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A comparative analysis of two advanced hydroinformatic tools for rainfall – runoff phenomena modeling

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Abstract: Study of rainfall-runoff phenomenon is important especially in small watersheds, with an increased risk of flash flood occurrence. By modeling this phenomenon with advanced hydroinformatic tools can forecast with acceptable accuracy the maximum water discharges and levels in sections where a risk of significant damages is high, for various scenarios of torrential rains production and different land use. The paper made a comparative analysis of two modeling programs: HEC-HMS and MIKE11 and as well as a case study.

Keywords: rainfall, runoff, hydroinformatic tool, modelling

1. INTRODUCTION

Runoff on the watershed hillslopes occurs when rain or snowmelt intensity exceeds infiltration capacity of the soil surface. Runoff is generated by excess of gravitational forces that surpass the forces developed by irregularities of surface and surface tensions. This flow begins as a thin cloth, then channels into small channels going at each other and thus forms the runoff domain.

Factors influencing the precipitation transformation in the runoff are: the characteristics of rainfall, topography, soil, vegetation and lithological factors or bedrock characteristics.

Flash floods occurrence is due, in specially, to both climate change and anthropogenic causes: heavy rain, massive deforestation, irrational exploitation of sloping lands, and absence of small watersheds arrangements with runoff and soil erosion control works. Also, it may be caused by heavy rain, associated with meltwater from ice or snow flowing over ice sheets or snowfields.

Flash floods may occur also, after the collapse of a natural ice or debris dam, or a human hydrotechnical structures, such as a dams or dikes. Flash floods can occur under several types of conditions: when precipitation falls rapidly on saturated soil or dry soil that has poor infiltration capacity.

For flash floods study are important the following aspects: causes, concentration time of runoff, maximum water and solid discharge and maximum water level in different cross section of valleys.

Flash flood effects are multiple and complex: social effects (loss of life, health effects - illness, psychological effects, destruction and damage to homes and family farms, impairment of educational, cultural, sports activities, damage to transport infrastructure and deterioration objectives and social-cultural institutions.); economic effects (direct and indirect damage, damage to multiple items with economic importance, loss due to malfunctioning of public institutions 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: landslides, collapses). [1]

By modeling the phenomenon of rainfall-runoff with advanced hydroinformatic tools can forecast with acceptable accuracy the maximum water discharges and levels in sections where a risk of significant damages is high, for various scenarios of torrential rains production and different land use.

Based on modeling results, the authorities can establish and take timely necessary measures to protect population and material goods in areas possibly affected by floods.

2. HEC – HMS HYDROINFORMATIC TOOL

The U.S. Army Corps of Engineers' Hydrologic Modeling System (HEC-HMS) is a watershed-runoff and routing model. HEC-HMS is comprised of a graphical user interface, integrated hydrologic analysis components, data storage and management capabilities, and graphics and reporting facilities.

HEC-HMS is developed to simulate the rainfall-runoff processes of dentritic watershed systems. It is designed to be applicable for solving different problems: large river basin water supply and flood hydrology to small urban or natural watershed runoff. The results of modeling (hydrographs) can be used for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, flood plain regulation, wetlands hydrology and hydrotechnical systems operation.

HEC-HMS model componenets (Figure 1) are used to simulate hydrologic response in a watershed, these componenets are: basin models (represent the physical watershed, developed by adding and

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connectig different hydrological elements – subbazin, reach, junction, source, sink, reservoir, diversion; hydrological element use mathematical models to describe psyhical processes in the watershed); meteorologic models (calculates the precipitation input required by a subbasin element); control specifications (set the time span of a simulation run – starting and ending simulation period, and computation time step); input data (time-series data, paired data, gridded date – often required as parameter or boundary conditions in basin and meteorologic models).

