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INFLUENCE OF ENLARGEMENT AND LOSS MODEL ON THE FLOOD HYDROGRAPH IN A SMALL HYDROGRAPHIC BASIN

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Abstract: The study of the flood hydrograph is especially important in the case of small hydrographic basins, with a high risk of producing flash floods, following a torrential rain. In the formation of the flood hydrograph an important role is played by the choice of enlargement and loss model. The paper aims to study the influence of enlargement and loss model choice on the hydrograph's duration and maximum discharge. For this purpose is used the MIKE11 model, the Rainfall-Runoff module, with the following options for choosing the enlargement and loss model (in UHM method): constant loss, proportional loss, SCS method and SCS generalized.
Keywords: flood, hydrograph, maximum discharge, small hydrographic basin.

1. INTRODUCTION

The hydrological response is the reaction mode of a hydrographical basin when it is subjected to a rainfall event (Figure 1). [1]

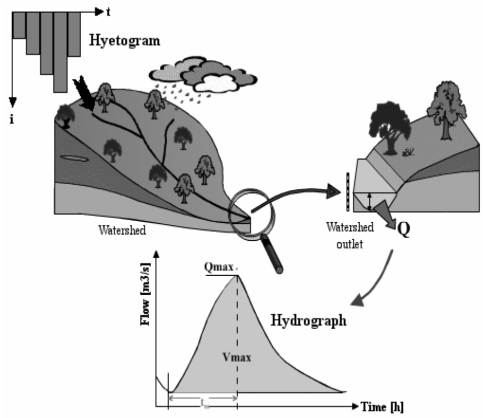

Figure 1. Hydrological response of a hydrographical Basin (after Musy, 2001)

The study of the flood hydrograph is especially important in the case of small hydrographic basins, with a high risk of producing flash floods, following a torrential rain. The characteristics of the hydrograph who are interested are: total duration, the growth time, the maximum discharge, which determines the maximum level in the exit section of the river basin (Figure 2). [1]

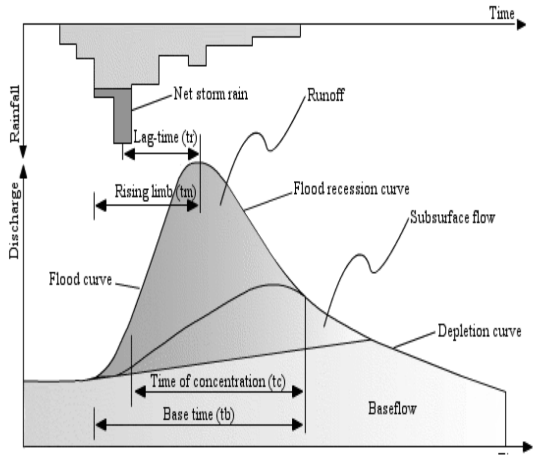

Figure 2. Hydrograph characteristics (after Musy, 2001)

An important role in the value of these characteristics are: the size and shape of the hydrographic basin (surface), the average slope of the hydrographic basin, the land use, respectively the length and the average slope of the valley, and of course, the rainfall characteristics.

Flash flood effects are multiple and complex: social effects (loss of life, illness, psychological effects, destruction or damage to homes and family farms, damage to transport infrastructure and deterioration of social-cultural objectives); economic effects (loss due to malfunctioning of and economical entities, as a result of the reduction or temporary interruption of work caused by lack of manpower, raw materials, interruption of power supply etc., payment of material and human goods insurances) and environmentally effects (pollution of flooded areas, changes in the physico-chemical and bacteriological properties, silting of reservoirs, bio-edaphic effects, reducing the stability of slopes). [2]

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2. MIKE11 MODEL

MIKE 11 is a professional engineering software package for simulation of one-dimensional flows in estuaries, rivers, irrigation systems, channels and other water bodies. MIKE 11 is a 1-dimensional river model. It was developed by DHI Water • Environment • Health, Denmark.

The UHM methods of Rainfall-Runoff module of MIKE11, simulates the runoff from single storm events by the use of the unit hydrograph techniques Unit hydrograph is a hypothetical unit response of the hydrographic basin to a unit input of rainfall.

