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Application of HEC-HMS programme for the reconstruction of a flood event in an uncontrolled basin

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Abstract

The paper presents an assessment of the applicability of HEC-HMS programme to simulate a precipitation flood event in an ungauged basin. The programme has been developed by the Department of the Army Corps of Engineers and enables conducting hydrological calculations for basins with different characteristics and including a number of meteorological factors. The application of this model in Polish conditions was verified in the basin of the Stobnica River – a right tributary of the Wisłok River. The calculations were carried out for the flood event caused by a continuous rain, which occurred in April 1998. Four hydrological models were compared: geomorpho-climatic instantaneous unit hydrograph by Nash – GcIUH_Nash, Snyder's synthetic unit hydrograph with the determination of parameters by regression models – Snyder_reg and standard method – Snyder_stand and Clark's instantaneous unit hydrograph – IUH_Clark, where the model parameters were optimized in the programme. The calculations revealed that the best simulation results were obtained with the Snyder_stand and Snyder_reg models. Further research should be directed to verifying the applicability of HEC-HMS programme for hydrological analyses of much more extensive hydrometric material and basins with different characteristics.

Key words: *HEC-HMS programme, flood simulations, unit hydrographs, optimization*

INTRODUCTION AND AIM OF THE STUDY

Increasingly frequent extreme hydro-meteorological events are the cause of significant property and social damage. Climate changes contribute to increasing intensity of precipitation, rising temperatures and sea levels. High probability of flooding and climate change, resulting in multiplication of extreme events, point to the importance of broadly defined planning. Therefore, the determination of characteristics describing the scale of the threat by potentially extreme meteorological and hydrological events is particularly important from a practical point of view and is socially justified. Compared with other natural disasters (droughts, volcanic eruptions, landslides, forest fires, etc.), floods have the greatest destructive potential and affect people throughout the world. They generate about 1/3 of total costs associated with natural disasters and affect approximately 2/3 population across the globe. In Europe, the amount of damage caused by floods is increasing. Since 1998, over 100 major floods have caused the relocation of about half a million people and economic losses amounting almost 25 billion euro [EEA 2003]. Given the importance and scale of the problem, it is necessary to develop tools that will be helpful in predicting and estimating the flood risk. To be maximally reliable in predicting the course and effects of floods, it is necessary to consider a number of factors affecting their progress. From the computational point of view, it is often a difficult task to achieve due to complicated mathematical description of the processes determining the runoff from basins and in riverbeds. In practice, the application of computer programmes is an extremely useful tool in conducting hydrological analyses. They facilitate the analyses and allow to consider numerous, temporally and spatially variable, factors affecting the basin's response to meteorological events. The most popular and advanced solutions in this area are complex packages developed in the United States and used worldwide, such as: (1) Hydrologic Modelling Systems [USA CE, EC... 2008], (2) Storm Water Management Model [SWMM 2005], (3) Watershed Management System WMS (using a complete set of HEC-HMS, SMS and others), as well as some of European solutions, based on the MIKE package (e.g. DHI Water and Environment [2007]) developed by DHI (Danish Hydraulic Institute) or German and Spanish solutions – dealing comprehensively with precipitation, basin runoff and flow transformation system in riverbeds. Many programmes cooperate with GIS applications, which greatly facilitates the spatial analysis of hydrological processes. Unfortunately, many of the specialised computer programmes require the purchase of a license before use, which can generate significant costs. This is why it becomes more and more popular to use freeware such as WMS or SWMM.

The aim of this study is to characterise and evaluate the applicability of HEC-HMS programme to simulate the precipitation flood event. The practical possibilities of this programme were verified using an example of the basin of the Stobnica River – a right tributary of the Wisłok River, where the simulation of a selected flood wave was conducted based on four hydrological models.

