THE USE OF ADVANCED HYDRAULIC TOOLS TO OBTAIN FLOOD HAZARD MAPS

Tomi Alexandrel HRĂNICIUC[1], Anca BĂLAN[2]

e-mail: hraniciuc_tomi@yahoo.com

Abstract

The aim of this paper is to obtain a hazard map using hydraulic modeling tools. Floods are some of the natural phenomena that have deeply marked human society, being some of the most widespread disasters around the world and also the largest producer of damage and casualties. Flood events cannot be avoided, but they can be managed, and their effects can be reduced by measures and actions to help mitigate the risks associated with these phenomena. To study these phenomena or prediction of their evolution in time, we need physical or mathematical models that reproduce them with accuracy as fine. A very useful tool for the study of phenomena related to free surface water runoff is represented by hydraulic modeling. Currently, hydraulic modeling is successfully applied worldwide, both in scientific research and in engineering.

Key words: water management, flood hazard map, hydraulic modeling.

To allow us to defend against extreme events and reduce potential damage caused by these, specialists from different fields are trying to devise and improve different calculation methods, tools, software, by means of which could predict in advance any disaster intervening in time to remove them or diminish the total amplitude. Floods represent a great danger to society, especially in the current context of climate change. To reduce the damage caused by them, at international level was decided the preparation of flood hazard and risk maps, based on them different decisions can be take about the actions and work that must be undertaken in order to not have losses. These maps can be drawn based on classical engineering calculations, also by using modern hydraulic calculation software.

This paper presents drawing of a hazard maps using modern software and the comparison of modeled results with the flooding strip observed during the floods phenomenon.

MATERIAL AND METHOD

To draw the hazard map specialized software as WMS and HEC-RAS have been used. WMS is hydrologic and hydraulic analysis software. It was developed by the Research Laboratory for Environmental Modeling - Brigham Young University, in cooperation with the US Army Corps of Engineers - Station Experiments for Waterway. WMS is organized into eight modules. Each module is associated with a particular object type. While modeling only one module can become active (Brigham Young University, 2002; Hraniciuc T., 2011).

WMS interface for hydraulic modeling uses HEC-RAS software. HEC-RAS model can be run both in steady state and unsteady movement and the results are used to delimit the expansion of the flooded areas, also can run animations of flood wave transit.

The mathematical equations underlying modeling are the Saint-Venant equations in one-dimensional system:

• One-dimensional system:

Continuity equation (1): $$\frac{\partial \zeta}{\partial t}+\frac{\partial (uh)}{\partial x}=0$$

Momentum equation (2): $$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+g\frac{\partial \zeta}{\partial x}+c_f\frac{u|u|}{h}=0$$

where: y - the water local depth; A - the cross section area; B - the width of the water surface; *Z* - water level (compared to baseline), defined as: $\zeta = h + z_b (m)$; *h* - the local water depth (m); z_b – thalweg local level (m); *u* - flow velocity (m/s) and c_f - the coefficient of friction (dimensionless).

The main steps required for drawing the hazard map are (http://www.aquaveo.com; http://www.emrl.byu.edu/wms.html):

- Define a stream centerline and bank stations;
- Define cross section locations;
- Automatically cut cross sections and derive Manning's roughness values from elevation and ground material data;
- Export cross sections to the HEC-RAS model;

[1] "Gheorghe Asachi" Technical University, Iasi

- Run the hydraulic model and read the water elevations back into WMS;
- Read water surface elevation data from a hydraulic model or manually input known water surface elevations;
- Create flood extents and flood depth maps using digital terrain data and water surface elevation data points.

Case study. The case study has been made on the Jijia River, and one tributaries i.e. Buhai river. Jijia river is located in the north-east of Romania *(figure 1)*.

Figure 1 **Research location**

The first step to make a HEC-RAS model is creating a conceptual model that defines the river with its tributaries, the river cross sections position, the banks location and related land use. The conceptual model will be used later to create a schematic network with the location of the rivers cross sections in the hydraulic module (Giurma I. *et al*, 2009).