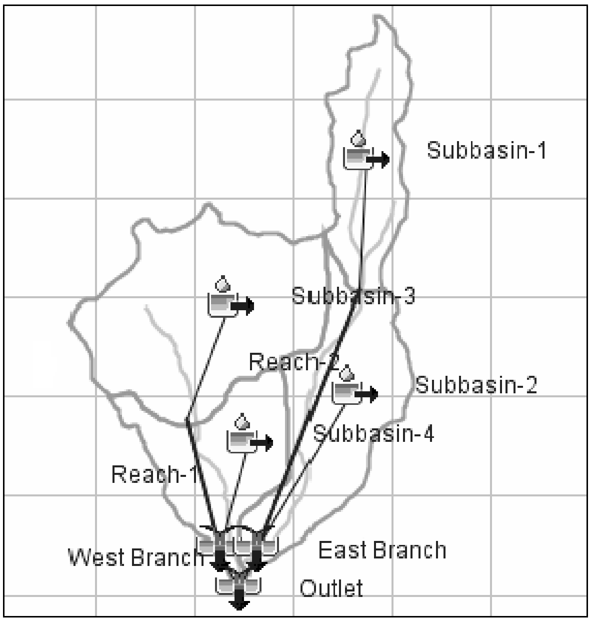


Figure 1. HEC-HMS model

A simulation calculates the rainfall-runoff response in the basin model given input from the meteorologic model. [2]

3. MIKE11 HYDROINFORMATIC TOOL

MIKE11 is a advanced hydroinformatic tools, professional engineering software package for simulation of one-dimensional flows in water bodies. MIKE11 is a 1-dimensional river model. It was developed by DHI Water • Environment • Health, Denmark.

MIKE11 have the following modules: Hydrodynamic Module (HD), Rainfall-Runoff (RR) Module, Sediment Transport (ST) Module, Water Quality (WQ) Module. The RR module includes the following methods: UHM, NAM, SMAP, Urban, FEH, DRiFT.

The UHM methods of Rainfall-Runoff module of MIKE11 (Figure 2), simulates the runoff from single storm events by the use of the unit hydrograph techniques and constitutes an alternative to the NAM model for flood simulation in areas where no streamflow records are available or where unit hydrograph techniques have already been well established. Unit hydrograph is a hypothetical unit response of the watershed to a unit input of rainfall.

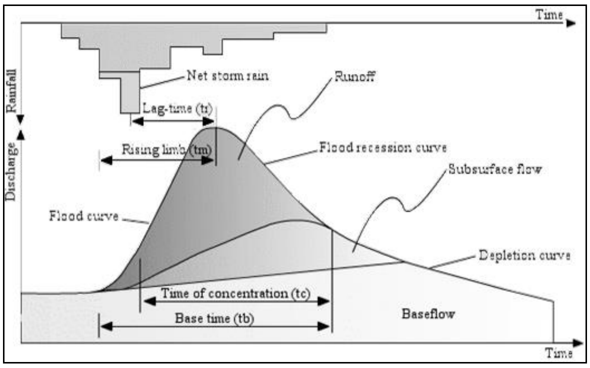


Figure 2. UHM method - terminology

The module calculates simultaneously the runoff from several catchments and includes facilities for presentation and extraction of the results. The output from the module can further be used as lateral inflow to the advanced hydrodynamic module in MIKE11.

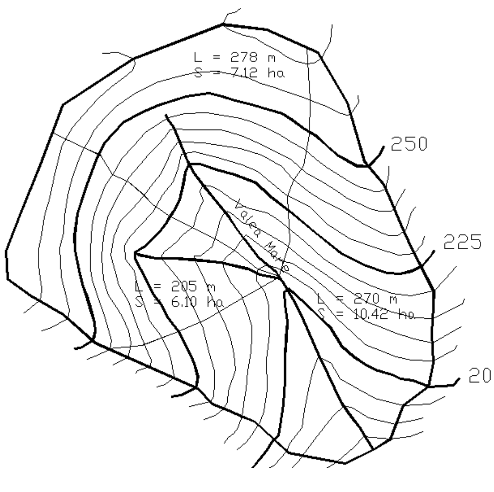
Input data requirments: area of the subcatchment (GIS); hydraulical lenght (GIS); land use and percentage area of individual categories; soil hydrologic groups (A-D) and percentage area of individual categories; average slope in the catchment (GIS); observed values: rainfall and runoff (for calibration).

In the unit hydrograph module the excess rain is calculated assuming that the losses to infiltration can be described as a fixed initial and constant loss, a proportional loss (the rational method) or by the SCS curve number method.

The excess rainfall is routed to the river by unit hydrograph methods. The module includes the SCS-dimensionless hydrographs as well as facilities for establishing and management of databases with user defined unit hydrographs and time series of recorded rainfall and stream flow. [3]

4. CASE STUDY

In this case study was simulated the rainfall-runoff phenomenon by two hydroinformatic tools in Valea Mare watershed, a component of Bega river catchments (Figure 3).



