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THE HYDROLOGICAL MODELING OF THE USTUROI VALLEY - USING TWO MODELING PROGRAMS - WetSpa and HecRas

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ABSTRACT: The number of flood disasters worldwide has increased significantly in recent years. While this may partly be due to a changing climate, the increasing utilization of flood plains and a reduction in the natural retention capacity of catchments play a significant role.In our studies we obtained a flood risk map for a small watershed, near Baia Mare, called The Usturoi Valley. In order to obtain this map we used two modeling programs Wet Spa and HecRas. For this we combined the two models using the output datum from the WetSpa program as input datum for the HecRas modeling program. For both of these models we used ArcView 3.2 , as a GIS support. Starting from classic topographic maps and field measurements we created a DEM (Digital Elevation Model), a land use map and soil type map.

Keywords: Hydrological modeling, Flood prediction, GIS, WetSpa, HecRas

1. FLOOD RISKS

Flood risk is among the most severe risks of human lives and properties, and has become more frequent and severe along with local economical development. As the watershed becomes more developed, it also becomes more hydrologically active, changing the flood volume, runoff components as well as the origin of stream flow. In turn, floods that ones occurred infrequently during pre-development periods have now become more frequent and more severe due to the transformation of the watershed from rural to urban land uses. The forecast and simulation of floods is therefore essential for planning an operation of civil protection measures and for early flood warning.

By developing advanced floodplain mapping, detailed risk assessments, enhanced early warning systems, multiple emergency notification measures, understandable response plans, workable recovery plans, and ongoing storm monitoring, we can be prepared for the disasters. Floodplain maps provide the basis for flood management, regulation, and insurance requirements by identifying areas subject to flooding which threaten life safety and damage to property. These maps then guide the community in adopting flood management programs including floodplain preservation, preparedness, education, regulation and mitigation.

Floodplain maps are periodically updated and revised to reflect changing conditions, such as new topography, land development, updated mapping studies, impacts of flooding, and construction of floodplain improvements.

2. HYDROLOGICAL MODELING

In our studies we obtained a flood risk map for a small watershed, near Baia Mare, called The Usturoi Valley. In order to obtain this map we used two modeling programs Wet Spa and HecRas.

For this we combined the two models using the output datum from the WetSpa program as input datum for the HecRas modeling program. For both of these models we used ArcView 3.2 (as a GIS support). Starting from classic topographic maps and field measurements we created a DEM (Digital Elevation Model), a land use map and soil type map (Jolankai, 2001).

For the public to understand our work, we come with a few detailed explications regarding the two models that we used.

The WetSpa model is an extension for ArcView 3.2, being made by the Vrije Universiteit Brussel, which contains a hydrological model of spatial distribution based on a GIS support (Geographical Information System).

The Usturoi Valley is situated in the south part of the Gutai Mountains. The studied area is located in the central-southern part of the Ignis Mountains. Structurally speaking Usturoi Valley is located in the trans-Carpathian flinch. From the geomorphologic point of view, our area is situated in the Land of the Oriental Carpathian, the land of the volcanic mountains.

The systematic study of the soils follows the climatic study, in a logical way, because the climate is one of the essentials factors in the soils formation. According to the development of the Pedology it was noticed that the soil forms a dynamic layer within took place many chemical, physical and biological processes. Far from being static, without life, the soil is in a permanently movement and development. On the entire surface of the Usturoi Valley there different types of soils, such as: alluvial soils.

Because of the fact that the basin of the Usturoi Valley is situated between 600-800 m altitude, it has a boreal climate, with an average temperature in the winter,

-8 and -3 ° C.

The main water flow is Sasar River, wich has a lot of affluents, among that Usturoi Valley. Regarding the vegetation, in our study area there is the land of the beech forest.

2.1 The WetSpa model

The WetSpa program is used especially for flood prediction and to simulate a water balance situated in any point of the watershed at which it's added a variable time component, which can be set at different intervals (Liu. 2004).