The cross sections will be extracted automatically by the program WMS, if this will have an available contour plan in electronic format. In WMS the plan contour can be obtained if a network of scatter associated with the corresponding rates i.e. a TIN (Triangulated Irregular Networks) is provided.

Thus, we have digitized the contour plan at 1: 5000 scale, resulting the network scatter *(figure 2)* based on which we achieve the TIN in plan *(figure 3)*, i.e. 3D visualization *(figure 4)*.

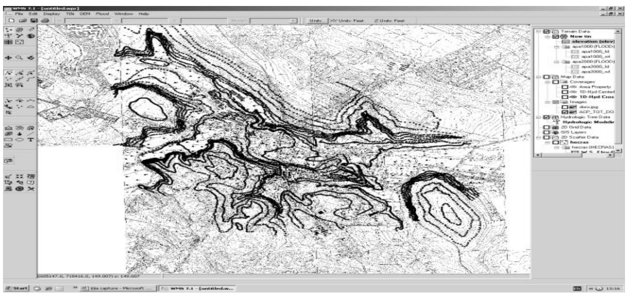
Figure 2 **Scatter network after contour**

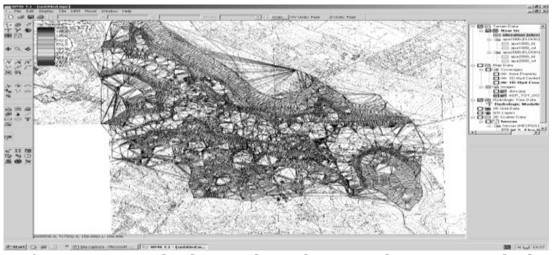
Figure 3 **TIN (Triangulated Irregular Networks)**

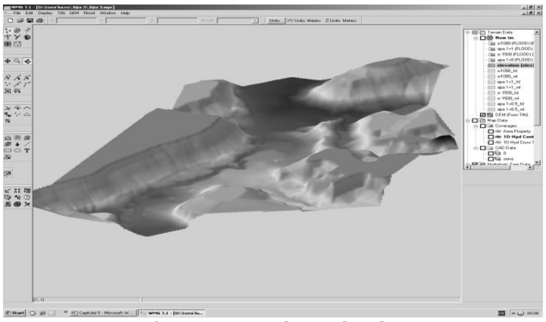
Figure 4 **TIN (3D View)**

The next stage is tracing the contour of the rivers from upstream to downstream determining the water flow direction, followed by drawing the related *banks (figure 5).*

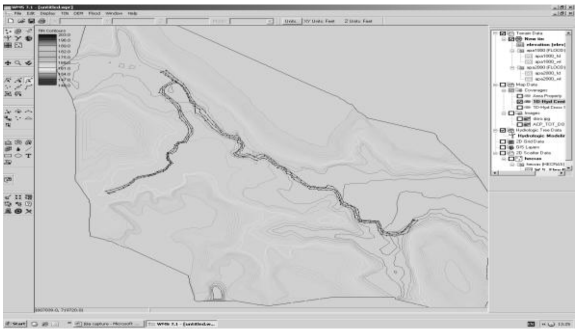
Figure 5 **Rivers network and the banks**

Given that will be applied a hydraulic modeling, the main parameter to be entered into the program is the roughness, which will depend on the calculated water level. Thus, depending on the land use, each cross section will contain different roughness in the major river beds. We will create a new layer that will contain different types of soil which we assimilate different properties based on ortophotoplans which relates precisely the type of land use.