DESCRIPTION OF HEC-HMS PROGRAMME

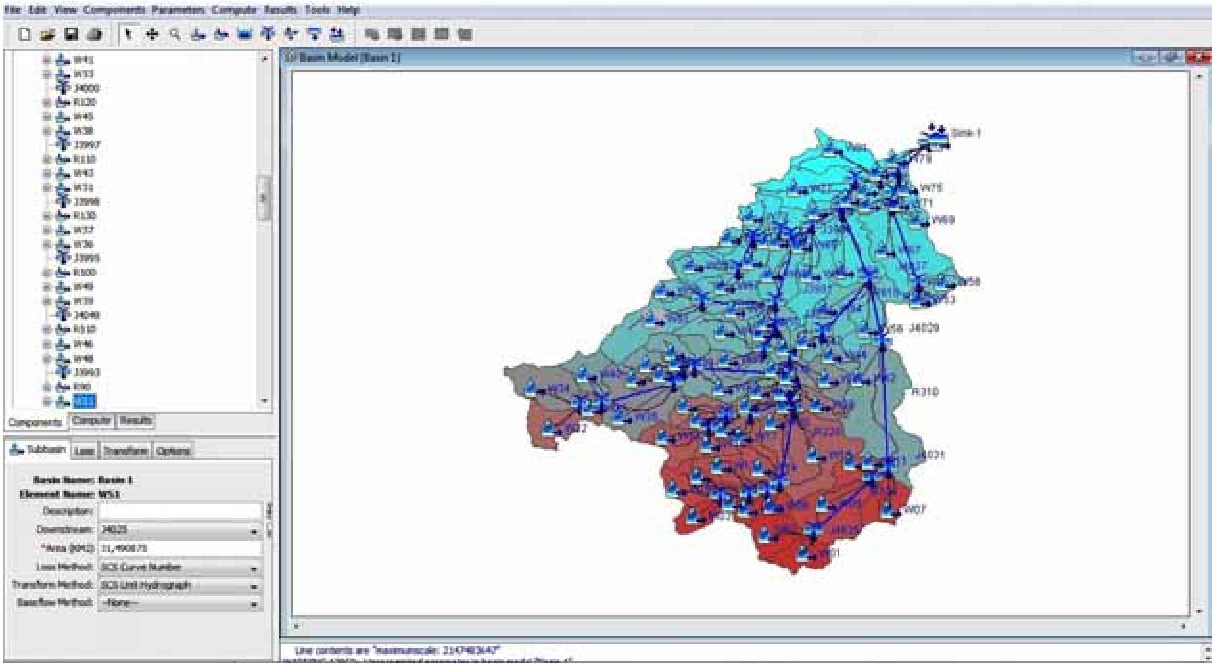
The described application was developed by the Department of the Army Corps of Engineers. It is applied to simulate surface runoff and flood wave transformation in the watercourse system in basins with dendritic hydrographic layout. Generally, this programme is a rainfall-runoff type of models, where the input parameters are the components representing meteorological factors such as: precipitation, evaporation and snowmelt water. Additional modules allow to determine losses to infiltration and the supply of watercourses by groundwater. The basin parameters are: area, length of watercourses, ground properties, etc. All calculations are carried out in the direction from the watercourse source to its estuary, therefore the backwater effect cannot be included in the simulation. The main components of the programme are: basin model, meteorological model and control specifications. The basic calculations are performed in the "basin model" component, where the user, after entering the basic parameters such as basin area, defines the method for calculating the loss of precipitation and the effective transformation of precipitation into runoff – Table 1. It is also possible to enter the user-defined unit hydrograph. The "meteorological model" component analyses meteorological elements such as: precipitation, evaporation, temperature, etc. Among the options of the programme there is a possibility to enter the so-called hypothetical precipitation hietograms showing probable rainfall distribution in time. The authors of the programme introduced among others the SCS curves valid within the United States and synthetic hietograms determined from curves: precipitation intensity-probability-duration. It is possible to enter time series of meteorological (precipitation, temperature, radiation) and hydrological (water levels and flows) data, which are the input variables to the model and calibration data. Meteorological and hydrological data may be entered to the programme manually or by using an external application HEC-DSS, which is a type of data-management programme. The authors of HEC-HMS included the possibility of external data entry in the system with SI and English units. In order to carry out detailed analyses such as simulation of wave passage through a storage reservoir, it is necessary to enter the so-called *paired data*, which are simple relationships between dependent and independent variable, e.g.

