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NEW GUIDELINES FOR FLOOD FLOW ASSESSMENT AT HYDROLOGIC STATIONS IN SERBIA

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ABSTRACT

The last organized effort to create legal framework for flood flow assessment in Serbia took place in 1989. Draft guidelines on the matter were published, but had never received adequate legal power. In 2012, Public Water Management Company "Srbijavode" initiated the "Research for improvement and development of flood flow protection in Serbia: standardization of methodology for flood flow assessment in Serbia" project with an aim to produce a publication that would undergo review by practitioners and scientists, and after public consultations and review of draft publication, suggest adoption of the publication as a legal binding document. The research is planned in three phases. Phase one is dedicated to determining flood flow frequency in gauged basins i.e. at hydrologic stations and is currently being implemented. Other two phases should deal with ungauged basins and development of regional relationships. The paper presents the draft publication content for the first phase, and findings on the applicability of methodologies presented in the similar documents from Europe, Russia, and the U.S., as well as a brief presentation of flood flow characteristics in Serbia. Several elements that differ from the previous guidelines and recommendations for a methodological update of statistical analysis in Serbia are highlighted.

KEYWORDS

Flood flow frequency analyses, flood flow policy instruments, gauged hydrologic sites, legal framework in Serbia.

1. INTRODUCTION

In 2010, the Public Water Management Company "Srbijavode" launched an initiative for standardizing methodologies for flood flow estimation in Serbia. A significant number of the state institutions' representatives, leading experts and researchers in hydrology and water resources management took part in "Flood Flow Assessment in Serbia – Current Status and Needs" round table as a kick-off event. It was concluded that a consistent methodology for flood flow assessment (FFA) is necessary in order to: 1) establish a methodological base for comparison of flood-related variables, regardless of the expertise and experience of design engineers and/or reviewers in Serbia; 2) enable coordination between state institutions and other stakeholders (both private and public) that participate in flood risk management from planning and design to maintenance; 3) provide a basis for flood risk insurance programs. This was recognized in the U.S. in the 1960s (Stedinger and Griffis, 2008).

The efforts made in the field of FFA in the majority of developed countries have led to the practices and research results rendered into standards or recommendations, often with mandatory usage in design of hydraulic structures and in water resources systems management. Well known Bulletin 17B (ICWD, 1982) is still in use in the United States, although the scientific community calls for its revision (Stedinger and Griffis, 2008). This document is a basis for a number of other documents, guidelines and recommendations in all engineering areas that require FFA. Similar documents in the Russian Federation are legally binding design and construction norms and procedures (SNiP 33-01-2003, SP 33-101-2003), issued in 2004 as an update of the documents from 1983.

The last organized effort to standardize FFA methods and procedures in Serbia was made in 1980s in former Yugoslavia. The task force, appointed by the Yugoslav Association for Hydrology (YAH) and National Committee for International Hydrologic Programme (NC-IHP), has completed draft FFA guidelines in 1989 (YAH and NC-IHP, 1989). Unfortunately, due to the huge crisis and breakup of Yugoslavia, this document had never been adopted as a binding document for the engineering practice.

The initiative launched by Public Water Management Company ”Srbijavode” more than twenty years later led to commencement of the “Research for Improvement and Development of Flood Flow Protection in Serbia: Standardization of Methodology for Flood Flow Assessment” project. The project goal is to produce a publication that would undergo review by practitioners and scientists, followed by a public debate, and at the end to suggest adoption of the publication as a legal binding document. The research is planned in three phases, with the following outcomes:

1. Guidelines for statistical analysis of flood flows at hydrologic stations (in gauged basins);
2. Guidelines for flood flow estimation in ungauged basins;
3. Atlas of flood indicators for Serbia with application of regional FFA.

The publication with draft guidelines for statistical analysis of flood flows in gauged basins are the first tangible result of the project. This paper presents the contents of these draft guidelines, which are prepared for the public debate and review process. In the following text we shall refer to this publication as to Guidelines. The next section presents the main activities that led to completion of the publication. The third section is an overview of some characteristics of floods in Serbia, and highlights the elements of Guidelines that differ from the previous publication by YAH and NC-IHP (1989). The final section briefly describes the recommendations for a methodological update of statistical analysis in Serbia that are proposed in the Guidelines.

2. METHODS

The methodology applied in the process of composing the Guidelines is shown through the activities undertaken by the research team for the first phase of the project.

