

A creek's hydrological model's generates in HEC-RAS

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Abstract. During my research I have studied the Ronyva creek's 3.7 kilometers long stage and the Ronyva-spillway, both are located in Sátoraljaújhely. The area had significant flood damages in 2010 which resulted great reconstructions along both beds. During my work I used all the available data, I have made the hydrological model of the streams, then I ran flood models according to real and hypothetic flowrate in the built-out model-environment. By the help of the models the mostly endangered areas during an inundation can be predicted, and the bed's ability of excess water control can be studied.

The collection of significant amount of data is required to create the model-environment. To build the geometrical frame of the model a DEM (Digital Elevation Model) was needed which covered the whole study area including the riverbed. Based on field survey and satellite images the Manning's Roughness Coefficients of the bed and the surface has been identified. The further components have been measured on the basis of topographical maps in 1:10000 scale and the results of the field surveys. The built-in modul of ArcGIS, the HEC-GeoRAS was used to develop the geometrical frame. Further modelling processes were performed in HEC-RAS.

I have added the flowrate to the geometrical frame in HEC-RAS. The 1D permanent models have been run with the value of 160 m³/s and 142 m³/s flowrates. I have studied both bed's ability of excess water control. The first given value is the specified design discharge from the studies of '70s, the second value is the highest measured flowrate. As the results showed, in the case of both defined flowrates the flood was not successfully drained. The water covered a significant part of the study area. The generated flood maps can support the watermanagement and the decision-makers to elaborate prevention plans for floodings.

Keywords: flood, HEC-GeoRAS, HEC-RAS, hydrological modelling, Ronyva,

1 Introduction

In the last years and decades larger and larger climatic extremities affected by the climate change have characterized Hungary and the Carpathian basin. Due to this and the different anthropogenic effects the flow regime of the rivers and the creeks are altering. The increasing size of highwaters mean steady risks. The records of the flowrates fall after each, therefore the service of the flood barriers and the up-to-date protective plans stand first. For assistance of these, more and more hydrologic models started to be used in more and more projects also in Hungary in the last one and a half decade. I refer to the HEC-RAS software models, since I used them in this work: Kocsis (2013), Koncsos et al. (2011), Nagy (2009), Pregun et al. (1999), Réti (2012).

1.1 The hydrological modelling

First of all, the relevant discipline, the hydrology has to be defined. According to Urbanovszky (2002) the hydrology investigates the occurrence, the distribution, the exploration and the recording of the water on Earth, furthermore the circulation of the water in the nature. The processes of the nature are considerably different, as well as their modelling processes. The hydrological modelling is a more and more significant auxiliary science of the hydrology. This is also a complex process, like all the model-using sciences. Passed processes can be reproduced and serious water management problems can be answered by means of the complex hydrological models, they can facilitate the decision-making of the engineers (Szatmári, 2013). According to Szatmári (2013) the category of the hydrological modelling is considered wider. It includes the collecting, storing, assimilation, modelling, analysis of the data, respectively the presentation of the gained data and the drawn conclusions, therefore he nominates as hydroinformatics. The working phases mentioned above constitute the process of the mapping of the reality.

1.2 The Ronyva creek and its problem

The Ronyva creek, the subject of my research is a stream located in Borsod-Abaúj-Zemplén County, in the North-eastern part of Hungary (Fig. 1). Its major length represents the border line between Slovakia and Hungary. It belongs to the catchment area of the river Tisza via river Bodrog. In this paper I concentrate the stage of the creek

in the area of Sátoraljaújhely. By the border of the town, the stream branches two arms: the main arm of the border bed (Határ-meder) and the Ronyva-spillway. The modelling process dwell on the 3,7 km stage of the former, between the 2+601–6+338 RKM's so long, as the entirety 2,2 km of the latter.

The floods of the stream meant a constant hazard to the deeper situated parts of the settlement also in the middle ages. The main reason of this is the very torrent character of the stream. The flowrate of the creek use to rarely exceed the $1 \text{ m}^3/\text{s}$, whereas it could reach the $300 \text{ m}^3/\text{s}$ during its flood periods. The present stages and shapes of the beds are completely resulted by anthropogenic impact (Serf 1941).

