Proposal for a IAHS-PUB Working Group on *Design Flow Estimation in Ungauged Basins* Faculty of Engineering – University of Bologna

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Participants

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Specific objectives

A. Design flow estimation via regional studies
B. Flood frequency estimation via simulation studies

Objective A
The main focus within objective A is to develop and test regional approaches for the estimation of design flood flows. The scientific literature on regional frequency analysis of hydrological extremes reports a vast number of studies addressing the estimation of rainstorms and floods associated with a given nonexceedance probability. These methods are generally based on pooling the historical information collected for several sites that are hydrologically similar, without being necessarily located within a geographical region in the strict sense of the word (*focused pooling*, e.g., Schaefer, 1990; Faulkner, 1999; Burn, 1990). Concerning this research avenue, the identification of indexes that effectively quantify the hydrological similarity among sites and can be determined for ungauged basins plays a fundamental role (see for instance Castellarin et al., 2001 for flood flows and Brath et al., 2003 for rainstorms). Therefore, the research activities within objective A will investigate the descriptive capabilities of several hydrological indexes (measures of humidity\aridity of the climate, imperviousness of the catchment etc.) to be used in the process of forming homogeneous pooling groups of basins. The uncertainty of the design flood flows estimated for ungauged sites will then be determined using jack-knife and bootstrap resampling techniques (e.g., Brath et al., 2001 and 2003).

Objective B
Activities within objective B are aimed at developing a framework for inferring the flood frequency distribution for ungauged basins via simulation studies. The growing availability of computing

power has made simulation a viable approach for the analysis of the river flow regime in absence of historical data, as a number of contributions recently presented in the literature prove (Cameron et al. 1999 and 2000; Blaszkova and Beven, 2002; Moretti and Montanari, 2003; Blaszkova and Beven; 2004). In detail, the working group will explore the possibility to couple a multivariate stochastic rainfall model with a spatially distributed, DEM-based rainfall-runoff model for the generation of long series of synthetic river flows. The aim is to use the synthetic series for inferring the shape of the flood frequency distribution.

Working group outcomes

Recent floods occurred all over Europe have brought to light once again the urgent need for obtaining reliable estimates of the peak river flow for ungauged basins, to support the design of river engineering works and flood protection measures. The Working Group will focus on this problem, by considering two different methodologies.

The first methodology is a classical approach in hydrology, namely the use of regional models for flood frequency estimation. When historical data are not available, an approach that is frequently adopted consists of pooling the historical information collected for a group of basins that are assumed to be homogeneous with respect to the flood frequency regime. Although regional flood frequency analyses have a long tradition in hydrology, the literature still dedicates a lot of attention to the problems associated with the regionalization of the frequency regime of flood flows. In particular, the scientific community shows an increasing interest for the so called *focused-pooling techniques*, which form groups of highly similar sites according to physically based criteria, by taking into account the geomorphological and climatic characteristics of the sites themselves.

The second methodology is based on the use of hydrological simulation studies. This approach also received a lot of attention at the research level in recent times, since the growing availability of computing means allows to use complex simulation models, that can today run very long simulations within limited computing time. In particular, it is now possible to run high-definition, spatially-distributed rainfall-runoff models even for hundreds of years at very fine temporal resolutions.

The two approaches described above need different types of hydrological information. The regional approach requires the availability of peak flow series for the region of interest (which is identified accordingly to a suitable pooling criteria), while the simulation studies necessitate of continuous-time rainfall and river flow data (not necessarily observed in the site or catchment of interest). Therefore, with regard to practical applications, the two methodologies can be regarded as complementary.

The research activity of the Working Group in the context of regional studies will be supervised by Dr. Armando Brath and Dr. Attilio Castellarin. In detail, the activity aims at developing and testing an efficient regionalization procedure for estimating design flood flows for ungauged basins. Recent analyses have shown that the frequency regime of rainfall extremes for different storm durations is mainly controlled by the local value of mean annual precipitation, MAP (e.g., Schaefer, 1990 and Alila, 1999). This important outcome was efficiently exploited to derive regional estimators of design rainstorms for locations where only a limited amount of historical information (or none) is available that dispense with the identification of a subdivision of the study area into fixed and contiguous rainfall regions (e.g., Alila, 2000; Brath et al. 2003). Accordingly, the research activities of the Working Group will address three main topics: (*a*) the development of geomorphological and climatic descriptors (e.g., characteristics of permeability, humidity/aridity, frequency regime of severe rainstorms) that can be (promptly) derived for ungauged basins and adopted to form homogeneous pooling-groups of basins for regional frequency analysis; (*b*) the comparison of pooling schemes that quantify the hydrological similarity among basins by using different descriptors (see for instance, Castellarin et al., 2001) and (*c*) a comprehensive cross-validation of

the regional estimators through resampling techniques (see for instance, Brath et al., 2001 and 2003) aiming at assessing the uncertainty of the design flood flow estimates for ungauged sites.