WetSpa is a grid-based distributed hydrologic model for water and energy transfer between soil, plants and atmosphere, which was originally developed by an engineer, named Wang and adopted for flood prediction on hourly time step by Desmedt and Liu.

For each grid cell, four layers are considered in the vertical direction as vegetation zone, root zone, transmission zone and saturated zone. The hydrologic processes considered in the model are precipitation, interception, depression, surface runoff, infiltration, evapotranspiration, percolation, interflow, ground water flow and water balance in the root zone and the saturated zone (figure 2). The total water balance for a raster cell is composed of the water balance for the vegetated, bare-soil, open water and impervious parts of each cell. This allows accounting for the non-uniformity of the land use per cell, which is dependent of the resolution of the grid (Corluy. 2003).

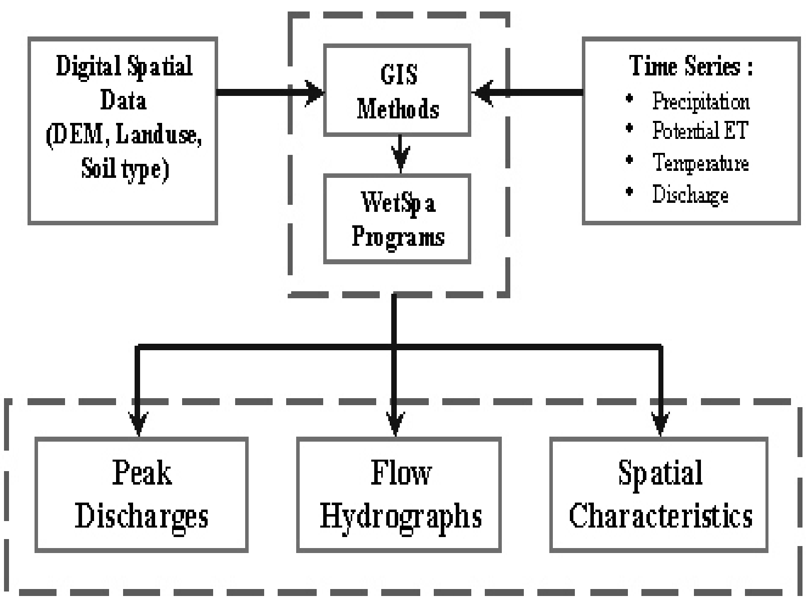


Fig. 1. The WetSpa Model

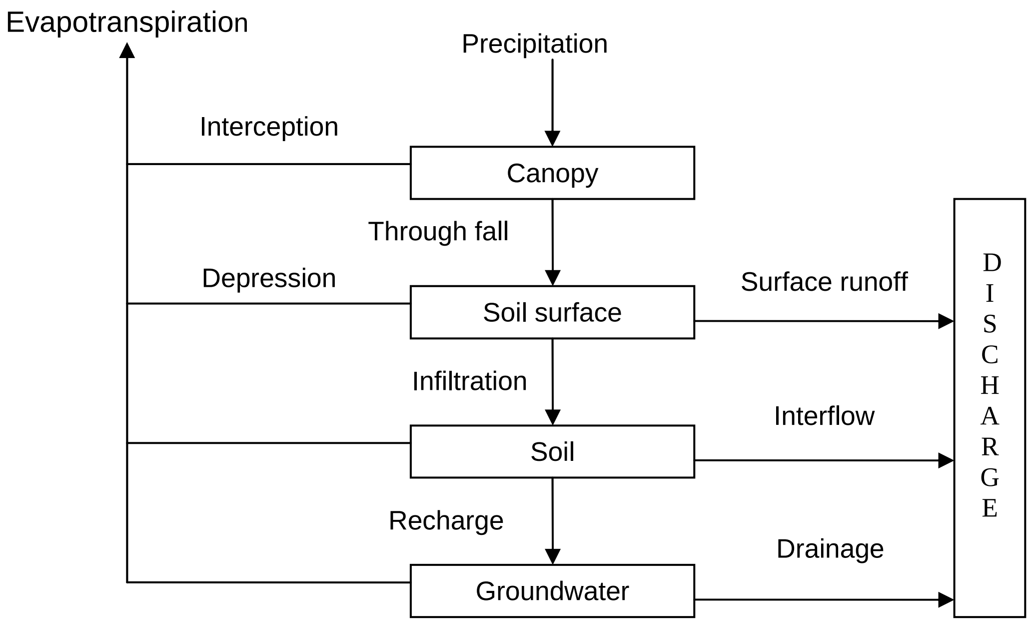


Fig. 2. Model structure of WetSpa at pixel cell level

The model predicts peak discharges and hydrographs, which can be defined for any numbers and locations in the channel network, and can simulate the spatial distribution of catchment's hydrologic characteristics.

2.2 The HecRas model

The second model that we used, the HecRas is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. Other special features include optimization of flow splits, automatic roughness calibration, and multiple-opening bridge and culvert analysis. HecRas is an integrated system of software, designed for interactive use in a multi-tasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities.

The HecRas system will ultimately contain three one-dimensional hydraulic analysis components for steady flow water surface profile computations unsteady flow simulation; and movable boundary sediment transport computations.