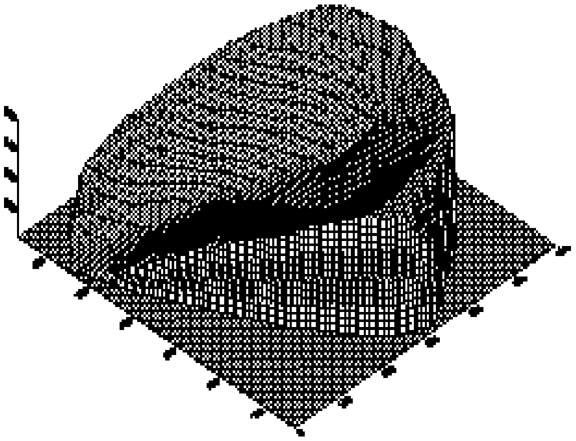


Figure 3. The studied area

Hypotheses and input data were:

- Rainfall hydrograph – Figure 4

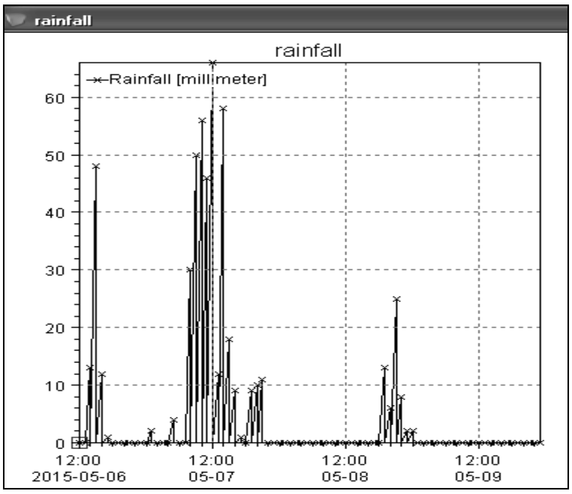


Figure 4. Rainfall

- SCS curve number - 79 (deciduous forests)
- Soil hydrological group - C
- Base flow - 0
- Initial abstraction - 0
- Catchment average slope - 20.64 %
- Total area - 23.54 ha
- Simulation period – 06 May 2015, 12:00 AM – 09 May 2015, 11:00 PM
- Time step – 1 hour.

The results were shows in Figures 5, 6 and 7 for HEC-HMS and in Figure 8 for MIKE11.

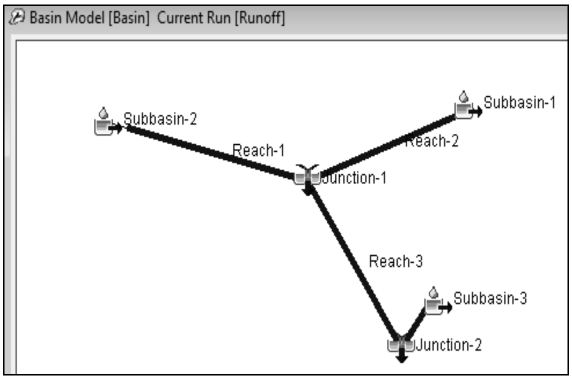
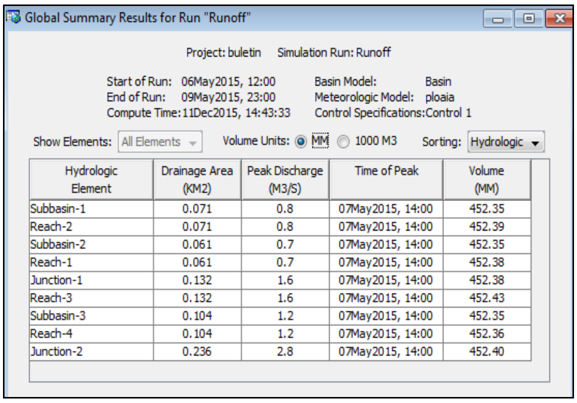


Figure 5. Calculus scheme in HEC-HMS



Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
Subbasin-1	0.071	0.8	07May2015, 14:00	452.35
Reach-2	0.071	0.8	07May2015, 14:00	452.39
Subbasin-2	0.061	0.7	07May2015, 14:00	452.35
Reach-1	0.061	0.7	07May2015, 14:00	452.38
Junction-1	0.132	1.6	07May2015, 14:00	452.38
Reach-3	0.132	1.6	07May2015, 14:00	452.43
Subbasin-3	0.104	1.2	07May2015, 14:00	452.35
Reach-4	0.104	1.2	07May2015, 14:00	452.36
Junction-2	0.236	2.8	07May2015, 14:00	452.40