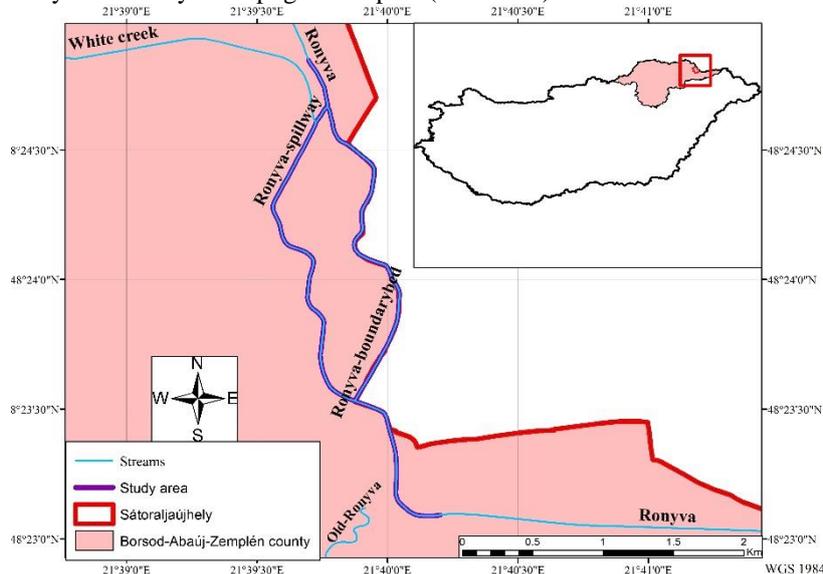


Fig. 1. The location of the study area in Hungary.

The first control works carried out in the 19th century. The channel, born with the building of the embankment of the railway line (presently belongs to Slovakia) was originally meant to spillway, still the creek relocated its bed by the cutting the parting. After some corrections, nowadays this means the so-called border bed of the Ronyva. From that time the White Creek (Fehér-patak) run across the town in the former bed. However it did not mean solution for the flood problems, since it could drain off merely a $100 \text{ m}^3/\text{s}$ flood without overflow. The adequate control of the stream was aggravated by the building directly to the banks and the railway line on the Slovakian bank (Serf 1941).

Because of the flood exposure the stream was controlled in the 1970s. The first step was the cutting of the bed in the southern part of the settlement; therefore the so-called Old Ronyva (Ó-Ronyva) was disconnected. Instead of that, new bed was dug in direction of East, which streams to river Bodrog. In parallel with the narrow bed, a spillway was built; furthermore the bed of the border was corrected. During the implementation, $160 \text{ m}^3/\text{s}$ $Q_{1\%}$ rate of great flow was considered in the segment of the waterworks building of Sátoraljaújhely at the Ronyva. The Establishment of principles was that the flow splitter above the border and the spillway divides the water of the creek between the two beds in the ratio of $1/3-2/3$. This means 106 and $54 \text{ m}^3/\text{s}$ in this particular case. These steps accelerated the floods, as regards increased the flow capacity of the beds (Molnár, 2011).

In 2010 May and June, considerably amount of sudden precipitation fall on the catchment area, a large parts of the town was inundated by the increased water level 3 times. In the next year a number of reconstructions were initiated. The embankments were heightened, however they was raised by parapet walls where the buildings located too close (Molnár, 2011).

