.75\ m^3/s) < 0.0001$$

return period is:

$$T(X>x=HE) = T(Q_{\max,annual}|Q_{\min,annual} \geq HE(0.75\ ;\ 400) =$$
$$= T(Q_{\max,annual} \geq 400\ m^3/s;\ Q_{\min,annual} \leq 0.75\ m^3/s) > 10.000 \text{ years}$$

Table 1 Step-by-step results of conditional probability assessment for both historic flood and drought occurrence in the same year at two gauge stations in Serbia.

River	H.S.	λ	$Q_{min,av}$ m³/s	$Q_{min30,av}$ m³/s	$Q_{max,av}$ m³/s	$Q_{max,outlier}$ m³/s	$Q_{min,outlier}$ m³/s	$Q_{max}(\lambda)$ m³/s	$Q_{min}(\lambda)$ m³/s
Drina	Kozluk/Radalj	1	-	107	2061	5370	46	3864	1074
Raska	Raska	0.1	-	2.82	69.7	410	0.958	200	21
Raska	Raska	0.1	2.34	-	69.7	410	0.75	250	19.3
River	H.S.	SK		Cs	$K_{max}(\lambda)$	$K_{min}(\lambda)$	s m³/s	K(p)	T year
Drina	Kozluk/Radalj	0.292		1.04	3.05	-1.83	571.7	5.79	5000
Raska	Raska	0.456		1.62	5.398	-1.233	27	12.6	10000
Raska	Raska	0.563		2	5.91	-1	33.4	9.89	10000

5. CONCLUSIONS

The aim of the presented research is improvement of methodology for probability calculation of coinciding occurrence of historic floods and droughts in the same year. The original procedure was developed in order to determine the occurrence probability of such an extreme historic event.

For an objective detection of separate historic events under extreme hydrological conditions (floods and droughts) Pilot and Harvey test was used. An assessment of historic floods and droughts occurrence was carried out on 144 gauge stations in Serbia, using the absolute maxima annual flow data for floods and absolute minima annual flow or thirty days minima for hydrologic droughts.

According to detected outliers, historic floods in Serbia occurred at 14 gauge stations (river basins) with return period from 77 to 1000 years. In the case of minimum annual flow, 26 historical droughts with return period of 80 to 1500 years were detected, while according to 30 days minima, 20 historical droughts occurred with similar return periods.

Both historic floods and hydrologic droughts occurred at two gauge stations. A combined numerical and graphical example of occurrence assessment of historic flood and drought in the same year was given for gauge station Raska on the river Raska in detail. Return periods, calculated separately, were 539 years for flood and 238 years for drought. However, calculated probability for occurrence of these two historic events in the same year (magnitude of historic flood of 1979 and historic drought of 1951) is less than 0.0001, corresponding to the return period longer than 10.000 years. Results of assessment of conditional probability in two more cases are given for combination of extreme flood and 30 day minimum flow.

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METODOLOGIJA ZA ODREĐIVANJE VEROVATNOĆE KOINCIDENCIJE EKSTREMNIH HIDROLOŠKIH DOGAĐAJA

Stevan Prohaska, Borislava Blagojević, Aleksandra Ilić

Cilj prikazanog istraživanja je poboljšanje metodologije proračuna koincidencije pojave istorijskih poplava i suša u istoj godini. Razvijen je originalan postupak za određivanje verovatnoće javljanja takvog istorijskog događaja.

Postupak proračuna verovatnoće javljanja istorijskog događaja ima dve faze. U prvoj fazi se otkrivaju izuzeci, kao pokazatelji ekstremnih događaja, sračunavaju njihovi povratni periodi i prilagodjaju statistike serija.U drugoj fazi, sračunavaju se uslovne verovatnoće: nanose na dijagram empirijske tačke i procenjuje verovatnoća javljanja ekstremne poplave i suše u istoj godini.

Otkrivanje izuzetaka obavljeno je za serije na teritoriji Srbije. Rezultati su prikazani u obliku karata regiona podložnih poplavama, sušama, i oboma. Dat je detaljan numerički primer za određivanje uslovne verovatnće javljanja poplave i suše na profilu Raška na reci Raški. Prikazani su rezultati proračuna za još dva slučaja, kada se u istoj godini javlja ekstremna poplava i suša karakterisana 30 dnevnim minimumom.

Ključne reči: *Uslovna verovatnoća, otkrivanje izuzetaka, koincidencija ekstremnih hidroloških pojava*