During a storm a part of the total rainfall infiltrates in the soil, depends on the initial soil moisture and vegetation. Large parts of the infiltration evaporate or reach the river a long time after the end of storm as base flow. In event models it is proper to describe the major part of the infiltration as loss. The amount of rain actually reaching the river, i.e. the total amount of rainfall less the loss is called the excess rainfall. The unit hydrograph module includes four optional methods for calculation of the excess rainfall. They are all lumped models considering each basin as one unit and hence the parameters represent average values for the basin. [3]

Fixed Initial Loss and Constant Loss

In this method no excess rainfall will be generated before a user specified initial loss demand has been met. Subsequently excess rainfall will be generated whenever rainfall rate exceeds a specified constant loss rate.

$$P_{excess}=\begin{cases}0 & \text{for } P_{sum}<I_a+I_c\cdot dt \\ A_f\cdot P\cdot I_c & \text{for } P_{sum}>I_a\end{cases} \quad (1)$$

where: P_{excess} - excess rainfall (mm/hr); P_{sum} - accumulated precipitation since start of storm event (mm); I_a - user defined Initial loss (mm); I_c - user defined constant loss rate (mm/h); A_f - areal adjustment factor; P - rainfall (mm/hr); dt - calculation time step (hr). To some extent this method accounts for the losses being highest at the start of the storm. [3]

Proportional Loss

In this method the losses are assumed to be proportional to the rainfall rate and thus the excess rainfall is given by:

$$P_{excess} = a \cdot A_f \cdot P \quad (2)$$

where: P_{excess} - excess rainfall (mm/hr); a - user defined runoff coefficient between 0 and 1; A_f - areal adjustment factor; P - rainfall (mm/hr). [3]

SCS Loss Method

This method was developed by U.S. Soil Conservation Service (SCS) in 1972.

The basic equation for computing the depth of excess rainfall or direct runoff from a storm by the SCS method is:

$$P_{excess}=\frac{(P-I_a)^2}{P-I_a+S} \quad (3)$$

By study of results from many small experimental hydrographic basins, was developed the following empirical relation:

$$I_a = 0.2\cdot S \quad (4)$$

Result:

$$P_{excess}=\frac{(P-0.2\ S)^2}{P+0.8\ S} \quad (5)$$

where: P_{excess} - depth of excess precipitation or direct runoff (mm); P - depth of precipitation P (mm); I_a - (initial loss before ponding); S - potential maximum retention S (mm). The potential maximum retention S is calculated from a dimensionless curve number (CN) using the empirical formula derived by SCS on the basis of rainfall runoff analyses of a large number of hydrographical basins:

$$S = ((1000/CN) - 10) \cdot 25.4 \quad (6)$$

The curve number depends on the soil type, the land use and the antecedent moisture condition (AMC) at the start of the storm. CN varies between 0, resulting in no runoff, and 100 which generate an excess rain equal to the rainfall. For natural basins normally CN is in the range (50, 100). [3]

SCS Generalised Loss Model

The SCS generalised loss model corresponds closely to the SCS loss model, but it differs in a few important ways. In this model the initial loss (initial abstraction depth) I_a is given directly as an input parameter. The curve number is an input parameter and is not changed during the simulation as for the SCS loss model. [4]

3. CASE STUDY

For the study of the influence of enlargement and loss model choice on the hydrograph's duration and maximum discharge was used the MIKE11 hydroinformatic tool, the Rainfall-Runoff module, with the following options for choosing the enlargement and loss model (in UHM method): constant loss, proportional loss, SCS method and SCS generalized. The studied area is Valea Mare hydrographical basin, a component of Bega river catchments (Figure 3).

Hypotheses and input data were:

- Rainfall is show in Figure 4
- Hydrographic basin average slope - 20.64 %
- Total area - 23.54 ha