Table 1. The selected computational methods available in the sub-basins

Hydrological element	Aim of calculations	Methods
Sub-basin	precipitation losses	deficit and constant losses exponential Green-Ampt initial and constant losses SCS
	transformation of effective precipitation into runoff	Clark's unit hydrograph kinematic wave Clark's modified unit hydrograph SCS unit hydrograph Snyder's unit hydrograph S-hydrograph user's unit hydrograph
	base flow	constant monthly flow linear reservoir non-linear Boussinesq reservoir recession curve
Streambed	routing	kinematic wave flow delay method modified Puls Muskingum Muskingum-Cunge
	flow increase/ loss	constant precolation

Source: [Hydrologic… 2008]

flow volume curves, water level – flow curves, volume-flow, etc. Among these relationships one must mention the component for entering the *cross sections* of riverbeds or elevations of user-defined unit hydrographs (users unit hydrograph). Installation of an additional application HEC-GeoHMS allows the use of GIS data such as precipitation, inclination, ground permeability, which enables to precisely consider the spatial distribution of meteorological and physiographic factors in the basin. There is a possibility of automatic interpolation of input data, if the time step of simulation is smaller than the time step of input data. Working with the model begins with basin description by introducing one or more subbasins, where the actual calculations are performed (Fig. 1). Defining the meteorological model as an input element for each of the sub-basins is crucial for making these calculations. The sub-basin system is connected using junctions and by the network of reaches, in which the flood wave transformation is performed. The model contains additional items, such as reservoirs and diversions like pumping stations, side dams or bifurcation, when a certain volume of water is drained from the watercourse. The simulation results can be presented graphically and in tables. Table 1 summarizes the available computation methods that appear in HEC-HMS programme.



Basin Name: Basin 1
Element Name: W51
Loss Method: SCS Curve Number
Transform Method: SCS Unit Hydrograph
Baseflow Method: --None--

Fig. 1. Schematic basin presentation in HEC-HMS programme along with the parameters required to be defined for each sub-basin; source: own study

The possibility to make an automatic calibration of the model parameters is an extremely useful feature for hydrologists. Automatic calibration is conducted using Newton's method or by inverse gradients [CUNDERLIK, SIMONOVIC 2004]. The calibration is performed by minimizing the objective function values defined by the user in order to obtain the best match between the observed and calculated hydrograph. The availability of hydrological data from water gauges is a prerequisite for conducting the calibration.

EXAMPLE OF THE PROGRAMME APPLICATION TO SIMULATE THE PRECIPITATION FLOOD EVENT

The applicability of HEC-HMS programme in a simulation of precipitation flood event was presented using the example of the Stobnica River – a right tributary of the Wisłok River. The basin area is 335.84 km^2 and the average inclination of the basin equals 0.78%. The basin is located in the Dynowskie Foothills [KONDRACKI 2009]. Soils of medium and low permeability dominate there. The predominant type of land cover includes arable lands and forests [WAŁĘGA *et al*. 2009]. Figure 2 presents the land use structure of the Stobnica basin. The average annual precipitation in the basin from the period of 1971–2000 is about 650 mm and the annual mean number of days with thunderstorms is 28–30 days [LORENC (ed.) 2005]. The aim of calculations with the use of HEC-HMS programme was to assess the description accuracy of the observed hydrograph caused by continuous rain by the ones calculated based on selected unit hydrographs. The analysis was based on the hydrograph from April 1998. The flows were recorded at the water gauge Godowa. Hietogram from precipitation, recorded at Brzozów station, was adopted as

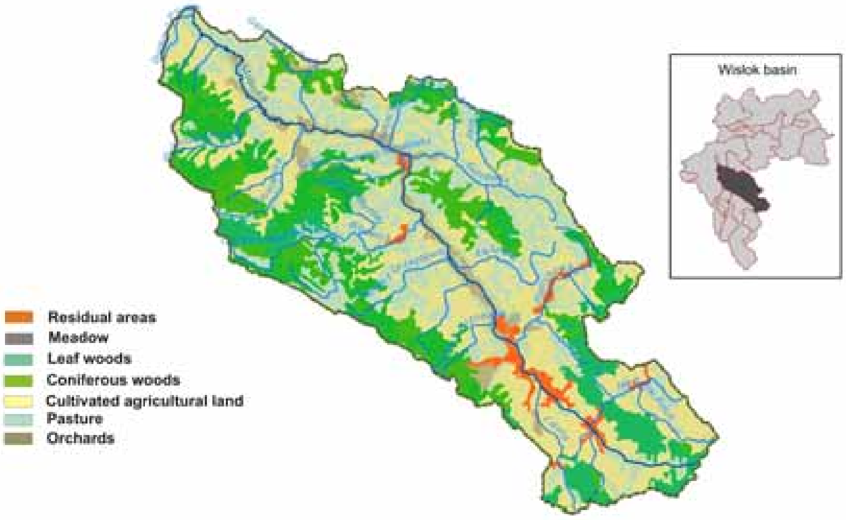


Fig. 2. Land use in the Stobnica basin; source: WAŁĘGA *et al.* [2009]