Currently steady and unsteady flow is available and sediment transport is under development. A key element is that all three components will use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the three hydraulic analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed; including bridge scour computations, uniform flow computations, stable channel design, and sediment transport capacity (HecRas user's manual).

Water surface profile data and velocity data exported from HecRas simulations may be processed by HEC-GeoRAS for GIS analysis for floodplain mapping, flood damage computations, ecosystem restoration, and flood warning response and preparedness.

3. CASE STUDY – THE USTUROIU VALLEY

Our entire work was built up in order to achieve a map delimitation of the possible flood zones of the valley and for that we had to split the activity in two different parts: the field activity (land use observations, GPS measurements, rain fall quantities, outputs) and the computer modeling activities. The field activity helped us to create and to gather the necessary datum for the proper running of the Wet Spa.

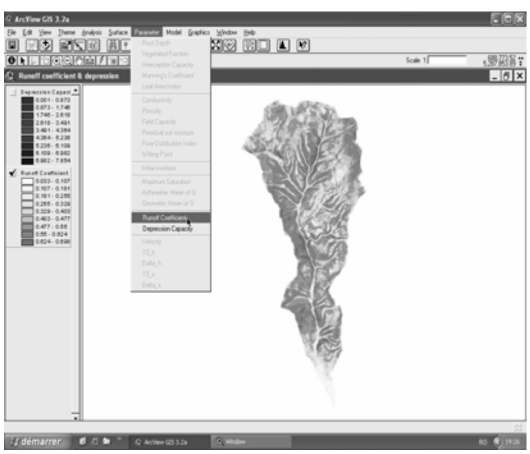


Fig.3. Hydrologic basin slopes derived by the program

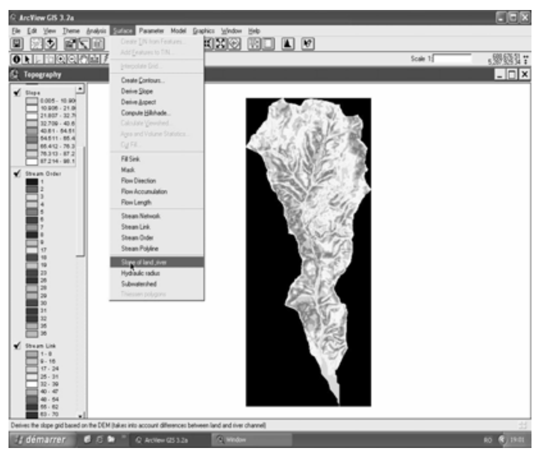


Fig.4. The runoff coefficient

Starting with the Digital Elevation Model, the soil map and the land-use map, all of them created with the help of the ArcView soft, Wet Spa generated a series of other maps like flow direction, flow accumulation, stream network, slope (figure 3), subwatershed, the soil hydraulic conductivity, the soil porosity, the soil wilting point, runoff coefficient (figure 4), the Manning's coefficient (figure 5), depression capacity and the velocity map.