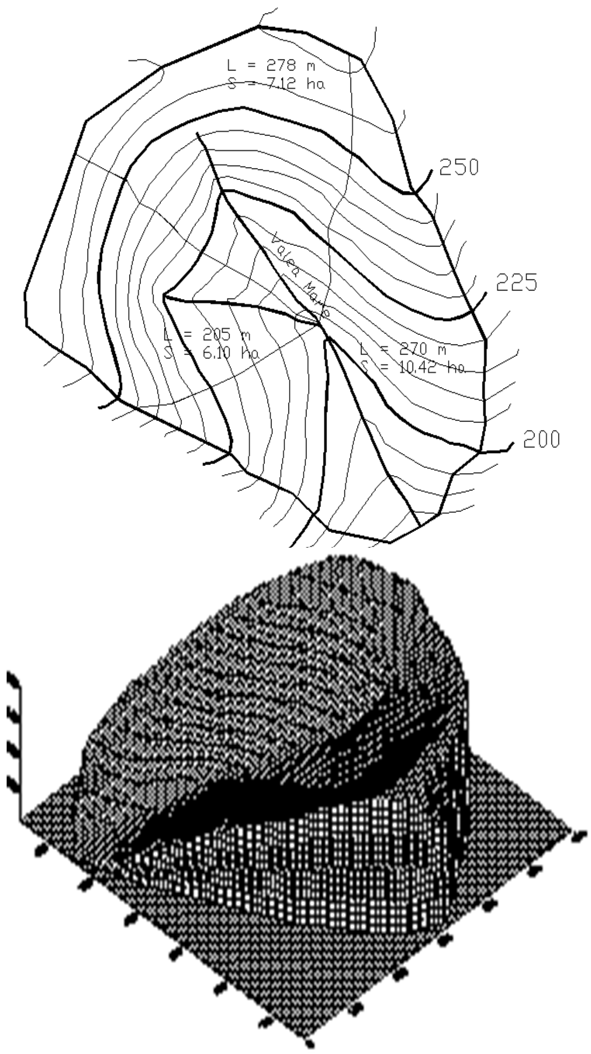

Figure 3. Studied area

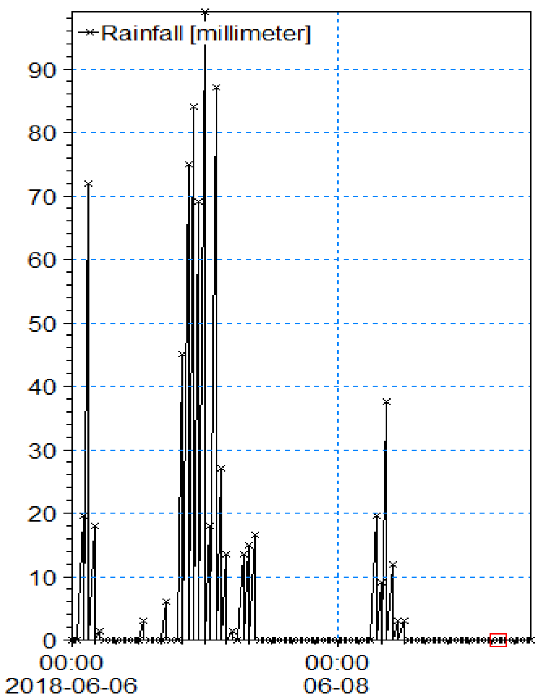

Figure 4. Rainfall

- Land use: mixed forests CN = 75
- Soil hydrologic group C
- Time step 30 minute
- Base flow - 0
- Simulation period: 06/06/2018, 00:00 – 06/09/2018 11:00 AM
- Initial loss 5 mm
- Runoff coefficient 0.75.

4. RESULTS AND DISCUSSION

The runoff hydrographs are shows separately for all four enlargements and loss model in Figures 5, 6, 7 and 8; and the comparative result can be seen in Figure 9. The net rainfall is the same for all four models (Figure 10).