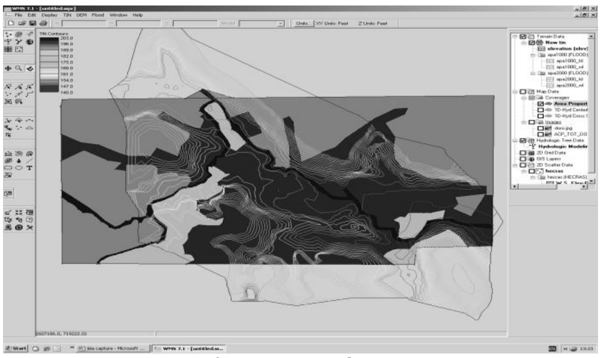
Figure 6 **Land use**

The next step is creating *(figure 7, 8)* and extracting the cross sections that contain parameters such as terrain elevation, type of material through which the section is crossing, of sections points properties. These will be extracted from TIN, land use and centerline layer. After extracting them, we can visualize the properties in a special window assigned to them.

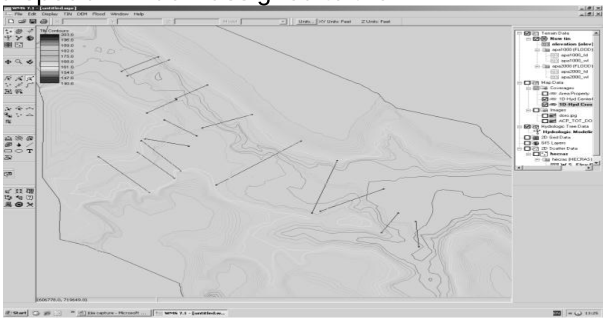

Figure 7 **Cross sections**

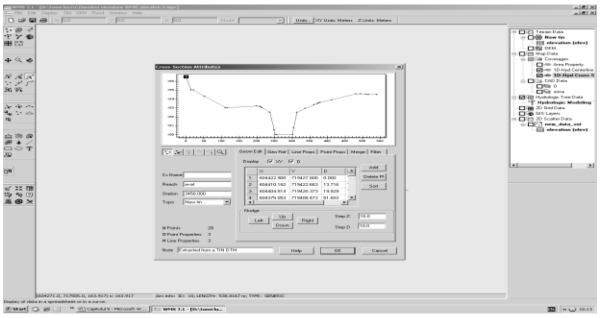

Figure 8 **Cross sections attributes**

The second step was to create the schematic network in WMS and introducing roughness on each type of material. WMS interacts with HEC RAS using a geometric file HEC-GeoRAS. This file contains the cross-sectional data used by HEC RAS besides three-dimensional georeferenced data. After creating the schematic network *(figure 9, 10)* WMS will include two separate data representations. The first is the conceptual model previously created and contains all layers, and the second is the numerical model stored in the cross sections schematic network of each river or portion of the river. After that, the bridges will be introduced in the conceptual model, the last step is represented by the introduction of boundary conditions such as flow rates if we have steady movement or measured hydrographs for unsteady movement.

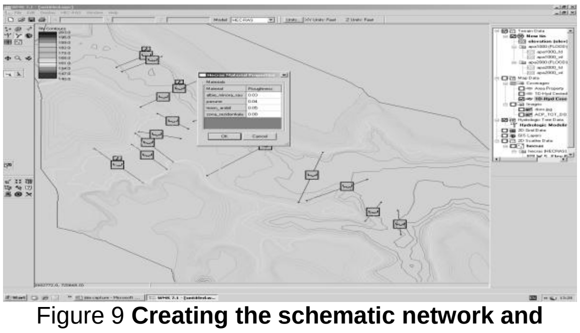

Figure 9 **Creating the schematic network and introduce roughness on each type of material**

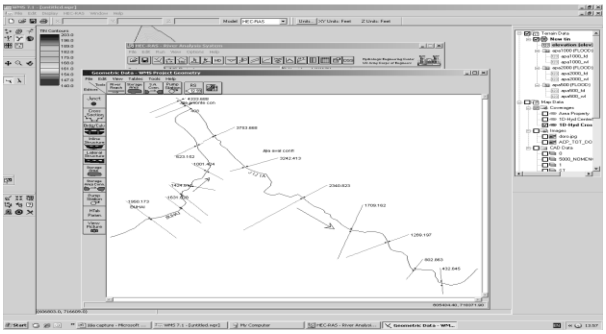

Figure 10 **Rivers geometric network in HEC - RAS**

With the help of HEC RAS we set up and run the simulation, and then the processed results are exported back to WMS for visualization.