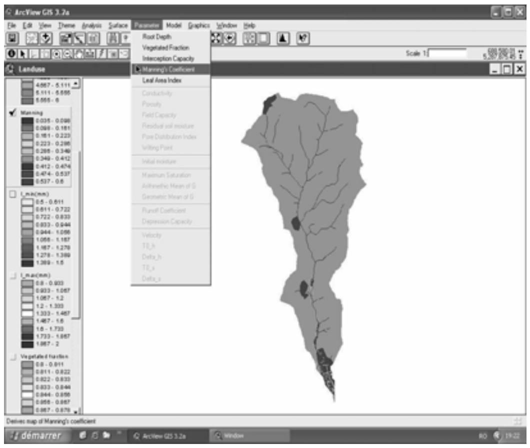


Fig.5. The manning's coefficient or the terrain roughness related to the water flow

All these maps, which are generated by the program, are well related. For better results, the program calculates all the parameters dividing the whole area into raster cells.

In order to obtain more realistic results, a raster cell, on the map, corresponds to ten square meters in the field.

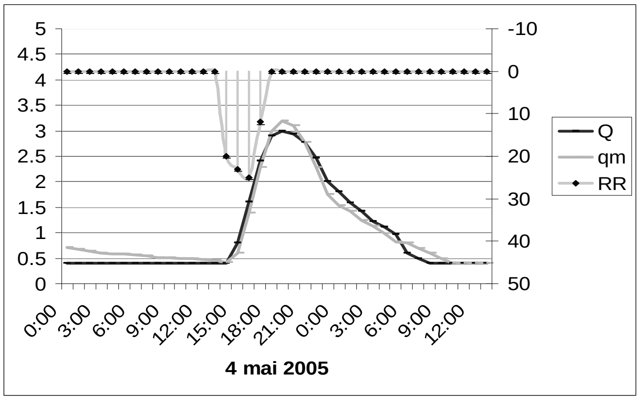
All these maps are used by the program to generate the final result which consists in quantities of flow outputs for each subwatershed. All of those quantities are exemplified in the third column of table 1.

Tabel 1. The debits for each subbasin

Main channel	Stream orders at subbasin level	Max. Flow
1	3	0.540
1	4	0.553
1	3	0.886
1	3	0.449
1	3	0.846

The next step was the calculation of the flow quantity for the entire watershed, after which we had obtained a 3.274 m^3/s output at the confluence point with the Sasar River.

Working with such a complex program and mentioning the fact that the maps were created at a very big scale (one grid cell is equal to 100 square meters) the interpretation of the results is given by the flow hydrograph for the entire watershed. The flow hydrograph (figure 6) is a graphic result, which monitories the output evolution in time, taking in account the rainfall occurred during the measurements. To calibrate the model we had compared the results with the direct results which were measured with the hydrographic hand mill.



Where:
Q = the program debit
qm = the hand mill measured debit
RR = the rainfall quantity

Fig. 6. The flow hydrograph

The numbers from the left side shows the debit values and the numbers from the right side represent the rainfall quantities. From the graphic analysis one may see that the model results are comparables with the measured ones.

The visualization of the model can be made only if we export the datum into de HecRas program (Zsuffa, 2003), which will process them in order to create a risk scenario.

As we said before the HecRas model shows us exactly what will happen on the Usturoi Valley when the debit riches high values, it will reveal us the high risks areas, eventually it gives us a flood risk map. So, in the next paragraphs we will show how it works.