2 Subject and method

The first step of the modelling was the building of the geometrical frame. The adequate description of the surface is required for the accuracy of the HEC-RAS calculations. The steps of these are the follows:

- generating a digital elevation model (DEM) about the streams and the surroundings
- determination of the Manning's Roughness Coefficients of the surface and the bed
- subsequent data registrations in HEC-GeoRAS: river stream centerlines, banks, flowpaths, cross-sections, bridges, ineffective flow areas, blocked obstructions
- concatenation of the above mentioned data to a homogenous frame in HEC-RAS

2.1 The generating of the DEM

In order to plot the altitudes of the surface 1:10 000 scaled topographic maps were applied. The depth of the beds and the height of the embankments do not appear at these maps, therefore the data were gained by the processing of the paper-based line-, and cross-sections, which were received from the North-Hungarian Water Conservancy Directorate (Észak-magyarországi Vízügyi Igazgatóság). During the data gaining maps and sections were digitized in ArcGIS software. The TIN (Triangulated Irregular Network) model was generated from the shape files. Using this model in HEC-RAS is inexpedient, so it was transferred to GRID format. The software is capable of managing more types of GRIDs, still my experiences say the Binary Floating Point Raster (*.flt) format is easiest to import. The resolution of the model is 1 metre, because of the weakness of the bed, since the relatively small size of the sample area allows the using of so small resolution. The resolution of the hydrologic model is also 1 metre.

2.2 The determination of the Manning's Roughness Coefficients

The texture, the shape and the vegetation-cover of the surface have essential effect to the stream of the surface water. The cover, direction, and vegetation of the bed especially modify the stream. The roughness of the surface and the bed is expressed with the Manning's Roughness Coefficients (Chow, 1959). The equation of Manning is used to the exemplification of the energy wastes caused by the surface friction. Among the elements of the equation, the most difficult to determine is the roughness coefficients, the n value. This has to represent those factors, what can obstruct the stream. In order to define the most accurate n value possible, relying on the results of the persons with the greatest experience is recommended (Phillips-Tadayon, 2007).

In order to determine the roughness value, two methods were applied. To investigate the greater surroundings of the sample area, a LANDSAT-8 OLI satellite image (photographed on 5th July 2015.) was used, the analysis of that has happened in IDRISI softwares. The satellite image has 30 m resolution, thus it was perfect to identify the arable lands, fields and forests in the surroundings of the town. The interpretation was completed by the methods of the monitored classification and the Maximum Likelihood Classification. The former operation provides six types: surface waters, forests, fields and grasslands, arable lands1, arable lands2, arable lands3. The gained thematic surface cover map was transferred to a vector file in ArcGIS, and the correspondent roughness coefficients were assigned.

The different surfaces couldn't be exactly identified in the municipal area of Sátoraljaújhely, because the satellite image has 30 m resolution. Therefore the classification was manual here on the basis of a World Imagery image. Those areas were concerned, what are covered by the cross-sections recorded in HEC-GeoRAS. The same method was used in classification of the beds and the inundation areas, moreover it was completed with the own empiric surveys. Then the three files were integrated, thus the data base of the roughness coefficients of the area was completed.

2.3 The HEC-GeoRAS

The HEC GeoRAS is a free built-in module of the ArcGIS, it was collectively developed by the HEC (Hydrologic Engineering Center) and the Esri. It can be applied to the importation of the geometric data to the HEC-RAS, and the procession of the simulations exported from the HEC-RAS (Internet-1).

The HEC-GeoRAS is capable to integrate the former components of the geometric frame to a packet, which is perfectly interpreted by the HEC-RAS (Fig. 2). This program was applied to convert the DEM and the Manning's Roughness Coefficients to the HEC-RAS. The DEM represents the basis of the altitude data of the different layers. After saving, the module creates a geodatabase in the ArcGIS, where all the recorded files can be managed (Merwade, 2012).

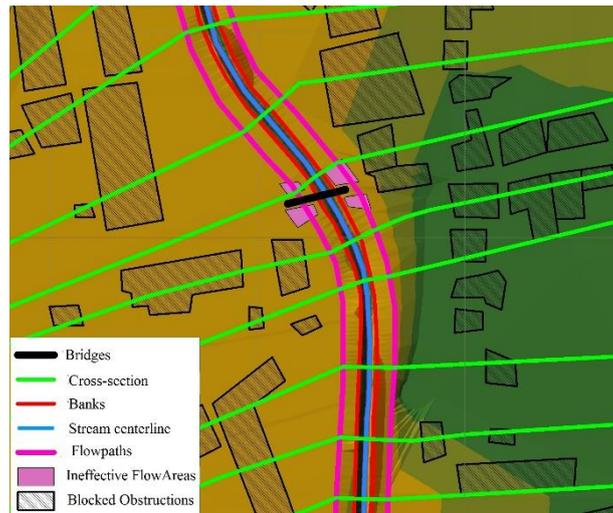


Fig. 2. A detail of the geometric frame in HEC-GeoRAS.