Figure 6. Detailed results from HEC-HMS

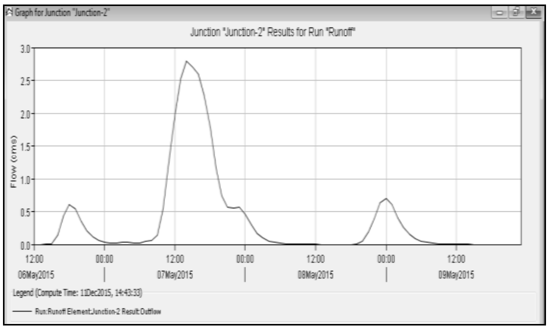


Figure 7. Runoff hydrograph in catchment outlet section (HEC-HMS)

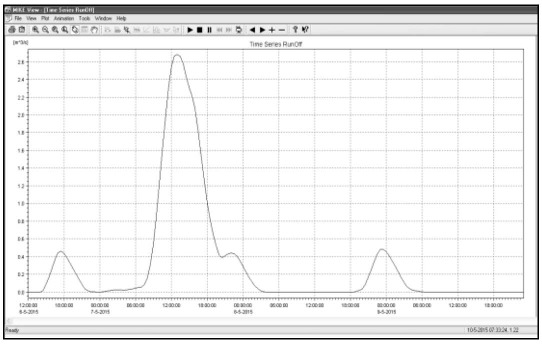


Figure 8. Runoff hydrograph in catchment outlet section (MIKE11 – RR module)

As you can see, the allure of runoff hydrographs were about the same, only the maximum values are different: 2.68 m^3/s for MIKE11 and 2.8 m^3/s for HEC-HMS.HEC-HMS need to run division of catchment in subbasins, data for each bad sector (length, slope, cross-section shape, roughness coefficients); SCS curve number, initial abstraction, base flow, type of hydrograph, rainfall time series, lag time. HEC-HMS offer different results for each river sector, subbasin and junctions (just discharges, water volume and time of peak discharge), but must chose the propagation model of flow in the river bed (kinematic wave, lag, modified puls, Muskingum, Muskingum-Cunge, Straddle Stagger).

RR module of MIKE11 need for run (without hydrodinamic modeling in river bad) just area of catchment, average slope of land, main river length, SCS curve number, initial abstraction, base flow, type of hydrograph, rainfall time series, lag time is calculated automatically. The obtained results are the runoff, net rainfall and loss hydrograph in closure section of catchment.

Building a simple model for rainfall-runoff phenomenon simulation through UHM methods for a small catchment without hydraulic structures and without many tributaries is much simpler in MIKE11 (required less input data). The obtained results are appropriate.

For detailed results for each river sector (discharges, water levels in different cross-sections, water volumes) is necessary to build a complex model in MIKE11, coupling the RR module with HD module (which is based on Saint-Venant equations). The input data are much more than for HEC-HMS (longitudinal profiles, cross section topographical data, roughness coefficients in main river bed and flood plains etc.).For both hydroinformatic tools exist the possibility to introduce in model different types of hydrotechnical structures: reservoirs, diversions, sinks, water sources – for HEC-HMS and simple structures (weirs, culverts, bridges, gates, pumps); advanced structures (user defined, regulation and control structures, dambreak mechanisms) – for MIKE11. From this point of view, MIKE11 is more complex than HEC-HMS.

5. CONCLUSIONS

The choosing a hydroinformatic tool for rainfall-runoff phenomenon modeling depends on available data and the desired type and accuracy of the results. If desire just obtaining the runoff hydrograph in catchment outlet section and more data are not available, MIKE11 is more appropriate and rapidly (in case of small catchment).

For a largest catchment with much more tributaries and developed hydrographical network, with different hydrotechnical structures, the appropriate method can be the combination between HEC-HMS and MIKE11. HEC-HMS hydrological model can use to generate the runoff hydrographs in confluence points of tributaries with main course and these hydrographs becomes boundary conditions for MIKE11. For hydrodynamic modeling of the main river, where it requires greater accuracy of results (and need more results - water discharge, water level, water velocity), MIKE11 is more capable than HEC-HMS.MIKE 11 is alone able to build a complex model (rainfall-runoff and hydrodinamic model), but also HEC-HMS can couple with HEC-RAS for the development of the same model.

Whatever is the chosen hydroinformatic tool, the accuracy of the results depends very much on the quantity and quality of the available data and of the user skills.

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