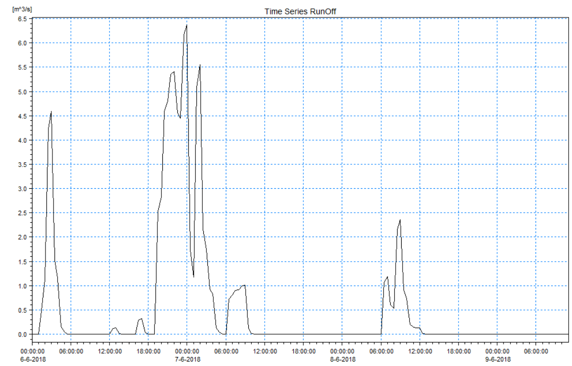

Figure 5. Runoff hydrograph for constant loss model

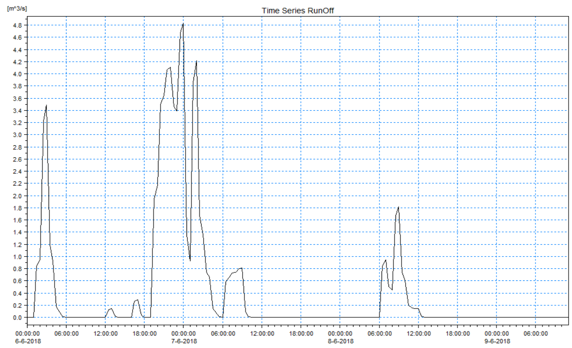

Figure 6. Runoff hydrograph for proportional loss model

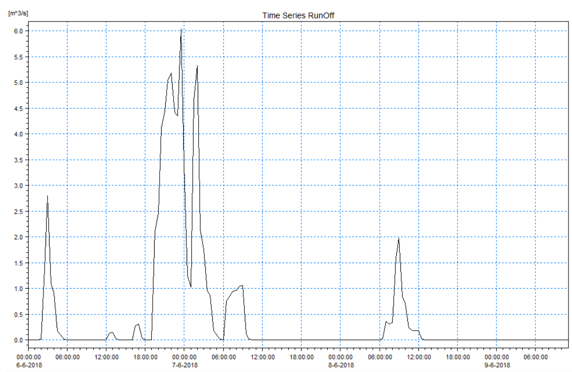

Figure 7. Runoff hydrograph for SCS method model

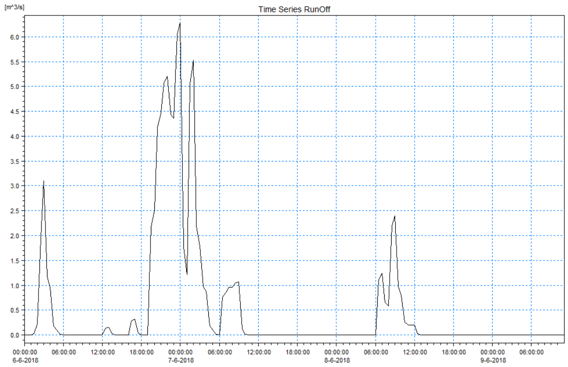

Figure 8. Runoff hydrograph for SCS generalised model

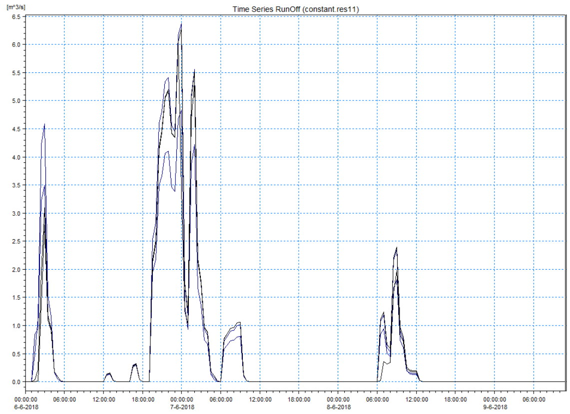

Figure 9. Comparative runoff hydrographs

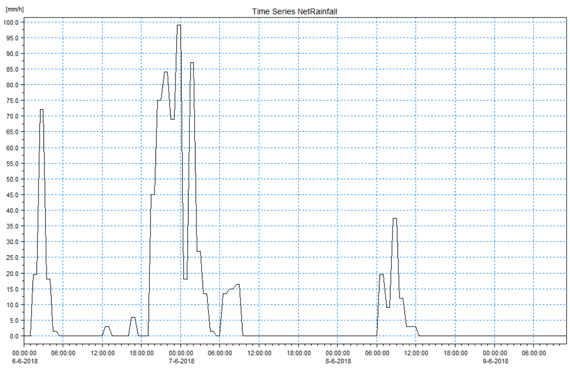

Figure 10. Net rainfall

The duration of maximum hydrographs is approximately the same for all four models, 10 hours.

The differences between maximum discharge values can be seen in Table 1.

Table 1

Model	Q max (m^3/s)	Relative difference (%)
Constant	6.373	31.979
Proportional	4.829	0.000
SCS method	6.037	25.021
SCS generalised	6.279	30.048

5. CONCLUSIONS

From this study we can see that for the same assumptions in all four models, differences of up to about 32% may occur for maximum value of runoff discharge. Therefore, it is very important, besides data collection and model building, and its calibration and validation. Large differences in maximum flow discharges lead to large differences for corresponding levels.

In establishing the plans of defense against the flash floods, the importance is not so much the maximum discharge, but the maximum level, the time of appearance and its duration. Therefore, the correct establishment of the enlargement and loss model is important to help specialists and local authorities in developing an effective defense plan against the effects of rapid floods.

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