The next step was to record the stream centerlines. In the research area the flow splitter divides the Ronyva, it branches and then joins again therefore three sections were separated: the Ronyva has upper, middle and lower sections. The Ronyva-spillway was managed equally with the Ronyva, because it streams the water of that. The banks and the flowpaths were checked by the topographic maps, the individual surveys and the Google Earth images. The banks distinguish the main bed from the higher parts of the inundation areas. Locating the banks helps the ordering of the different features to the cross sections (Merwade, 2012).

The most important items of the geometric survey of a stream are the cross-sections. More HEC-RAS attributes can be counted and located by the help of the stream centerlines and flowpaths. For instance, the bank points can be generated in the crossings of the cross-section and the banks. They specify the border of the main bed and the inundation area (Merwade, 2012). The lines of the cross-sections were specified manually, because the cross-sections couldn't meet, furthermore this helped to the gaining of the most possible information about the research area. The cross-sections were specified thickly in the more important inhabited areas, while they were specified sparsely in the outskirts. The maximum distance between two cross-sections was 60 m; the average distance was 40 m with 10 m deviation. They were specified directly before and after the bridges, because the stream is deeply influenced by the bridges, therefore exact information is required about them.

Moreover, different structures, objects, perhaps special areas can be specified in the HEC-GeoRAS: the eight bridges, the accidentally threatened buildings in the surroundings of the streams as blocked objects, the areas behind the piers as ineffective flow areas were identified in the geometric model. The piers tighten the stream as long as the blocked objects have diversionary effect. The value of the stream is 0 in their areas, because the way of the water is obstructed. The houses can hydrate some amount of water during the floods, but it was disregarded in the models (Merwade, 2012). The World Imagery image was used again during the digitizing of the former elements.

2.4 Modelling in HEC-RAS

The Hydrologic Engineering Center of the Department of US Army Corps of Engineers has been developing the HEC-RAS software since 1964. It is available free for everyone, since it has been developed at public expense. It has more separated modules. Permanent streams in 1D or non-permanent streams in 1D and 2D can be investigated by the help of it (Internet-2).

In order to run a HEC-RAS model 3 files have to be created:

- A geometric file
- A file with the boundary conditions of the stream, it can be permanent, non permanent or quasi-non-permanent (based on the used data)
- The two files above are joined by a "Plan" type file. This can contain the determining data for the running of the model.

After the importing into the HEC-RAS, the entered geometric data can be edited and upgraded by new data in the Geometric Data menu of the HEC-RAS. Only the localization of the bridge can be achieved in HEC-GeoRAS, the subsequent data must be entered in HEC-RAS. The border section of the bridges and more data (e.g. number of piers, width and height of the bridge) are required to model the bridges (Bonner-Brunner, 1996). The altitude data

were found in the North-Hungarian Water Conservancy Directorate's hydrologic line sections, they have centimetre accuracy.

The profiles (in case of 1D) and the boundary conditions (in case of 2D) what shows, where the stream step in and out from the model area are entered to the geometric file. The types of them can be given in the marginal condition file. The type is determined by character of the flow: is it inflow, outflow or interflow. The Flow Hydrograph type requires time-based streamflow data; the Stage Hydrograph type needs water stage data. The general value of falling gradient in the sample area is required to the Normal Depth type, used in the case of discharge.

The Plan files contain the temporal pass of the modelling, they give the temporal scales of calculations and output data. These files have to connect the geometric file and a marginal condition file (depended on the type of the modelling).