The analysis will refer to a broad geographical region (37200 km^2) located in northern-central Italy. The Po River bounds the area to the north, the Adriatic Sea to the east, and the divide of the Apennines to the southwest. A total of 36 unregulated catchments are located in the study area, with area ranging from 6 to 1500 km^2 (average catchment area: 420 km^2). The record length at the hydrometric stations varies from a minimum of 15 years to a maximum of 74 years with a mean value of 33 years. The available extreme rainfall data consist of the annual series of precipitation maxima with a minimum record length of 15 years and durations t equal to 1, 3, 6, 12, 24 hours and one day (i.e., from 9:00 AM to 9:00 AM of the following day) for a rather dense network of 208 recording and 619 observational-day (daily rainfall) raingauges. The working group will seek co-operation with researchers active in the neighbouring countries, in order to explore the possibility to pool together the historical information available. The aim is to verify the possibility to set up a common approach for hydrologic regionalization by referring to a wide region of Europe.

The activity of the Working Group in the context of hydrological simulation will be supervised by Dr. Alberto Montanari, Dr. Elena Toth and Dr. Greta Moretti. In detail, the aim of the research activity is to develop and test a simulation framework that can be applied in situations where only limited (or even none) historical hydrological records are available. The method is based on the preliminary generation of synthetic rainfall data for the catchment of interest, simulation that is performed by using the multivariate Neyman-Scott rectangular pulses model for rainfall (Cowpertwait, 1996). This is a stochastic approach for the generation of long rainfall series even at short time step and it needs to be calibrated on the basis of observed rainfall data. The first goal of the research activity is to propose a parameterisation procedure that can be applied on the basis of a limited historical information. In details, the model parameters are estimated on the basis of the (perhaps limited) continuos time rainfall records available for the basin of interest, or accordingly to a judgemental procedure, by using maximum likelihood (Montanari and Brath, 2000) or the method of moments (Cowpertwait, 1996). The estimated parameters are subsequently validated by comparing the simulated depth-duration-frequency curves for rainfall with the corresponding estimates obtained by analysing at site observed rainfall extremes, if available, or by applying a regional approach (see for instance Brath et al., 2003).

The synthetic rainfall data are subsequently routed through a spatially distributed rainfall-runoff model recently developed at the University of Bologna (see Montanari and Brath, 2004). It is an essentially conceptual, DEM (digital elevation model) based approach, which runs continuously in time. The model was specifically conceived in order to be applicable to watersheds characterised by a limited data availability and has proved to be effective in order to provide simulations for ungauged sections (see Brath et al., 2004). The model is written in Fortran code and the members of the working group are currently working with the aim to make the model available on the web. The proposed approach is capable of simulating 1000 years of hourly rainfall data in less than 15 minutes, referring to a 1000 km^2 wide basin, whose topography is described by a 25000 cells DEM. A recently proposed technique (Montanari and Brath, 2004) will be used in order to assess the uncertainty of the obtained simulations.

The proposed approach is therefore able to provide very long river flow simulations, that can allow to infer the flood frequency distribution. The simulation framework will be tested by using an extensive data base which refers to five river basins located in northern Italy, namely: the Secchia River basin (1214 km^2), the Samoggia Torrent basin (178 km^2), the Reno River Basin (1050 km^2), the Sieve River Basin (830 km^2), and the Elsa River Basin (650 km^2). For each basin, historical data of hourly river flows, for an observation period of at least three years, are available, as well as contemporary rainfall and temperature data observed over the basin. Moreover, detailed descriptions of basin topography, soil texture and land use are available.

Potential user groups of the predictive scheme evaluated

The activity proposed by the working group has a relevant scientific interest, which is proven by the number or contributions proposed by the international literature on the subject. The working group will be open to all the interested researchers. The activity of the working group will be partially supported by the Italian Government through national grants. The members of the group are evaluating the possibility to submit a proposal to the Italian Government for a research programme focused on the activities described above.

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