precipitation data with the time step of 24 hours. The total amount of precipitation was 81.2 mm, its duration was 72 hours and average intensity was 1.13 mm·h^{-1}. The maximum instantaneous intensity equal to 2.61 mm·h^{-1} occurred between 24 and 48 hour of the episode.

Effective precipitation was calculated based on the *Loss* module using the NRCS-CN method. In Poland this method was extensively described e.g. by IGNAR [1988] or IGNAR *et al.* [1995]. To calculate the effective precipitation using the programme, a value of *CN* parameter and optionally the volume of initial abstractions need to be provided. The user may not enter the initial abstractions, but then the programme will calculate them according to 0.2*S*, where *S* is the maximum potential basin retention [VEN TE CHOW *et al.* 1988]. In this study the *CN* value was determined based on optimization, using the observed rainfall-runoff effect. For this purpose, the total observed runoff hydrograph was divided into ground (base) runoff and surface runoff. The beginning of the surface runoff was assumed as a point on a hydrograph, from which a significant flow increase is observed, while the end of the surface runoff was considered as the intersection of the sloping arm of the hydrograph and the recession curve in the semi-logarithmic system. The volume of the resulting surface runoff hydrograph is the so-called direct runoff. The difference between the sum of the total precipitation causing particular flood and the level of direct runoff gives the size of retention *S*. This value was determined from the detailed equation [SOCZYŃSKA *et al.* 2003]:

$$S = 5[P + 2H - (4H^2 + 5P \cdot H)^{0.5}] \tag{1}$$

where:

S – basin's retention volume, mm;

P – sum of total precipitation causing the flood, mm;

H – direct runoff, mm.

The *CN* value, calculated from the equation:

$$CN = 25400/(254 + S) \tag{2}$$

reached 93 and was similar to the 3rd level of ground moisture according to NRCS. MILER [2012] conducted similar studies on optimizing the *CN* parameter values in Polish conditions in the basin of the Krynica River (Tomaszów Lubelski Forest District) covered in 49% by forests. According to this author, the *CN* parameter values determined using the optimization method for a particular basin may be the basis for the development of more objective scenarios of changes in water conditions resulting from changes in the land use.

The next stage of calculations included the transformation of effective precipitation into runoff. This was conducted using four methods: geomorpho-climatic instantaneous unit hydrograph by Nash – GcIUH_Nash [SOCZYŃSKA 1997], Snyder's synthetic unit hydrograph with the determination of parameters by regression models according to WAŁĘGA [2012] – Snyder_reg, by standard method [PONCE 1989] – Snyder_stand and with Clark's instantaneous unit hydrograph – IUH_Clark [CLARK 1945], where the model parameters were optimized in the programme. Due to the fact that the built-in GcIUH_Nash model is not included in HEC-HMS application, the *Paired data* option was used and the user's unit hydrograph was entered. This required prior determination of its parameters – the retention factor k and the number of the Nash cascade reservoirs in the function of geomorphological and climatic parameters of the basin. Geomorphological analysis of the basin included the determination of Horton-Strachler's stream order and the calculation of the following ratios: bifurcation R_B, stream length R_L and the basin's area R_A. A detailed description of the calculation of these ratios can be found e.g. in POCIASK-KARTECZKA [2006]. A Hydrographical Map of Poland was used for calculations of the drainage system laws. The average R_B value in the Stobnica basin was 5.5, R_L was 3.90 and the R_A ratio was 8.43. The R_B/R_A ratio of 0.65 is typical of natural basins. For the *CN* parameter, which was 93, the average intensity of effective precipitation was 1.94 mm·h^{-1}. The reservoir's retention parameter k was calculated from the equation:

$$k = 0.70 \left(\frac{R_A}{R_B R_L}\right)^{0.48} \frac{L_M}{v} \tag{3}$$

and the number of the *N* cascade reservoirs – from the formula:

$$N = 3.29 \left(\frac{R_B}{R_A}\right)^{0.78} R_L^{0.07} \tag{4}$$

where:

L_M – length of the highest order stream, km;
v – stream flow velocity, m·s^{-1}.

