

TOPOGRAPHICAL MEASUREMENTS AND INFORMATICS FACILITIES IN THE TORRENTIAL HYDROGRAPHIC NETWORK MANAGEMENT

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Abstract: *In the present paper the facilities offered by different software concerning selecting the best management solution for a torrential hydrographic basin will be pointed out. The first part of the paper presents the features offered to the users of AutoCAD software in order to quantify the parameters which enable the determination of the peak discharge of a watershed. The second part of the paper is dedicated to the use of HEC-RAS software which, through the calculated value of the peak discharge of the watershed, succeeds to highlight the water level in each studied cross section, which on the basis of the adopted slope of silt deposition, enables the choice of a certain alternative of managing the torrential watershed and, moreover, to draw up the flood natural risk map for the studied area. In the final part of the paper, the possibilities offered by AutoCAD for optimizing the positioning of mainstream transversal works are exposed.*

Key words: *torrential watershed, GIS, AutoCAD, HEC-RAS.*

1. Introduction

Chaotic development of weather phenomena of recent times need new methods of study, with direct involvement of the latest technology, in view of adopting the most accurate solutions to counteract their effects. Torrential rainfalls of last summer (2009) have adversely affected many areas in our country. Such a situation occurred in the locality Bran-Poarta, Braşov County, where, negative effects were obvious both at the level of Communal Road DC 51 Bran-Poarta (Figure 1) and the level of other objectives such as: homes, parking area and annexes

related to the ski slope Zănoaga etc.

Starting from the negative implications of this, the problem of planning and management of the hydrographic basin Valea Porţii in total area of 2135.05 ha has been studied. As particular problems were found in the section located immediately downstream of the forestry sector and, following the principle laid down by late Professor S. Munteanu according to which “the field is defending at mountain”, the question of management of the sector upstream the inhabitable area was raised. Consequently, the study will consider a torrential hydrographic basin of 1256 ha (Figure 2).

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Geologically, the land was formed in inferior to middle Cretacic and it is made up from conglomerates and limestones with a crystalline and bladed support and from the depression pathway with crystalline nuclei, limestone bocks that are bladed and included in conglomerates, sandstones and marls also, these constituting in geological substratum on which the soils created.

With a medium and even low resistance at erosion, these rocks encourage the starting of pluvial erosion and amplify the torrential transport.



Fig. 1. Road degradation DC 51

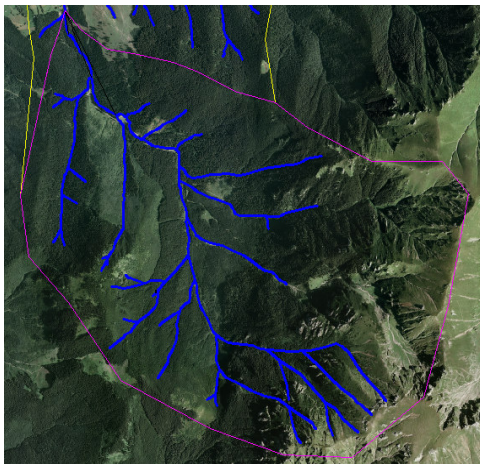


Fig. 2. Hydrographic basin examined

2. GIS Facilities in Planning Torrential Hydrographic Basins

2.1. Using AutoCAD to Determine the Elements of Basin and Hydrographic Network Morphometry

A. Morphometrical elements of watershed

a) *The surface* was calculated by utilization of function *Terrain - Terrain Model Explorer - Create Surface* [4], that creates automatically the *NamelayeSRF-BDR* layer and it specifies the value of surface in area *Extended Surface Statistics*. The founded value is $F = 12564950.667 \text{ m}^2 \approx 1256$ hectares;

b) *The perimeter* results automatically in AutoCAD, the numbers of the both characteristics appearing together. In this case, $P_b = 14052.997 \approx 14$ [km];

c) *The mean length of watershed* was computed with the known formula:

$$\bar{L}_b = \frac{P_b}{4} + \sqrt{\frac{P_b^2}{4} - F} = 9580 \approx 9.5 \text{ [km]}; \quad (1)$$

d) *The shape of watershed* was studied using the next coefficients:

- Gravelius coefficient:

$$Gr \approx 0,282 \cdot \frac{P_b}{\sqrt{F}} = 1.12; \quad (2)$$

- Ratio of circularity:

$$RC = 12,566 \cdot \frac{F}{P_b^2} = 0.80. \quad (3)$$

These results indicate that the studied watershed is slightly elongated;

e) *The minimum, maximum and mean altitude*. Minimum (H_{\min}) and maximum (H_{\max}) altitude haven't important signification regarding hydrology. Their identification is very easy, either consulting of database for

the elaborated project or using *Inquiry - Surface Elevation* function. On the situation of studied watershed, the next values were computed:

$$H_{\min} = 914.50 \text{ [m]},$$

$$H_{\max} = 2260.80 \text{ [m]},$$

$$H_{\text{med}} = \frac{H_{\min} + H_{\max}}{2} = 1587.65 \text{ [m]}, \quad (4)$$

$$H_{\text{med}} = \frac{\sum_{i=1}^{n+1} F_{i,i+1} \cdot \frac{H_i + H_{i+1}}{2}}{F} \quad (5)$$

$$= 1255.30 \text{ [m]}.$$

The last formula (5) gives the best solution obviously. Using AutoCAD the mean altitude is found automatically with *Create Surface - Terrain - Terrain Model Explorer* function;

f) **The height of watershed.** In accordance to each situation, either maximum height or mean height of the watershed can be computed [1]. The values of studied watershed are as follows:

$$R_{\max} = H_{\max} - H_{\min} = 1346.30 \text{ [m]}, \quad (6)$$

$$R_{\text{med}} = H_{\text{med}} - H_{\min} = 673.15 \text{ [m]}, \quad (7)$$

$$R_{\text{med}} = H_{\text{med}} - H_{\min} = 340.80 \text{ [m]}; \quad (8)$$

g) **The slope of watershed** can result using AutoCAD in two ways:

- by achievement of network with vertical and horizontal lines using *Array* function, overlapping with digital model of land. In the knots of network, the values of slopes result resorting to *Label Slope (Terrain - Surface Utilities)* function. With this values, the mean slope of the watershed can be calculated ($I_{\text{med}} = 40.82\%$);

- by recourse to *Create Surface (Terrain - Terrain Model Explorer)* function, in the area *Extended Surface Statistics* the mean

value of slope results too ($I_{\text{med}} = 41.65\%$);

h) **The length of mountainsides from watershed.** Usually, the length of a mountainside can be computed with AutoCAD in a few ways:

- in the case of 2D system, the length of a mountainside results using a polyline (with actively perpendicular mode in *OSNAP*), to draw the line of the highest slope between one point from thalweg to the chosen point from topographical line of the analyzed mountainside;

- in the case of TIN model, *Slope Arrows...* (*Terrain - Surface Display* ►) function is used to indicate the general orientation of trickling from watershed. By their analyze, the line of the length for each mountainside can be discovered.

The mean length of mountainsides from watershed was calculated with the next expression:

$$\bar{L}_v = 5.5 \frac{F}{L_r} = 280 \text{ [m]}. \quad (9)$$

In this case, to determine the length of the hydrographic network an *AutoLisp* sequence has been developed which automated this calculation. This sequence relied on calling the function *Inquiry - Continuous Distance* and 'cal. To automate this process of measuring the hydrographic network and, at the same time, to label each bed segment with a value corresponding to its length, when creating the basic hydrographic basin the order corresponding to each segment must be taken into account. Thus, for development and proper functioning of *AutoLisp* sequence the following actions will be made: indicating how hydrographic network runs (upstream to downstream, so from 1st order segments towards higher order ones), calling function *Inquiry - Continuous Distance, OSNAP Midpoint* mode for labeling bed segment in the middle with values corresponding to the hydrographic order

and its length, specifying the next bed segment, at each network node making an interrogation of the order of segments that intersect and labeling the following segment as follows: if the order of intersected segments is identical, the next segment will have the order higher by one unit; if the intersected segments order is different, the highest order will be kept (Figure 3).

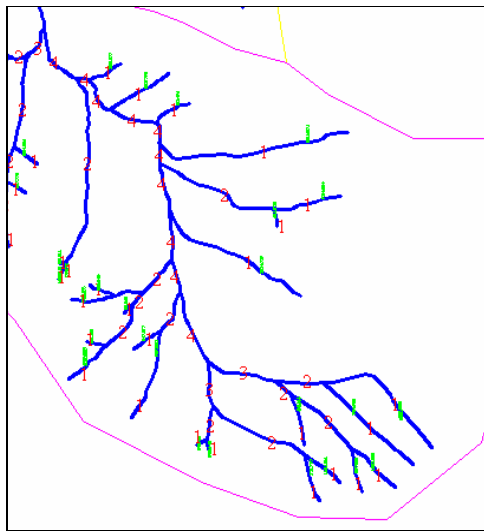


Fig. 3. Automated labeling of hydrographic network

B. Morphometrical elements of the hydrographic network

a) **The hydrographic order.** In concordance with Strahler system, the torrential watershed contains sectors with I, II, III and IV orders;