Activity I.1. Overview of experience in other countries and current state of the art practice related to FFA, including:

- Overview of the statistical methods for FFA used in Europe from the COST action ES0901 report (Castelarin et al., 2012);
- Overview of the FFA related legislation in the Russian Federation (SP 33-101-2003, SNiP 33-01-2003);
- Overview of the U.S. guidelines (Bulletin 17B, ICWD, 1982) and suggested improvements (Stedinger and Griffis, 2008);
- Detailed overview of the approaches and contents of the Austrian FFA guidelines (BLUFW, 2011).

The main goal of this broad overview was to identify directions in which the current FFA practice in Serbia should be improved. It was concluded that the Guidelines should include the method of L-moments for estimating distribution parameters. The usual set of probability distributions used for flood frequency analysis in Serbia (normal, log-normal, Gumbel, Pearson type 3, and log-Pearson type 3) should be extended with other theoretical probability distributions, such as the Pareto and GEV distributions.

Activity I.2. Collection and systematization of the existing studies, recommendations, technical documentation and other flood-related material published in Serbia, and their evaluation for further use. This activity was mainly focused on the content and scope of the previous FFA guidelines (YAH and NC-IHP, 1989), and analysis of data and information already in use for FFA available in the Republic Hydrometeorological Service of Serbia (RHMSS). The previous FFA guidelines from 1989 included a detailed theoretical background on probability and statistical methods. With the currently available literature and references, it was concluded that it is not necessary to preserve the extent and the level of detail from the former FFA guidelines.

One of the main features of the current FFA practice is that the regional flood information is used only as a qualitative tool. A typical example is the use of flood envelope curves developed in 1989. It was

therefore concluded that these curves should be updated in order to support practitioners in their everyday practice.

With the assistance of the RHMSS, which is responsible for hydrometric measurements in Serbia, special attention was given to an overview of the procedures for gauged flood data quality control. Problems related to the hydrometric network were also identified. There are very few hydrologic stations with catchment area below 100 km^2 and a limited number of stations in the mountainous areas prone to flash floods. Stations not suitable for frequency analysis due to disturbed flow regime and/or short or incomplete data records are also identified.

Activity I.3. Composition of the draft Guidelines. This activity is completed and presented in the next section. The remaining activities include review of the draft Guidelines and organization of the public debate (Activity I.4), and publication of the final version of the Guidelines (Activity I.5).

3. RESULTS AND DISCUSSION

Table of contents of the draft Guidelines for flood frequency analysis is given in Appendix in order to illustrate the scope of the document. Some flood characteristics for Serbia available at the moment are highlighted in this section.

3.1 Flood characteristics in Serbia

Frequency analysis of floods on the nation-wide level in Serbia has been undertaken several times in the last 30 years. The existing flood envelope curves for Serbia rely on the studies performed in 1980s. In the 1990s, another round of flood frequency analysis was conducted for the purpose of Water Resources Master Plan of Serbia (WRDI, 1996). This document was revised in 2010 in order to comply with the current Water Law in Serbia, and included results of the flood frequency analysis for data records until the year 2006.

Ministry of Education and Science of the Republic of Serbia and Public Water Management Company “Srbijavode” are currently financing several flood-related research projects. These projects cover classification of water bodies in Serbia that can be used to choose FFA methodology based on the status of hydrologic regime (natural/disturbed). Findings and conclusions published before the end of public debate on the FFA Guidelines will be reviewed and added to the final version of the document.

Recently, flood frequency analysis was conducted for 70 hydrologic stations as a part of the Air World Wide project (Despotović et al., 2012). The study used the annual maxima series (AMS) with data up to 2010. The following probability distributions were fitted to data: two-parameter log-normal, Gumbel, Pearson type 3 and log-Pearson type 3. Choice of the best probability distribution for each station was based on three goodness-of-fit tests: Kolmogorov-Smirnov, Cramer-von Mises and chi-square. Figure 1 shows the choice for 14 selected hydrologic stations. The prevailing probability distribution is the Pearson type 3. The next step for the FFA Guidelines would be to conduct additional goodness-of-fit tests to determine if any other probability distribution can be applied. Furthermore, it should be decided if it is reasonable and needed to adopt one standard probability distribution for Serbia.