Basically, if the roughness of the minor and major riverbed were chosen well based on field observations or orthophotomaps updated during the phenomenon of flooding, should the flooding simulated band to coincide quite well with the observed one, which means that the model was calibrated.

RESULTS AND DISCUSSIONS

The modeling was done on Jijia River at the confluence with Buhai River in Dorohoi city. The data used for calibrating the results was considered the flood in June 2010 in the town of Dorohoi, which resulted in considerable damage.

The results are shown in one-dimensional format (1D) in HEC-RAS, but also in two-dimensional (2D) by depths and water levels. In one dimensional format can be view the water depth processed from HEC-RAS in both cross-sectional and longitudinal profile (*figure 11, 12*).

Due to the abilities of the program WMS to interpolate the water level calculated in HEC-RAS with the ground line based on available TIN, the result consist in the flood hazard map *(figure 13, 14, 15)*.

As can be seen, the observed band during flood coincides and overlaps almost perfectly over the one simulated using software. This means that the digital terrain model on which the sections were extracted coincided with field reality, and the roughness applied to the cross sections are according to the land use of the studied area. It can respond that the model was calibrated. The main hydraulic parameter which was varied for calibration was the roughness coefficient. Its value depends on the land use in the area, and for the best possible accuracy is required dated ortophotoplans during extreme events. To obtain the result, the collaboration between the two software was necessary. HEC-RAS is giving only the one dimensional outcomes and WMS needs the hydraulic calculations performed in HEC-RAS, in order to obtain the 2D results.

Basically there is interdependence between the two software. The two dimensional results dimensional might be achieved by intersecting the water level obtained in HEC-RAS with the line soil surface line, using other specialized software, but on the building of HEC-RAS model we need to have already the complete dataset, such as completely cross sections and their subsequent processing by introducing roughness.

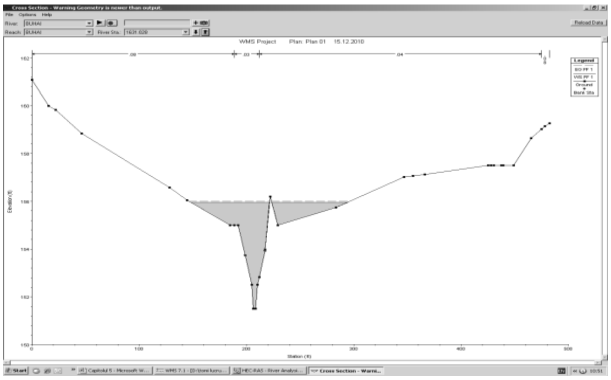

Figure 11 **Water level in cross section inHEC RAS**

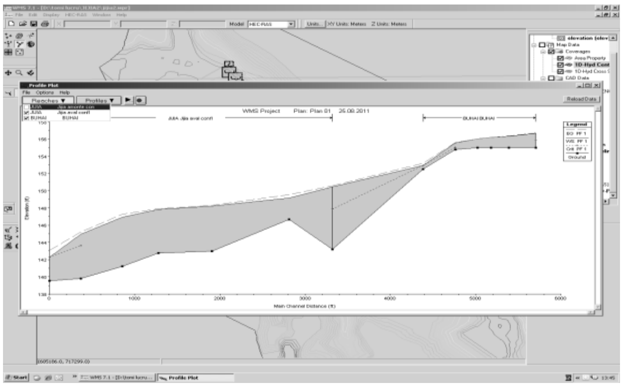

Figure 12 **Free surface of water line viewed in longitudinal profile in HEC RAS**

The advantage of using WMS is that we can automatically extract the cross sections from DTM, which have already set up the hydraulic parameters extracted from the land use layer. Also, we are benefiting from the automatic processing of cross sections by extending them, which we cannot do in HEC-RAS. Thus, it shrinks very much the working time and painstaking work, which in case of a large model would only take several days to process the sections. WMS has GIS tools which are very user friendly, also thanks to advanced tools for visualization of results and possibilities for their processing as well as data entry model.