The permanent stream tests don't require temporal limit, however one rate of flow value have to be assigned to all sections. The test is used to the hydrologic investigation of the streamflow, the foreshore and the inundation area. Molnár's (2011) referent streamflow values were used in these works. The 142 and 160 m³/s streamflow values were divided between the border bed and the spillway in the ratio of $1/3-2/3$ as it determined in the time of the building. The boundary conditions were the upper and lower end of the Ronyva. In case of the latter, 0,001 value of the Normal Depth was given, as the general gradient of the relief.

3 Conclusions

The height above the sea level is between 95,5 and 107 m in the research area. According to my hypothesis, the most threatened area by the floods are the area between the two beds and the 300–400 m width stripe on the right bank of the Ronyva-spillway. The height is gently declining in the direction of South. The depth of the beds varies between 96,94 and 100,16 m in the spillway, while it varies between 95,00 and 100,35 m in the border bed of the Ronyva. The height difference is generally 3–4 m between the dike and the bottom.

The manually categorized land cover data distinguish the build-up areas and the roads within the town. The sections with different roughness were represented with the same method in the case of bed and inundation plains, too. After the union of the two land cover database, the Manning's Roughness Coefficients values were assigned to the different categories (Table 1). Roughness Coefficients in winter were used in the case of vegetation, where it was possible.

In order to find the most endangered areas, extreme values were taken for basis during the modelling (Fig. 3). The greatest difference between the two basis streamflows is that the border bed also inundates some areas. In case of 160 m³/s streamflow, almost 6,8 hectares more area could be flooded.

Table 1. The Manning's Roughness Coefficients of the surface and the bed (Chow, 1959).

Code	Channel type and description	<i>n</i>
Short grass	Short grass	0.025
High grass	High grass	0.035
Light brush and trees	Light brush and tress, in winter	0.035
Medium brush 1	Medium to dense brush, in winter (minimum)	0.045
Medium brush 2	Medium to dense brush, in winter (normal)	0.070
Fields and grasslands	Scattered brush, heavy weeds	0.035
Weald (city)	Cleared land with tree stump, no sprouts	0.030
Forest	Same as above, but with heavy growth of sprouts	0.060
<i>Cultivated areas:</i>		
Arable lands 1	Mature field crops	0.030
Arable lands 2	Mature row crops	0.025
Arable lands 3	Mature field crops	0.030
Roads	Asphalt, rough	0.016
Built-up area	Houses, courts, difficult definable gardens	0,030
Waters	Lakes and streams	0
Bed 1	Sluggish reaches, weedy, deep pools	0.050
Bed 2	Dense weeds or aquatic plants in deep channels	0.035
Bed 3	Clean, winding, some pools and shoals, some weed and stones	0.035
Bed 4	Clean, straight, full stage, no rifts or deep poolswith more stones and weeds	0.040

Bed 5	Dragline-excavated or dredged, no vegetation	0.025
Bed 6	Stony bottom and weedy banks	0.025

The model had to be validated by real data (Fig. 4). The map of in 2010 inundated streets was used, which was received from the city government. The map was not entirely accurate, but we can see, they are the same (in the polygon of the inundated areas all is not flooded). The streamflow could be probably more than $142 \text{ m}^3/\text{s}$. Inadequate functioning of the flow splitter could causes the large-scale inundations along the border bed.

On the basis of the available databases a model-environment was built and models were run there. These models can help in the defence and location of the most threatened areas and real-estate properties in case of the further possible floods. It can be determined, that the model of the spillway bed is not capable to discharge greater inundations, however the age of the available data can affect this. After the join, the bed is more available to discharge the floods. Due to the broader foreshores, the volume and the capacity of the bed increase. The narrowness of the spillway in the built-up area can causes the large-scale inundations is case of extreme streamflows. Actually, the foreshore of the border bed has typically 20–25 m width; the same value of the spillway is less than 10 m. After the join of the two sections, the foreshore can be 35–50 wide.