b) **The length of riverbed.** This parameter can result in AutoCAD using *Inquiry - Continuous Distance* function. The function achieves a labeler of the measured element with corresponding distance also, for case:

$$L_{ar} = \frac{L_a}{\cos \alpha} = 8.13 \text{ [km]}. \quad (10)$$

c) **The mean slope of the main riverbed.**

In the classical mode this parameter results such as a fraction between the level difference of extreme points and horizontal length of the riverbed:

$$I_a = \frac{H_{am} - H_{av}}{L_a} = 0.23 \rightarrow I_a = 23\% \rightarrow I_a = 13^{\circ}8'.$$

The values $H_{am} = 2247.45$ [m] and $H_{av} = 914.50$ [m] were computed using *Inquiry - Surface Elevation* function.

2.2. Estimation of the Maximum Flow Capacity of High-Water

In situations of torrential watersheds from Romania, the forecast of the maximum flow capacity of high-water is accomplished by indirect methods. That is methods based on the rain which is the source of high-water and the elements of watershed that can influence the formation and propagation process of high-water [1], [3].

Even there are many methods to compute the maximum flow capacity of high-water, in this paper we used only two of them:

a) **The rational method**, that utilizes the follow expression [2]:

$$Q_{\max 1\%} = 0.167 \cdot c \cdot i_{1\%} \cdot F, \quad (11)$$

where: c is the mean runoff coefficient in the watershed; $i_{1\%}$ [mm/min] - the mean intensity of rain used in estimation with 1% probability, having an equal duration with the concentration time in the watershed; F [hectare] - the area of watershed.

First, the concentration time of trickling was calculated. The *Hidrology (Hidrology - Runoff ► - Time of Concentration (Tc)...) module* was utilized for this, finding in this way $T_c = 31$ [min]. The mean intensity of rain required in estimation was computed further on, using the concentration time

($i_{1\%} = 1.62$ [mm/min]). Therefore, considering the precipitation generated by rain used in estimation and the hydrological category of land, the retention coefficient resulted (c_z). After that, the infiltration coefficient (c_l) was found depending on mean intensity of rain used in estimation and the soil texture. Using the c_z and c_l values, the runoff coefficient for the watershed resulted ($c = 0.24$). In this way $Q_{\max 1\%} = 81.58$ [m³/s] was computed;

b) **The method of hourly rain** is base on the follow formula:

$$Q_{\max 1\%} = \frac{0.28 \cdot F \cdot c \cdot H_{60}}{(F + 1)^n}, \quad (12)$$

where: F [km²] is the area of torrential watershed; c - mean runoff coefficient, that is established for geographical regions from Romania ($c = 0.70$); H_{60} [mm] - maximum hourly precipitation, in cases of climatic zones from Romania, at 1% probability ($H_{60} = 115$ mm); n - exponent smaller than one, having districts in Romania ($n = 0.48$).

As result, $Q_{\max 1\%} = 81.00$ [m³/s].

2.3. Topographical Measurements on the Torrential Hydrographic Network

To estimate the level water in any point from torrential hydrographic network, topographical measurements regarding cross sections in three points situated in each sector of the riverbed, were made. The minimum number of the points (3) depending on GIS software (HEC-RAS) that provides a general representation of the network based on development of hydrographic network in space and of cross sections that are configured. These points were in advance established on 530-442 ortophotoplan. For each section two or three points from riverbed and three points from each bank were taken (Figure 4). Therefore, a few stages were followed:

a) digitization of hydrographic network. This operation can be done directly in HEC-RAS, by anticipated bringing of base plans or/and corresponding ortophotoplan, either in AutoCAD or another software and its processing in HEC-RAS [5];