The flood wave velocity was $v = 2.99$ m·s^{-1}, $k = 8.22$ h and $N = 6.93$. The ordinates of Nash instantaneous unit hydrograph were described by the equation:

$$u(t) = \frac{1}{k\Gamma(N)} \left(\frac{t}{k}\right)^{N-1} exp\left(-\frac{t}{k}\right) \tag{5}$$

where:

$u(t)$ – ordinates of the instantaneous unit hydrograph, h^{-1};
t – time from the beginning of the coordinate system, h;
k – reservoir's retention parameter, h;
N – number of cascade reservoirs,
$\Gamma(N)$ – gamma function, whose value for the total number of reservoirs is $\Gamma(N) = (N - 1)!$

The programme enables the transformation of effective precipitation into runoff using the Snyder's model. In the standard version Snyder_stand the model parameters are determined from equation:

$$T_l = C_t (LL_c)^{0.3} \tag{6}$$

and

$$q_p = \frac{2.78 \cdot C_p \cdot A}{T_l} \tag{7}$$

where:

C_p – empirical coefficient related to the basin's retention (adopted $C_p = 0.60$),
A – basin's area, km^2;
T_l – lag time, h;
C_t – coefficient related to the basin's inclination and shape (adopted $C_t = 1.35$),
L – distance along the main stream from the estuary cross-section to the intersection of the dry valley with the drainage divide, km;
L_c – distance along the main stream from the estuary cross-section to the basin's centre of gravity, km.

Due to the fact that the adopted time step of precipitation T_R equal to 1 day did not match the condition: $T_r = T_l/5.5$, where: T_r – the duration of a unit hydrograph, the adjusted lag time was specified by the formula:

$$T_{lR} = T_l + \frac{T_R - T_r}{4} \tag{8}$$

The calculations revealed that the adjusted lag time was equal to 15 hours. To generate the Snyder's hydrograph, the lag time and C_p values need to be entered in the programme. Because the Snyder's model parameters (C_t and C_p) were determined for basins in the Appalachian region, their usefulness in Polish conditions may be doubtful. Therefore, WAŁĘGA [2012] in his manuscript attempted to optimize the Snyder's parameters and to describe them by equations relevant to southern Poland. This resulted in equations, that can provide the lag time and C_p in a form that can be directly entered into the programme. The equations are as follows:

$$T_l = 55.124 - 0.394CN + 0.0001 \frac{LL_c}{\sqrt{i_r}} \tag{9}$$

$$C_p = 0.568 + 0.0046T_l - 16.342i_r \tag{10}$$

where: *CN* – *CN* parameter, i_r – river slope.

The parameter values for the Stobnica basin were: $T_l = 23.55$ h, $C_p = 0.66$. Similar research on the regionalization of Snyder's model parameter was conducted by BELETE [2009] in the Awash and Tekeze basins in Etiopia, where he demonstrated that a significant variability of this model's parameters depended on local factors.

