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Long Term Discharge Simulation through a Geomorphological Model

M. Giglioni[a], D. Orlando[a], M. Rianna[a], V.Montesarchio[a], F. Russo[a], F. Napolitano[a]

[a]Dipartimento di Ingegneria Civile, Edile e Ambientale, Sapienza Università di Roma, Rome, Italy
Corresponding Authors: maura.rianna@uniroma1.it, dario.orlando@uniroma1.it

Abstract. Flow duration curve estimation must be performed on the basis of continuous rainfall-runoff simulations. In ungauged basins, a under-parameterised model is needed to reduce the uncertainty of the results.
In this paper a geomorphological model based on a width function (WFIUH) was used to simulate low flows in a mean-sized basin in Central Italy. The WFIUH model [9]introduces a new approachto the curvenumber method and was used to evaluate the stream-flow for hourly event representation. The aim of this work is to evaluate the behaviour of the WFIUH model for long term simulation and then to compare the standard curve number approach to the curve number method implemented in the WFIUH model. To predict the behaviour of catchments for a long term, to know the response of catchments in different seasons or in different years, it is necessary to improve the model and to identify a new method for calculating base-flow.
To obtain these results, it is necessary to separate base-flow and stream-flow, simulate the two contributions and build a unique series of values that reproduces the answer of the basin to different rainfalls during the year to estimate the low flow during a dry period. The model can also be used in ungauged basins because a unique parameter is used.

Keywords: Continuous, Rainfall-runoff modeling, Low flow simulation,Calibration.
PACS:96.12.ka

INTRODUCTION

One of the fundamental challenges for hydrologists today is the prediction of stream-flow in different basins under different climatic conditions over a long period. Rainfall-runoff models are commonly used tools to extrapolate stream-flow time series and to obtain time series for low flow analysis. Although much progress has been made in simulating event response, especially for extreme events, the estimation of a continuous stream-flow time-series remains uncertain. Continuous approaches have been suggested to modellers for many years [5] because these models consider the complete hydrological cycle of a catchment. However, we must recognise that event-based approaches are still often chosen in real-time applications [4] because of the lower number of processes that can be estimated. A lower number of processes means fewer parameters to be calibrated [5]. Obviously, the aim of the project guides the choice of the type of model (event-based or continuous).
The first version of the WFIUH model [3,9] provides an excellent simulation for short hourly times series. The WFIUH model [3,9] averages daily events; this feature of the model is really useful to predict a flood. However, water resource and management hydrological problems are approached by using continuous time modelling and evaluating flow duration curves.
The flood is simulated with the method explained in Rianna et al. (2012). To take longer periods into account, the program works with daily average rainfall data.
The base-flow simulation is based on a very simple method. Using the historical records, a mean flow has been calculated for each month of the calibration year, and these uniform monthly flows were considered as the base flow in the test years.
After the simulation of the two different parts, the new program assembles the total stream flow for the basin for the whole period [2].

STRUCTURE OF THE PROGRAM

The WFIUH is divided into 3 different parts. The first part designs the soil geomorphology, starting from an ASCII file taken from a GIS software using an open-source model called topo-toolbox [11]. The model is calibrated

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with just one event realising a match with the concentration time of the basin calculated with theknown Giandotti's expression T_c:

$$T_c = \frac{4\sqrt{A}+1.5L}{0.8\sqrt{h_{med}-h_{min}}} \quad (1)$$

In the second part, an analysis of the rainfall based on the method proposed in Rianna et al. (2012) is performed. To consider the spatial variability, the rainfall that influences the AMC and the CN value was assumed to be the rainfall of a single cell of the basin discretisation. In addition to evaluation of the temporal variability of rainfall, the value of the CN of the single cell is not considered constant during the whole event, but instead varies throughout according to the time interval used to define the AMC conditions [1,6].

The rainfall net precipitation is also calculated using a standard method, then the AMC condition is chosen for the entire basin, and the CN value is maintained uniform during the event [10].

In the third part of the program, a value for velocity, based on the Maidment equation, is assigned to every cell of the DEM, and so the residence time of each cell is calculated. A width function for the river is then calculated, and finally, the stream-flow for the event is simulated using the convolution:

$$C_{xy}(t) = \int_{-\infty}^{\infty} x(t-\tau)y(\tau)d\tau \quad (2)$$

To verify the goodness of the simulation, the Nash-Sutcliffe coefficient, which permits the calculation of the distance between simulated and observed stream-flow, is used:

$$\mathrm{E} = 1 - \frac{\sum_{t=1}^{T}(Q_0^t - Q_m^t)}{\sum_{t=1}^{T}(Q_0^t - \bar{Q}_m)} \quad (3)$$

METHODOLOGY

To have a better representation, the flow is divided into base-flow and stream-flow using Lovovitch's method [8]. From this base-flow time series, it is possible to calculate the average value for each month of the year. We can use different years to have a better monthly value; in this case, we can start the calibration using years from 1999 to 2000 [4, 5, 7].