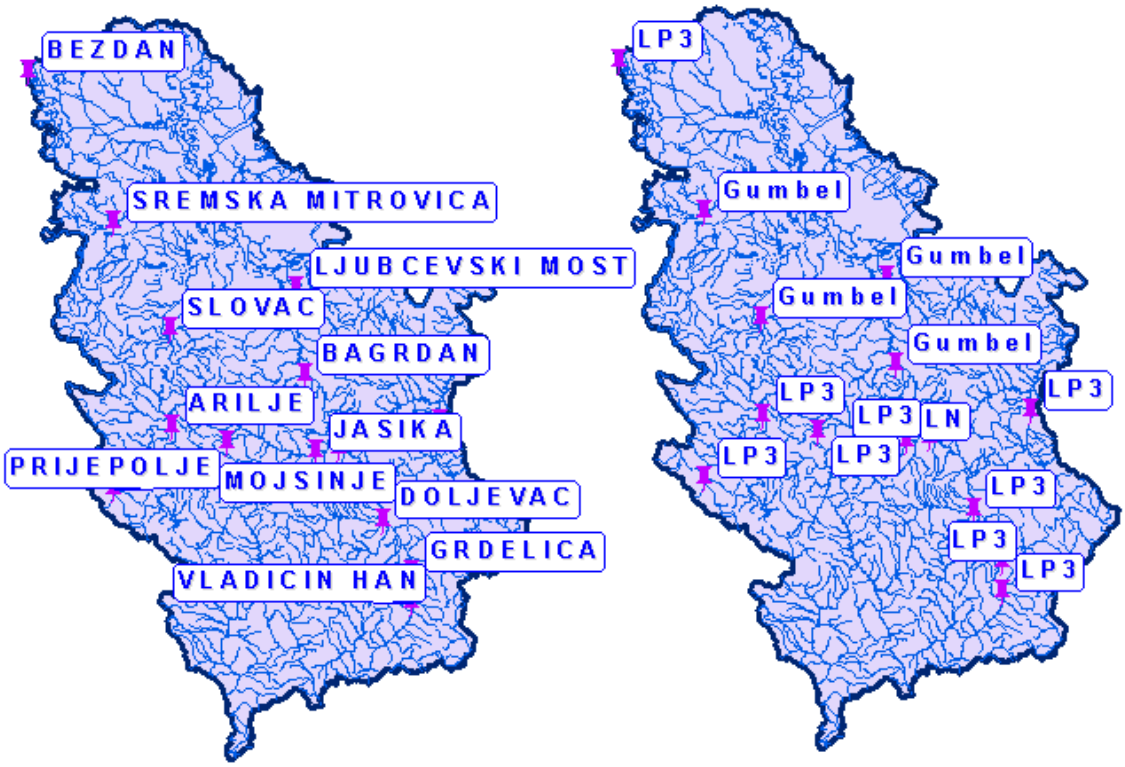

Figure 1 FFA: Probability distributions (right) for 14 hydrologic stations in Serbia (left) based on AMS data records until 2011. (Despotovic et al., 2012).

Table 1 Estimated return periods of low (L) and high (H) outliers in AMS data records until 2006 at hydrologic stations in Serbia (Blagojević et al., 2010).

River	Hydrologic station	Basin area (km^2)	Sample size	Return period (years)	Outlier
Mlava	Rašanac/V.Selo	1124	56	**70**	**L**
J. Morava	Mojsinje	15390	56	**583**	**L**
Kolubara	Valjevo	340	49	**1526**	**L**
Kolubara	Slovac	995	51	**322**	**L**
Kolubara	B. Brod	1896	48	**1325**	**L**
V.Morava	Varvarin	31548	59	**155; 153**	**L**
V.Morava	Bagrdan	33446	57	**178**	**L**
V.Morava	Lj. Most	37320	59	**216**	**L**
Drina	B. Bašta	14797	81	**163**	**H**
Drina	Radalj	17490	41	**554**	**H**
Lim	Priboj	3684	44	**265**	**H**
Ibar	L.Lakat	7818	59	**271**	**H**
Raška	Raška	1036	59	**811**	**H**
Vlasina	Svođe	350	52	**1810**	**H**
Ribnica	Paš./Mionica	107.8	50	**86**	**H**
Toplica	Magovo	180	33	**120; 74**	**H**
Lukovska	Merćez	112.6	40	**98**	**H**
Z.Morava	Jasika	14721	56	**189**	**H**
Moravica	Ivanjica	475	64	**489**	**H**

Outlier detection and estimation of their return period was also recently performed at all hydrological stations in Serbia south of the Sava and Danube Rivers (Blagojević et al., 2010). The study was based on AMS comprising data until 2006. Results of the study are mapped in Figure 2 and Figure 3, and shown in Table 1. The next step for the FFA Guidelines would be to update data records and conduct additional outlier detection procedure based on the Bulletin 17B methodology, following comparison of various approaches to treatment of detected outliers. Consequently, it should be decided if it is necessary to standardize procedure for outlier detection and adjust the results of flood frequency analysis accordingly.