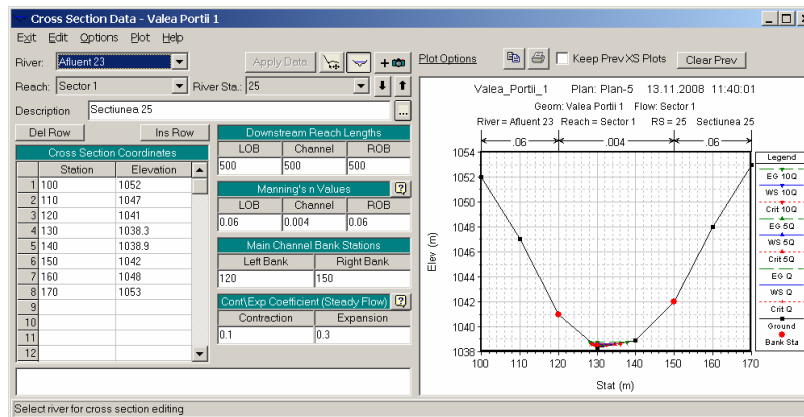


Fig. 4. Cross section from first sector of the tributary no. 23

b) introduction of specific data for each cross section from land, information that were taken with total station. The introduction can be achieved directly in *Cross Section Coordinates* database, specifically

in HEC-RAS software, or by their bringing from a GIS database;

c) introduction of the values computed for the flow-capacity of each riverbed sector. It was considered that each sector

takes the upstream flow-capacity too. Besides, potential values of the flow-capacity were taken into account from each sector with 5 or 10 years of interval;

d) definition of the corresponding junctions (points from confluence) and length of arcs that intersect in respective points;

e) specification of condition regarding the normal depth in estimable section;

f) starting of the simulation regarding plotting of water level from entire hydro-graphic network. Observing the studied sections, a conforming system of management works can be chosen (finding number and height of works), and on the other hand the

risk map of flooding can be elaborated in case of research area. In this example the volume of sediments wasn't computed and because of this the simulation began with the assumption of a sub-critically trickling regime (without the weight of sediments) (Figure 5);

g) analysis of each sector from riverbed, by observing the longitudinal development (Figure 6), by computing of slope for each homogenous part, by studying of cross section in each existing point, by analyzing of water level and its variation mode too, in concordance with cross development of the riverbed, by quickly computing of level differences between successive sections etc.

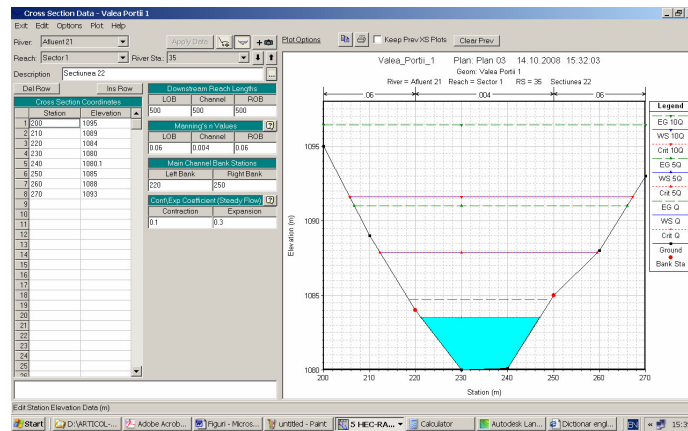


Fig. 5. Level of water in a cross section

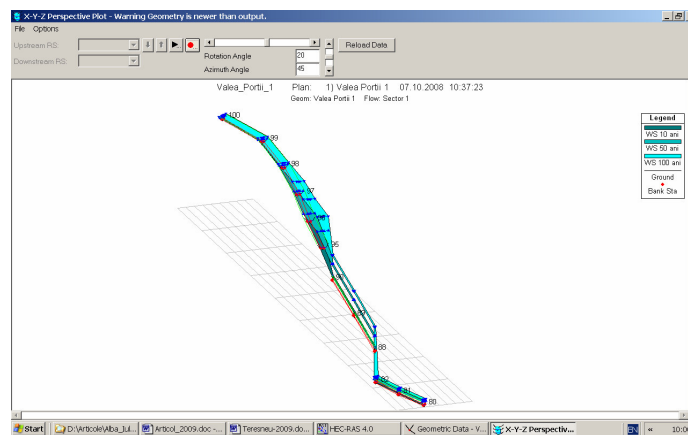


Fig. 6. Development of riverbed in space

2.4. Adopting Technical Solutions

Regarding adopting technical solutions were considered only aspects that can be GIS simulated.

By using the extension *Civil Design* of *AutoCAD* has been made the longitudinal profile of the main riverbed downstream (Figure 7).