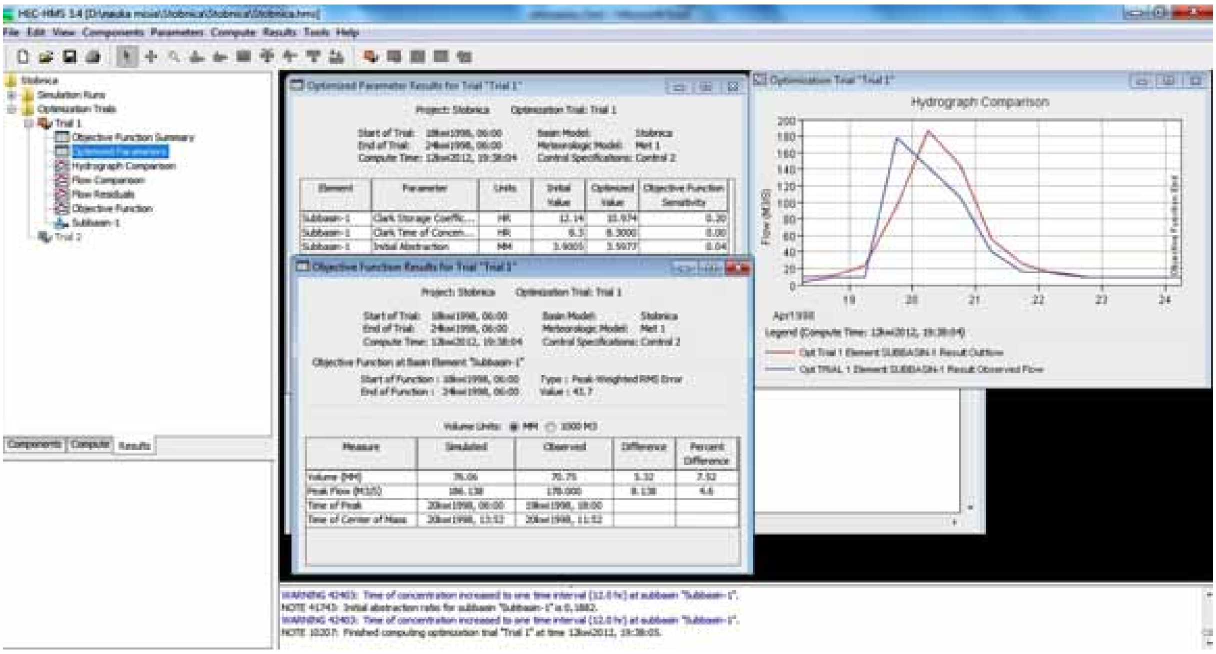
The Clark's instantaneous unit hydrograph assumes that the unit effective precipitation is transported in the stream bed and is subject to transformation as a result of the basin's area retention. Hence, the basin is treated as a linear reservoir in regard to water retention. In this method, the basin is divided into two isochrones, i.e. the lines of equal runoff time and for each of those separate parts, the retention factors are determined. This method includes the basin characteristics, such as shape, length, roughness and others to a much greater extent than the previously discussed methods. In this method the flood wave is flattened as a result of the basin's retention, which may be expressed by the straight linear reservoir's equation, in which the retention is functionally related to the reservoir runoff:

$$S = R\,Q \qquad (11)$$

where:

S – basin retention,
R – basin retention coefficient,
Q – basin runoff.

Clark's instantaneous unit hydrograph in the version implemented into HEC-HMS programme requires two parameters: time of concentration T_c and retention coefficient R. While the first of these parameters may be estimated empirically, by knowing runoff path length and the average flow velocity and then drawing a curve: basin area-runoff time (similarly as in the isochrone method), the R parameter requires optimization. This purpose was achieved by the application of the reversed gradient algorithm with the objective function: Peak Weighted Root Mean Square Error (*PWRMSE*), of the flow at culmination, which was subject to minimization. Figure 3 presents the programme screens of the calibration process using the IUH_Clark model.



Optimized Parameter Results for Trial "Trial 1"

Project: Stobnica Optimization Trial: Trial 1

Start of Trial: 18kwi1998, 06:00 Basin Model: Stobnica
End of Trial: 24kwi1998, 06:00 Meteorologic Model: Met 1
Compute Time: 12kwi2012, 19:38:04 Control Specifications: Control 2

Element	Parameter	Units	Initial Value	Optimized Value	Objective Function Sensitivity
Subbasin-1	Clark Storage Coeffic...	HR	12.14	10.974	0.30
Subbasin-1	Clark Time of Concen...	HR	8.3	8.3000	0.00
Subbasin-1	Initial Abstraction	MM	3.9005	3.5977	0.04

Objective Function Results for Trial "Trial 1"

Project: Stobnica Optimization Trial: Trial 1

Start of Trial: 18kwi1998, 06:00 Basin Model: Stobnica
End of Trial: 24kwi1998, 06:00 Meteorologic Model: Met 1
Compute Time: 12kwi2012, 19:38:04 Control Specifications: Control 2

Objective Function at Basin Element "Subbasin-1"

Start of Function : 18kwi1998, 06:00 Type : Peak-Weighted RMS Error
End of Function : 24kwi1998, 06:00 Value : 41.7