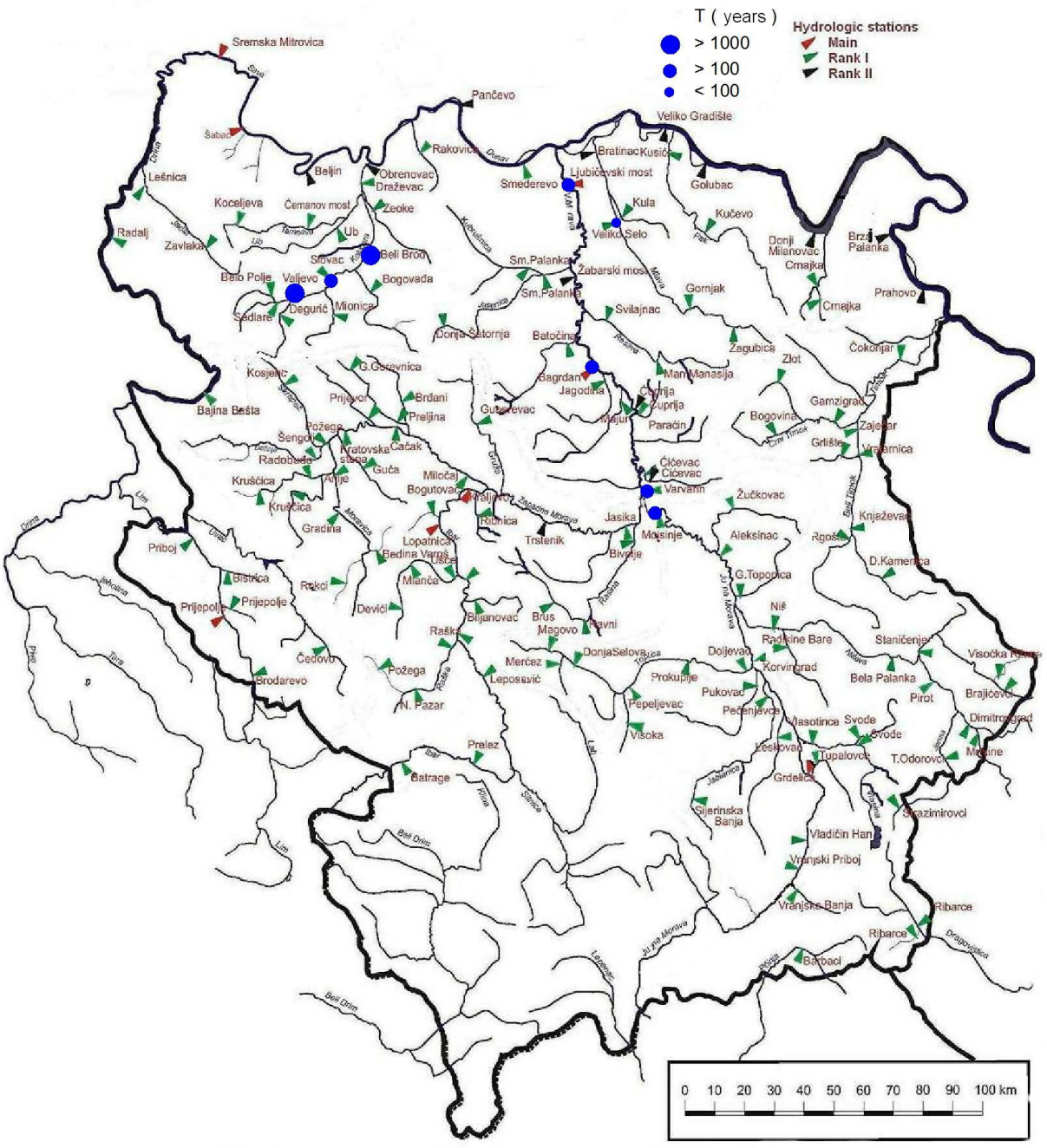

Figure 2 Detected low outliers in AMS data records until 2006 with symbolic representation of estimated return periods (Modified from: Blagojević et al., 2010).

Figure 3 Detected high outliers in AMS data records until 2006 with symbolic representation of estimated return periods (Modified from: Blagojević et al., 2010).

3.2 Discussion

The proposed Serbian FFA Guidelines differ from the former FFA guidelines by YAH and NC-IHP (1989) in several elements. Firstly, instead of a broad theoretical background on probability and statistical methods, new Guidelines discuss the experience in FFA standardization in the U.S., Europe and Russia in order to understand position of national FFA practice in contemporary tendencies. The background for understanding problems in flood flow analyses, and contemporary concepts (e.g. paleofloods) are explained in detail. Directions, guidelines and explanations are provided for flood data acquisition and processing phase. Several new statistical tests are suggested, with an emphasis on detecting inhomogeneity in the series (e.g. Wald-Wolfovitz, Wilcoxon, Kruskal-Walllis, Mann-Kendall, etc.). The outlier detection procedure is given in detail with several options for treatment of outliers in further statistical analysis.