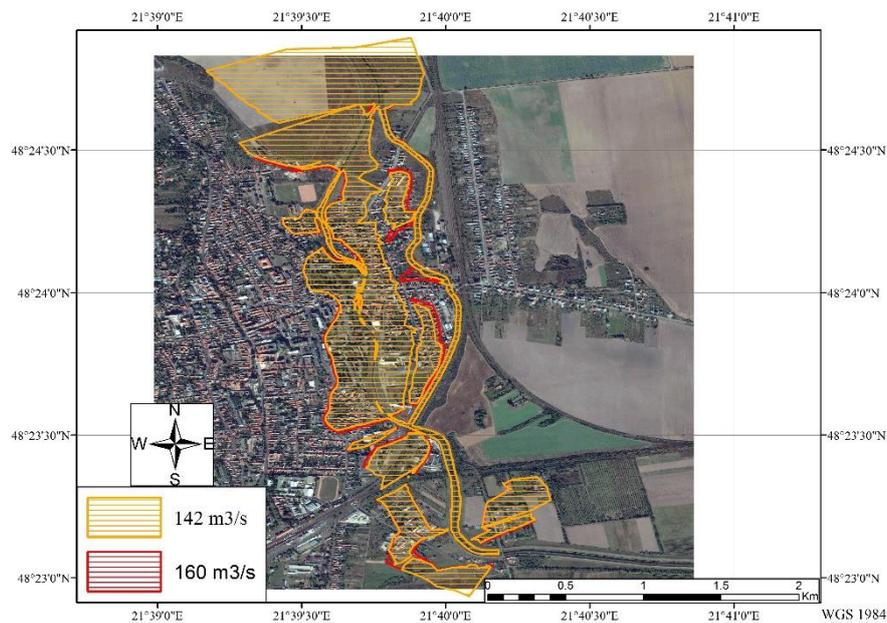


Fig. 3. The inundated areas in case of 142 and $160 \text{ m}^3/\text{s}$ streamflow.

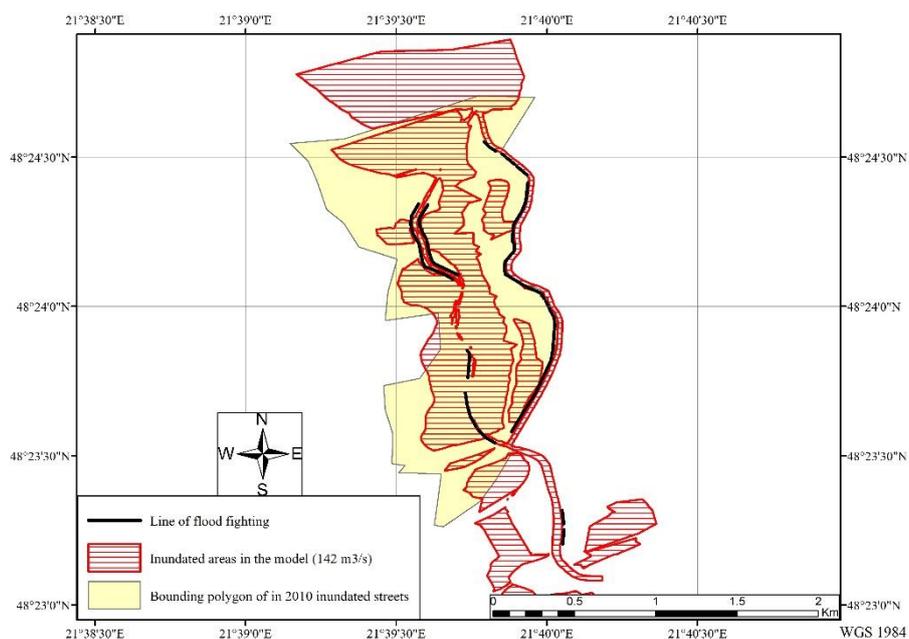


Fig. 4. Validation of the model with flooding data from 2010.

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3.1.1 Reference of Internet

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INTERNET-2: US Army Corps of Engineers, Hydrologic Engineering Center, HEC-RAS software URL: <http://www.hec.usace.army.mil/software/hec-ras/>