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Regional estimation of design summer flood discharges in small catchments of northern Slovakia

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Abstract Design floods in ungauged small and mid-sized basins in Slovakia are usually computed from simple regional flood formulae. In this paper other regional approaches have been tested in the flysh region in northern Slovakia. Sub-regions were constructed using hydrologic reasoning based on basin properties and *K*-means clustering of 17 physiographic basin characteristics and annual summer flood statistics from 43 basins. Regional formulae for the computation of the mean annual summer flood and its standard deviation were derived. Comparison of flood quantiles computed from data and from the formulae showed similar results for all tested methods. The practical applicability of the derived formulae is limited and possible reasons for this are discussed.

INTRODUCTION

During the last decades the estimation of design floods in ungauged small basins in Slovakia was prevailingly performed by the application of simple regional flood formulae for the computation of the 100-year flood (Q_{100}) from the basin area in geographical regions. Floods with shorter return periods were computed by regional frequency factors. Correction factors accounted for local runoff formation conditions. Envelope curves were applied in some cases in order to get an acceptable regional curve. Previous comparisons of design floods derived from the regional flood formulae with statistically computed values using new data from 260 small and mid-sized basins summarized in Kohnová & Szolgay (1996) showed a rather arbitrarily defined safety factor in these schemes. The need to test different regional approaches became apparent. The flysh region in northern Slovakia, which is traditionally considered as homogenous in various hydrologic contexts, was chosen for the case study. The region forms a belt, running east–west, approximately 1300 km long and 70 km wide, and is divided into two parts by the high core mountains. Due to the rather impervious upper layers, flash floods dominate the flood regime in the summer season. The growing number of gauging stations in small basins with longer records made it possible to question the necessity of the use of envelope curves in the previous approaches, and to examine how some of the concepts of homogeneity reported in the literature (e.g. Acreman & Sinclair, 1989; Zrinji & Burn, 1994; Meigh *et al.*, 1997) perform in the estimation of design discharges.

METHODOLOGY AND DATA

For a site with no records of flow, according to the experience from numerous studies, the mean annual summer flood (Q_S) and its standard deviation (S_D) were estimated as:

$$Q_S = kA^aB^bC^c \tag{1}$$

$$S_D = iU^uV^vW^w \tag{2}$$

where i, k, a, b, c and u, v, w. are regional parameters, and A, B, C and U, V, W are physiographic characteristics of the basins. Stepwise multiple regression was used to find the most adequate relationship. The number of predictors was kept less than four.

In this approach the homogeneous regions can be defined in numerous ways. The following were considered. Firstly, in method 1 the whole study area was considered to be homogeneous following an earlier tradition and allow this to be compared with the methods developed herein. Secondly, it was attempted to divide it into geographic subregions based on a subjective analysis of the physiographic and climatic basin characteristics in method 2 and on the comparison of the flood frequency curves for the individual sites in method 3. Thirdly, the idea of geographical regions was abandoned, physiographic properties of basins and flood runoff characteristics were used as variables in cluster analysis (K-means clustering with Euclidean metrics after Hartigan (1975)) to define homogeneous regions. In method 4 stations were clustered by choosing several groups of variables with strong influence on Q_S and S_D and little correlation among each other. In method 5 regions were defined using variables which were in use as correction factors in the classical formulae. In method 6 regions with similar flood frequency curves were sought using Q_S and S_D as variables. The number of regions chosen had to be less than four in each method in order to get a comparable number of basins in each group and acceptable estimates of parameters. Since no independent data set was available in the studied area, for each method the relative differences (i.e. $(X - Y)/Y)$) between Q_S, S_D and Q_{100} computed from the regional formulae and statistically from the data were compared at the analysed sites. Values of Q_S were computed from seasonal annual summer floods series in 43 basins with area in the range 20–350 km^2 with observation periods from 15 to 60 years. Seventeen climatic and physiographic parameters of the basins were used to characterize runoff generation.

RESULTS AND CONCLUSIONS

Given the restrictions, method 2 led to two regions, the western and eastern flysh, which are geographically divided by the high core mountains. Three regions were selected in method 3 with the coefficient of variation of Q_S ranging from 0.5 to 0.8, 0.8–1.1 and 1.1–1.4, respectively. In method 4 the basin area, the infiltration capacity index, the slope of the main stream and the mean annual runoff were finally selected as variables, which discriminated best among the three selected regions. In method 5, based on the aspect and the slope, two regions were formed. In method 6 two regions with similar first two parameters of the flood frequency distributions were created.

Different sets of predictor variables were to be selected for each region and method in equations (1) and (2). For the computation of Q_S the basin area, the main stream slope, the basin's shape coefficient, the mean annual runoff and the index of the infiltration capacity of soils were selected. Formulae for the computation of S_D were consisting of the basin's shape coefficient, the mean annual runoff, the index of the infiltration capacity of soils and the aspect.

Results of the comparison of the methods are given in Tables 1, 2 and 3. In the estimation of Q_S and S_D the subjective method 2 and more objective method 4 gave the best results. The regional estimation of design floods by each method dividing the region into sub-regions performed better than the one-region approach, but none of them can be regarded to be superior when compared with the others.

The results cannot be regarded as satisfactory for practical computations. The methods are valid on average, but under-design in approximately one half of the sites cannot be compensated for by over-design in the another half. Several problems remain open: aspects under which the concept of homogeneity can be used for design purposes, the influence of the variability of the flood process, the length and quality of the relevant data on the validity of the concept, the transferability of the concept to meso- and micro-scales, the relationship between homogeneity under ordinary and extreme runoff conditions, the profit from using other physiographic characteristics in the clustering, etc.

Regional envelope curves of the relationship between flood quantiles and predictors could represent a temporary solution to the problems for some design tasks, e.g. dam safety. However they are not applicable for others, e.g. river training and restoration. At-site estimates based on physical analysis could be preferable to regional methods in the flysh region despite the generally accepted assumption of the homogeneity of its basins in terms of hydrologic response.

Table 1 Statistics of the relative differences ($(X - Y)/Y$) between the values of Q_{100} estimated from the regional approaches and using the two parameter log-normal distribution.

	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
Minimum	–0.675	–0.639	–0.749	–0.604	–0.729	–0.714
Maximum	3.640	2.134	1.771	2.533	2.656	2.287
Mean	0.191	0.064	–0.002	0.066	0.077	0.032
Standard deviation	0.987	0.606	0.616	0.639	0.822	0.591

Table 2 Statistics of the relative differences ($(X - Y)/Y$) between the values of Q_S estimated from the regional approaches and from the series of mean annual summer floods.

	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
Minimum	–0.215	–0.328	–0.407	–0.200	–0.209	–0.314
Maximum	1.465	0.317	1.421	0.598	1.222	1.137
Mean	0.040	0.027	–0.007	0.011	0.046	0.001
Standard deviation	0.324	0.163	0.321	0.173	0.288	0.262

Table 3 Statistics of the relative differences ($(X - Y)/Y$) between the values of S_D estimated from the regional approaches and from the series of mean annual summer floods.

	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
Minimum	–0.257	–0.241	–0.208	–0.257	–0.500	–0.278
Maximum	0.369	0.353	0.430	0.277	0.417	0.348
Mean	0.028	0.041	–0.029	0.006	0.039	0.026
Standard deviation	0.158	0.143	0.162	0.144	0.215	0.147

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