Volume Units: ● MM ○ 1000 M3

Measure	Simulated	Observed	Difference	Percent Difference
Volume (MM)	76.06	70.75	5.32	7.52
Peak Flow (M3/S)	186.138	178.000	8.138	4.6
Time of Peak	20kwi1998, 06:00	19kwi1998, 18:00		
Time of Center of Mass	20kwi1998, 13:52	20kwi1998, 11:52		

```
WARNING 42403: Time of concentration increased to one time interval (12.0 hr) at subbasin "Subbasin-1".
NOTE 41743: Initial abstraction ratio for subbasin "Subbasin-1" is 0.1882.
WARNING 42403: Time of concentration increased to one time interval (12.0 hr) at subbasin "Subbasin-1".
NOTE 10207: Finished computing optimization trial "Trial 1" at time 12kwi2012, 19:38:05.
```

Fig. 3. Dialog screen with results of the IUH_Clark model parameter calibration; source: own study

Fig. 4 summarizes the hydrographs calculated by the discussed models. The calculations conducted in HEC-HMS programme revealed that the applied models differently described the analyzed flood wave. The analyzed flooding was worst described by the most commonly used in Poland geomorpho-climatic unit hydrograph by Nash, which was characterized by significantly lower culmination and was considerably delayed compared to the observed one.

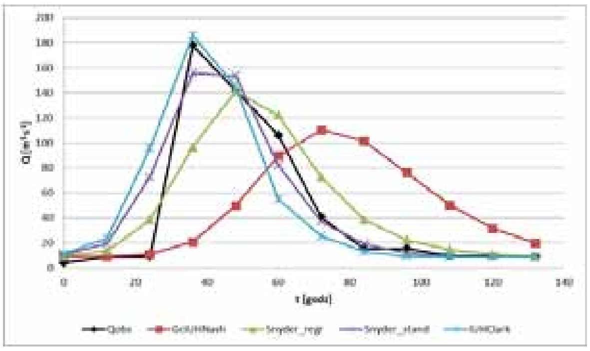


Fig. 4. Comparison of hydrographs described based on selected models using HEC-HMS programme; source: own study

On the other hand, the standard version of the Snyder's synthetic hydrograph has significantly higher culmination than the previously discussed hydrograph and the culmination coincides in time with the observed flood event. Satisfactory results were obtained when the Snyder's model parameters were determined based on the equations (9) and (10). Although the maximum flow rate in the calculated hydrograph is lower than in Snyder_stand and its culmination is delayed by 12 hours from the observed wave, its shape relatively well describes the actual flood event. The observed wave is also correctly described by the IUH_Clark hydrograph obtained by optimization. One should, however, remember that the model parameters can be optimized only when one obtains the observed flows and therefore it does not apply to uncontrolled basins. Equally good description of the observed hydrographs generated by the Snyder's model were obtained by WAŁĘGA *et al.* [2011] in the basin of the Grabinka River – a right tributary of the Wisłoka River. The coefficient of efficiency (E) was 89% there. Summary of the simulation results are presented in Table 2. The smallest error

Table 2. Quality measures of the applied models

Model quality measure	GcIUH_Nash	Snyder_reg	Snyder_stand	IUH_Clark
E	–27.3	76.8	86.6	73.6
PEP	–61.3	–26.0	–14.2	4.4
PETP	–100.0	–33.3	0.0	0.0
PEV	10.4	7.6	7.7	7.7

Explanations: E – Nash and Sutcliffe efficiency coefficient, PEP – percentage error in peak, PETP – percentage error in time to peak, PEV – percentage error in wave volume.
Source: own study.