After calculating the average monthly value of the base-flow, we have to sum the base-flow in the model.

TABLE 1. Table of calibrated base-flows [m^3/s].

July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
0.16	0.14	0.21	0.29	1.05	1.94	0.67	0.35	0.33	2.04	0.48	0.20

To conclude, the stream-flow is calculated, and the base-flow and the stream-flow are combined by a simple operation. The results are shown in the next paragraph

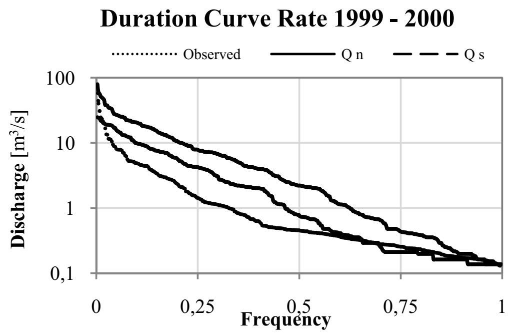
The area analysed for this study is the Mignone Basin, which is located in the northwest of the Lazio region. The surface of the region is 500 km^2,and the main stream is approximately 62 km. Five gauges are located in the basin. All of the information about land use was taken from the "Corine Land Cover" project. For this study, only four of the five gauges located over the basin area were used [3, 9].

The validity of the model was evaluated using the results obtained applying the WFIUH rainfall-runoff model with the CN proposed method and with the standard method through a Nash-Sutcliffe coefficient:

$$\mathrm{E} = 1 - \frac{\sum_{t=1}^{T}(Q_0^t - Q_m^t)}{\sum_{t=1}^{T}(Q_0^t - \bar{Q}_m)} \quad (4)$$

where Q_0 is the observed discharge, Q_m is the modelled discharge, Q_0^t is the observed discharge at time *t*, and $\overline{Q}_m$ is the discharge of the average model. Results of the method obtained by calibration show that the proposed method gives good simulation in comparison with the standard method (Figures 1 and 2 and Table 2).

Qn and Qs in Figures 1 and 2 represent results obtained with the proposed method and the standard method shown in terms of flow duration curves.



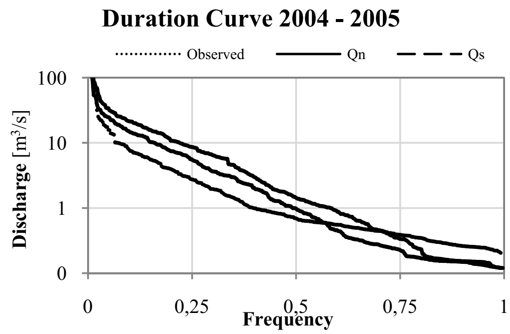
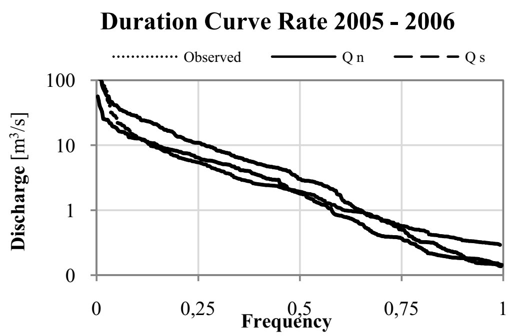


FIGURE 1. Long Term Simulation 1999-2000

FIGURE 2. Long Term Simulation 2004-2005



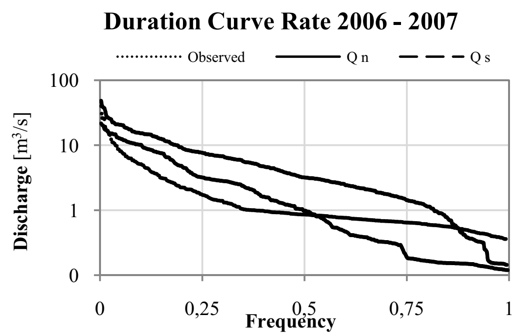


FIGURE 3. Long Term Simulation 2005-2006

FIGURE 4. Long Term Simulation 2006-2007

TABLE 2. Results of application to Mignone's Basin.

Year	Season	λ	E Model	E standard CN
1999 - 2000	II	0.3	0.55	-0.92
2004 - 2005	II	0.3	0.84	0.47
2005 - 2006	II	0.3	0.74	0.54
2006 - 2007	II	0.3	0.77	-0.34

CONCLUSIONS

The WFIUH model with the new curve number approach is good software to prevent a flood during a single event of rainfall. Its accuracy and precision facilitates knowledge of the stream-flow starting from rain with high quality of results. The paper implementation allows extension of this possibility to longer periods and to simulate low flows. The WFIUH model will be very useful for long term simulation in an ungauged basin because only one parameter needs to be calibrated.

Especially it will be very usefull for long term simulation in ungauged basin cause only one parameter needs to be calibrated.

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