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Implications of using direct or indirect approaches on design flood assessment in urbanized river basins

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ABSTRACT: A number of approaches are possible for estimating design floods. In cases where long records of measured streamflow data are available, a direct statistical analysis of the data may be feasible. However, the streamflow data series are often too short to perform robust statistical inference.

In many circumstances no measured streamflow data are available at the site of interest. Moreover, in urban area, when natural development of the watercourse is significantly altered by anthropic constraints such as bridges, detention ponds, and levees, design flood estimates may result significantly lower than natural discharge, with dangerous impact on downstream sections in case of further modifications of upstream river.

Under such conditions the design flood can be assessed from rainfall-runoff transformation, under the assumptions that the Depth Duration Frequency curve characterizes the rainfall regime and assuming the critical flood design method.

This work presents the application of distributed hydrological model FEST for the assessment of design flood of Olona river basin, a small watershed in northern Italy. The significant heterogeneity of river Olona basin is enhanced by the presence of a mixture of forest, natural landscapes, and highly urbanized areas that, despite small extent of the basin, require use of a spatially distributed hydrological model.

The work shows that indirect method provides design discharges significantly greater respect to direct method when discharge measurements are strongly affected by upstream river overflows like in highly urbanized area.

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INDEX FLOOD

The index flood method

For homogeneous region

$$q_T = x_T \cdot q_{index}$$

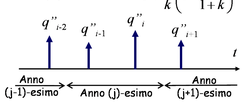
T-year quantile of flood flows

T-year quantile of normalized flood flows in the region, growth factor

index flood

Partial Duration Series PDS

$$\hat{\bar{q}}_{PDS} = \frac{1}{n''}\sum_{i=1}^{n''} q''_i \qquad q_{index} = \frac{1}{\varepsilon + \frac{\alpha}{k}\left(1 - \frac{\Lambda^k}{1+k}\right)}\hat{\bar{q}}_{PDS}$$



Threshold discharge: 40 m^3/s ➥ 14 floods in 8 years

Index flood: 60 m^3/s

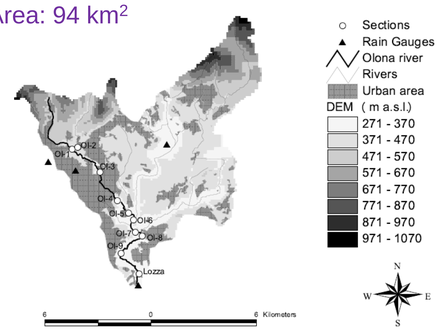
Bocchiola, D., De Michele, C., and Rosso, R., (2003). "Review of recent advances in index flood estimation." Hydrol. Earth Syst. Sc., 7(3), 283-296.

CASE STUDY

Olona river, Italy

Mean elevation: 455 m

Area: 94 km^2



AVAILABLE DATA

precipitation: 2003-2010, reliable data from 2009

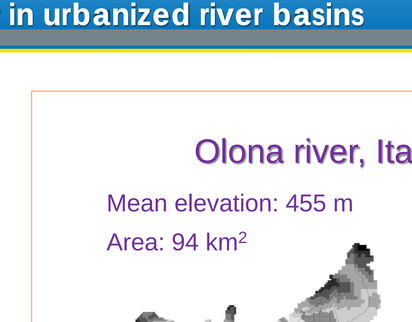
discharge: 2002-2010

Maximum discharge: 50 m^3/s

The Ponte Gurone Dam for Flood reduction (1.5 Mmc)

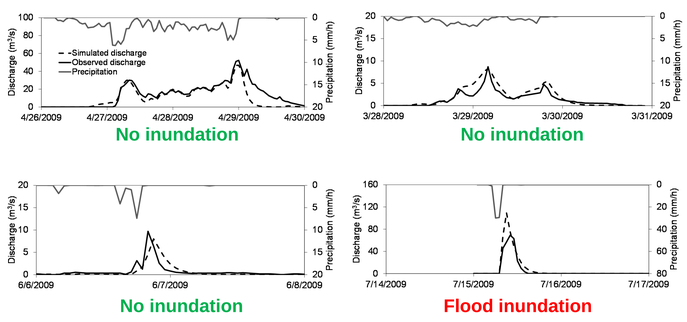
FEST MODEL

FEST: Flash – flood Event – based Spatially – distributed rainfall – runoff Transformation

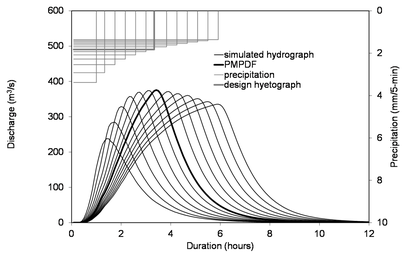


Montaldo, N., Ravazzani, G., Mancini, M. (2007), On the prediction of the Toce alpine basin floods with distributed hydrologic models. Hydrol. Processes 21, 608-621.

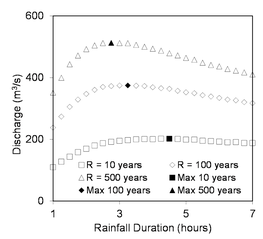
Calibration



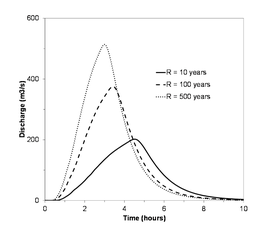
INDIRECT METHOD



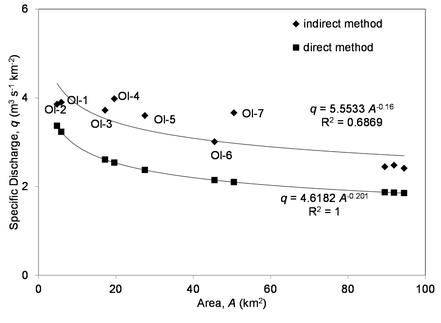
Procedure for the search of the design flood defined as that event which is characterised by the maximum peak flow. The probable maximum peak design flood (PMPDF) and design hyetograph are reported. The results refer to river Olona at Lozza for the 100-year return period



Series of peak discharges obtained from different rainfall duration for different return periods, R, for the river Olona at Lozza



Design hydrographs obtained with indirect method for the river Olona at Lozza for three return periods, R: 10, 100, and 500 years



Specific discharge per unit area obtained with direct and indirect methods.

In highly urbanized river basins annual maximum peak flow measurements may be strongly biased by upstream river overflows. In these cases, direct estimation of design flood can lead to significant underestimation of peak flow with negative impacts on downstream river reach when subsequent modification of water course would increase river conveyance, with catastrophic consequences in terms of loss of life and damage to property.

A procedure for indirect estimation of design flood is presented. We showed that it is possible to obtain an hydrograph for any duration at a given frequency from a family of depth duration frequency curves, by transforming rainfall into runoff, and finally, a series of hydrographs for each return period. For rainfall-runoff transformation a spatially distributed hydrological model was employed. This allows to take into account heterogeneity that generally characterizes river basins with high degree of urbanization

Despite the single case study presented in this paper, it could be assumed as representative of the response of densely urbanized river basins. In these cases differences between direct and indirect methods for design flood assessment are an indicator that direct methods can lead to underestimation of design flood with catastrophic consequences in terms of loss of life and damage to property.