was generated when using the wave described by Snyder_stand, while the observed flooding was worst described by the GcIUH_Nash model. The efficiency coefficient by Nash shows the correctness of adjustment of the entire calculated hydrograph to the observed one [NASH, SUTCLIFFE 1970]. It assumes values from –100 to +100%, and the closer is the coefficient E to +100%, the better the model describes the reality. As previously mentioned, the best adjustment quality was obtained by the Snyder_stand model. It should be emphasized that based on the *E* coefficient, the flood event hydrograph is much better described by the Snyder_reg model than by the GcIUH_Nash model. Despite better description of the observed hydrograph by the calculated hydrograph generated from the Snyder_stand model, it must be remembered that its parameters were adopted based on values established for basins located in completely different climate conditions than those found in Poland. In the case of uncontrolled basin, where it is impossible to compare the simulation results with the actual phenomenon, its use can lead to errors in the obtained results. Therefore, it is necessary to conduct further research on the determination of this model parameter values relevant to Polish conditions. Noteworthy, only Snyder_stand and Snyder_reg models met the criterion given by MORIASI *et al.* [2007], that with *E* values above 75% the model describes actual conditions very well. The IUH_Clark model described the observed flooding well, while the GcIUH_Nash model was found unsatisfactory. The analysis of *PEP* parameter shows that the smallest error (about 4%) occurs when applying the IUH_Clark model, while the greatest error occurs for GcIUH_Nash (*PEP* = –61.33%). In the case of Snyder_stand and IUH_Clark there was full compliance between the culmination of observed and calculated wave, while for the remaining models, the culmination of calculated hydrograph was delayed compared to the observed one. Concerning the wave volumes, similar results were obtained for all applied hydrographs – the *PEV* changed from 7.72% for Snyder_stand to 10.4% for IUH_Nash. The correctness of the observed floods' description by the IUH Clark's and GcIUH Nash models was shown by ADIB *et al.* [2010, 2011] in the basin of the Kasilii River (Iran), located in the Caspian Sea basin. This basin is characterized by a humid climate and mountainous character. According to the authors, the average values of efficiency coefficient *E* for the GcIUH Nash model were 53%, and for the IUH Clark – less than 50%.

CONCLUSIONS

The following conclusions may be drawn from the calculations and analyses:

1. HEC-HMS programme allows to conduct complex simulations for different hydrological and meteorological conditions or basin characteristics. Its operation is relatively simple and it offers a wide variety of computational methods. This application includes many of the processes that determine water circulation in the basin, such as precipitation, evaporation, infiltration or snowmelt. For definite confirmation of this programme's applicability for hydrological analyses in Polish conditions, studies on a larger number of basins with different characteristics are needed.
2. By working with HEC-GeoHMS application it is possible to include the spatial variability of factors affecting the runoff formation in the analysis. Apart from standard runoff formation analyses, the application enables to simulate the flood wave passage through dry retention reservoirs, where runoff is a function of the reservoir's bowl characteristics and drainage device parameters.
3. The conducted calculations showed that different flood description is obtained depending on the applied hydrological model. The best results were obtained by using the Snyder_stand model, followed by the Snyder_reg. Promising results with the latter model enable its application to simulate the precipitation flood event in uncontrolled basins located within the upper Vistula catchment.

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Zastosowanie programu HEC-HMS do odtworzenia wezbrania powodziowego w zlewni niekontrolowanej

STRESZCZENIE

Słowa kluczowe: *program HEC-HMS, symulacje wezbrań, hydrogramy jednostkowe, optymalizacja*

W pracy dokonano oceny możliwości stosowania programu HEC-HMS do symulacji wezbrania opadowego w zlewni niekontrolowanej. Program ten został opracowany przez Korpus Inżynierów Armii Amerykańskiej i umożliwia prowadzenie obliczeń hydrologicznych dla zlewni o różnej charakterystyce i z uwzględnieniem różnych czynników meteorologicznych. Zastosowanie tego modelu w warunkach polskich zostało zweryfikowane w zlewni Stobnicy – prawostronnego dopływu Wisłoka. Obliczenia przeprowadzono dla wezbrania wywołanego deszczem rozlewnym, które wystąpiło w kwietniu 1998 r. Porównano cztery modele hydrologiczne: geomorfoklimatyczny hydrogram jednostkowy Nasha – GcIUH_Nash, syntetyczny hydrogram jednostkowy Snydera z określeniem parametrów wzorami regresyjnymi – Snyder_reg i metodą standardową – Snyder_stand oraz z wykorzystaniem chwilowego hydrogramu jednostkowego Clarka – IUH_Clark, gdzie parametry modelu były optymalizowane w programie. Obliczenia wykazały, że najlepsze rezultaty symulacji uzyskano, stosując model Snyder_stand i Snyder_reg. Dalsze badania powinny iść w kierunku weryfikacji możliwości stosowania programu HEC-HMS do analiz hydrologicznych na znacznie bardziej obszernym materiale hydrometrycznym i w zlewniach o różnej charakterystyce.