In addition to the usual two- and three-parameter probability distributions, application of GEV distribution is recommended as compulsory. Brief description of recommended distributions is given in the Guidelines' appendix, including parameter estimators by different methods. Computational procedure for the probability weighted moments and L-moments is described, since there has not been relevant reference literature for these methods in Serbia. Moment ratio diagrams are also provided for assessment of applicability of theoretical distributions. The probability plot correlation coefficient test is recommended for the first time in Serbia along with other well-known tests.

The partial duration series or the peak over threshold (POT) method is presented in detail, since this method has a long tradition in Serbia, but is still rarely used in standard engineering practice. The Guidelines include a theoretic background, instructions for threshold selection, description of distributions for the number of peaks, peak magnitudes and the largest peak (annual maximum). The comparative presentation of the return period for the AMS and PDS method is shown.

In order to provide a tool for the FFA control and monitoring, to facilitate the review procedure, and to collect entries for the planned data base for Serbia, it is suggested that the key data, information and results are displayed in the Summary FFA sheet. The sheet is proposed to be an obligatory part of the project documentation submitted to the RHMSS in the process of issuing opinion on technical documentation. The sheet comprises the following elements:

- Site details: River, Cross-section, Coordinates (X,Y), Hydrologic station (Yes/No). For 'No', additional information is required: a) upstream or downstream distance from hydrologic station, b) if there are any significant tributaries along the river reach between the cross-section and hydrologic station, c) basin area difference to the gauged basin.
- Observed data series details: From-to, Total years of observation, Total data, Data origin (RHMSS/Other). For 'Other', additional information is required: data source, and if the time series is augmented or extended, method(s) should be listed.
- FFA purpose: Hydraulic structure type, if any.
- Hydrologic series: data assembly method. For PDS, threshold level is required.
- Flood registered out of the available data record (Yes/No): If 'Yes', the information on historic or/and paleoflood is required: year, magnitude, data source, etc.
- Statistical tests and results: Applied tests and related conclusions should be listed.
- Outliers: Outlier detection test applied, whether identified outlier is high or low. In the Note cell below, the procedure that followed detected outliers should be stated.
- Notes: Anything considered important for FFA.
- Probability distribution: Plotting position formula, Theoretic probability distribution, Goodness of fit test.
- Method for estimation of distribution parameters.
- Adopted distribution parameter estimates.
- Characteristic flood-related magnitudes (for 4 probabilities): peak flow [m^3/s], flood volume/ hydrograph volume [m^3], flood duration (flood hydrograph base) [h].

The proposed Guidelines include both improved and new concepts, methods, tests and analyses. Due to the extent of novelties compared to the existing FFA practice in Serbia, problems of inconsistent, non-representative, dependent and non-random data series are not addressed. Also, numerical examples are not included. It is expected that potential need for either computational examples or listed problems in the FFA would emanate from the public presentation process.

4. CONCLUSIONS

The extensive literature review and analysis of the existing methodologies, data and engineering practice, has led to the Guidelines on flood frequency analysis that would modernize the approach to flood flow assessment in gauged basins in Serbia. In addition to the detailed overview of the new tendencies in other countries and focused discussion on the most sensitive parts of the flood frequency analysis, the Guidelines are mainly oriented to provide clear recommendations for practitioners. The Guidelines bring three specific recommendations that are new to the Serbian practice:

- include GEV distribution in addition to the usually applied theoretical distributions,
- use the probability plot correlation coefficient as goodness-of-fit test, and
- present results of the flood frequency analysis in the Summary FFA sheet.

The draft Guidelines currently cover at-site flood frequency analysis, while the regional approaches should be covered in the third phase of its umbrella project "Research for improvement and development of flood flow protection in Serbia: standardization of methodology for flood flow assessment in Serbia". Consequently, more recommendations would be made upon completion of phases two and three of the project. Likewise, completion of the project would enable FFA control at hydrologic stations through regional comparison of flood-related parameters. For now, the existing flood yield envelope curves are available, while confidence intervals for quantile estimates are used as a kind of indirect control for obtained results.

The Guidelines users are provided with the extensive literature comprised of 69 references, or reference sources available on the internet. The research team hopes for good feedback from the users through the Summary FFA sheet, in order to be able to update and revise the next Guidelines edition, and to proceed to the next project phases.

5. ACKNOWLEDGEMENTS

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Appendix: Contents of the Flood Frequency Analysis Guidelines for Serbia