Figure 13 **Water depth in WMS**

Figure 14 **Free surface of water line viewed in longitudinal profile in WMS**

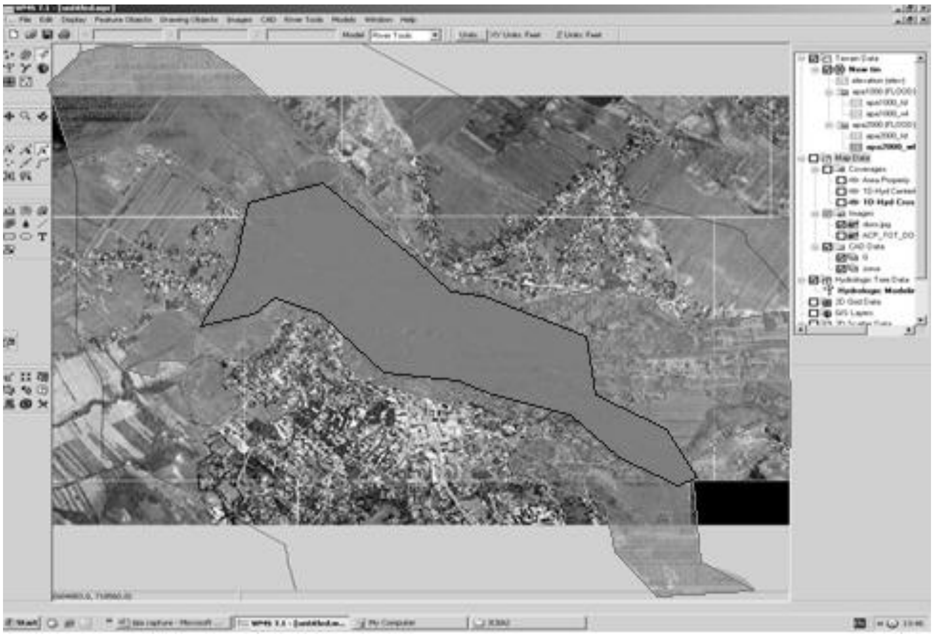

Figure 15 **Comparison between the observed flood strip during the flood (dark hatch) and the resulting WMS (light hatch)**

CONCLUSIONS

As a general conclusion of this work, one can say that the use of software engineering greatly eases the work of specialists. The results are obtained in a very short time compared to traditional methods. The results are also more expressive and have a more exact accuracy if the model is well built. Results can be seen using two-dimensional depths and water levels flooded the entire area, which greatly facilitates further processing such as flood risk mapping and quantification of damages. If the model shows errors in some ways like unacceptable values of the roughness coefficient, they are displayed immediately enabling the specialist to rectify the problem, while in a traditional calculation these errors may be overlooked leading to erroneous results.

Establishment of these hydraulic models on all watercourses, their calibration and validation, would mean a technical and scientific progress because with their help, experts in the field could draw up hazard and flood risk maps, could create floods prognoses, could study the morphological phenomena of rivers and simulate eutrophication and water quality. All of these are extremely useful because it would greatly reduce the damages as a result of extreme events, being able to easily make decisions on the different actions and engineering works which should be applied after using the results of running such models.

Once a model has been developed, calibrated and validated it can be used successfully to interpret different scenarios when initial conditions are changed. For example, changing the discharge coefficient due to deforestation of mass or modifying the longitudinal profile of a sector due to the proposed regularization, heightening the levels due to works of art, etc.

Therefore, it can be said that the results obtained using the software cannot be compared both quantitatively and qualitatively to those obtained by conventional methods. They are much more accurate. The only attention should be given to the right implementation of input data, the initial conditions and more accurate representation of the situation in the field by placing all buildings and works in the floodplain. Today, on the global market all specialists in the field, both working in design or execution, uses such programs to improve the accuracy of projects.

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