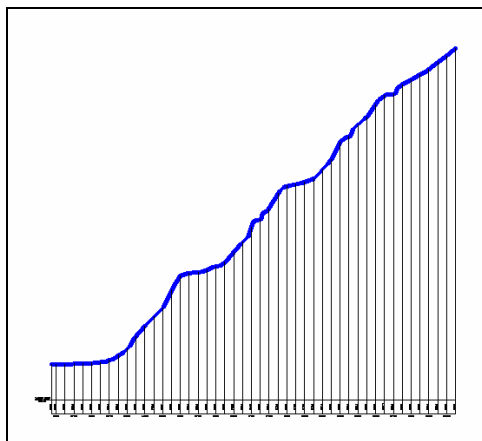


Fig. 7. Longitudinal profile of the riverbed

Based on topographic measurements made on the first 2 km of the main riverbed and using HEC-RAS software, an average transversal profile was made.

In order to adopt technical solutions, it has been made an *AutoLisp* sequence involving the following aspects preliminary to execution: selects polyline designating the longitudinal riverbed profile, indicating the riverbed width (which is assumed to be constant), Stereographic 1970 projection coordinates of the first point of dam location, dam height, depth of its foundation, length of apron, volume of silt able to form channel fill (W_{after}^{5year}), design slope. This sequence will make: draw of the first dam at indicated point and its apron, stimulates complete filling with silts at design slope value, determination of filling surface by

interrogation with function *Inquiry-Area* of the area bordered by dam wall, line of longitudinal profile and design slope, calling function 'cal to determine the channel fill volume of the first dam (will take into account the riverbed width), continues drawing and calculation of channel fill volume until covering the previously indicated value. In this case, resulted a number of only 33 transversal works (dams), the difference from the previous value ($N = 35$) being given by the fact that the longitudinal profile is not constant as slope (Figure 8).

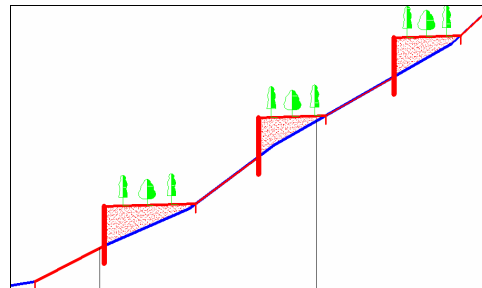


Fig. 8. Automatic location of dams

3. Conclusions

Because of damages occurred to a large number of objectives of Bran-Poarta, Braşov County, after downpours in the summer of 2009, the question of stopping torrents formed in this area was put. Immediate defense method of the objective downstream was used, taking into account that: funds assigned to torrent planning actions are limited, torrential hydrographic basins planning is a difficult and time action that cannot be carried out in phases.

This paper has highlighted the possibilities that *AutoCAD* provide to the user in view of easy determination of basin morphometric parameters, the maximum liquid volume of high-flood, as well as possibilities of *AutoLisp* programming that can lead to an optimal location of torrents

correction works in the studies basin. It is noted the possibility to locate these works downstream the main riverbed after specifying the geographical position of the first dam and, based on objective calculation of the volume of silt retained by each dam, setting the correct number of necessary dams, as well.

References

1. Clinciu, I., Lazăr, N.: *Bazele amenajării torenţilor (Grounds of Torrents Control)*. Braşov. Publishing House LuxLibris, 1999.
2. Munteanu, S., Clinciu, I., et al.: *Calculul debitului maxim de viitură prin formula raţională. Îndrumar de proiectare (The Calculation of Peak Discharge Flow by Rational Method)*. University of Braşov, 1979.
3. Munteanu, S., Traci, C., et al.: *Amenajarea bazinelor hidrografice torenţiale prin lucrări silvice şi hidrotehnice. Vol. II (Torrential Watershed Management by Means of Silvicultural and Hydrotechnical Works)*. Bucureşti. Publishing House Academiei Române, 1993.
4. Tereşneu, C.C., Brad, M.L.: *Realizarea modelului digital al terenului în AutoCAD în vederea explorării bazinelor hidrografice torenţiale (The Execution of the Digital Model of the Field Using AutoCAD Software In Order To Explore the Torrential River Basins)*. In: *Studia Universitatis Vasile Goldiş Arad, Academic Publishing House Vasile Goldiş Arad*, 2006, p. 77-86.
5. Tereşneu, C.C., Vasilescu, M.M.: *GIS Possibilities and Topographical Measurements on Torrential Hydrographic Network Used To Elaborate Risk Maps of Flooding*. In: *RevCAD, Journal of Geodesy and Cadastre, Alba Iulia. Aeternitas Publishing House*, 2009, p. 343-352.