First we created a triangulated irregular network (TIN), based on the topographic maps, on some fields observations and on the GPS measurements and after that we had drawn the river system and we had entered the cross-sections.

Subsequently, these cross-sections were used for constructing the Digital Terrain Model (DTM) and the digital land use map of the bed and floodplain of the subjected Usturoi Valley Reach.

Once that the geometric data are entered we started to introduce the unsteady flow data. In the images below one can see the Digital Elevation Model and the cross-sections on the Usturoi Valley. When all the data were entered (The Geometric data and the Flow data) we performed the Hydraulic Computations, both Steady Flow Analysis and Unsteady Flow Analysis

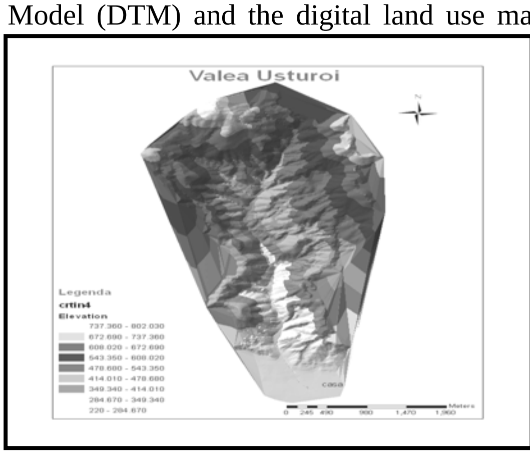


Fig. 7. The Digital Elevation Model of the Usturoi Valley

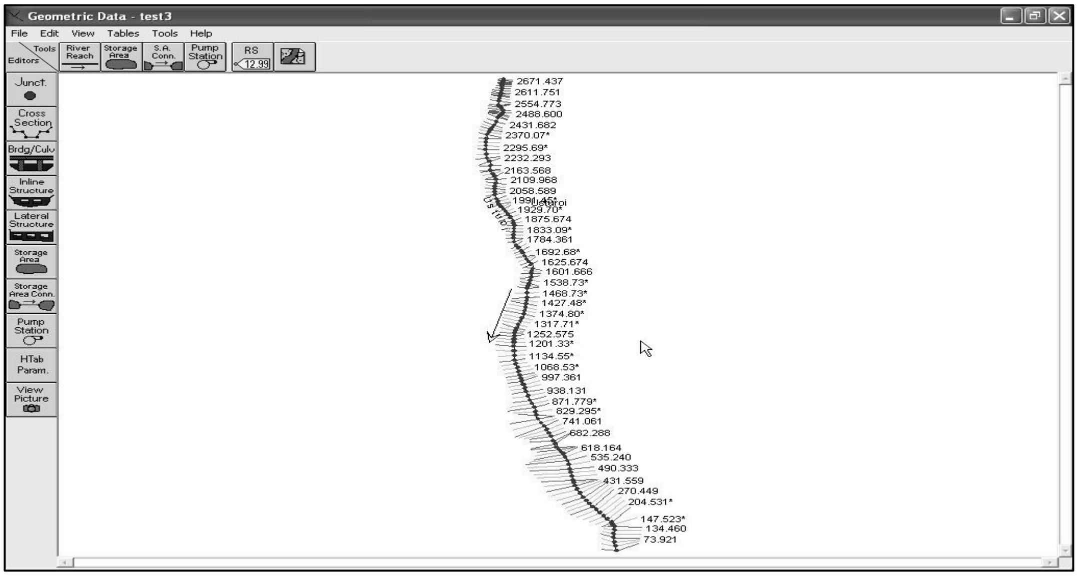


Fig.8.The cross sections of the Usturoi Valley,

We have computed the model for a debit of 1 m^3/s, which was measurated periodically in the month of April and for a debit of 2,3 m^3/s (obtained with the help of WetSpa model). The numbers, which appears in the following figures represents the distance from the cross-section to the outlet, measured in meters.

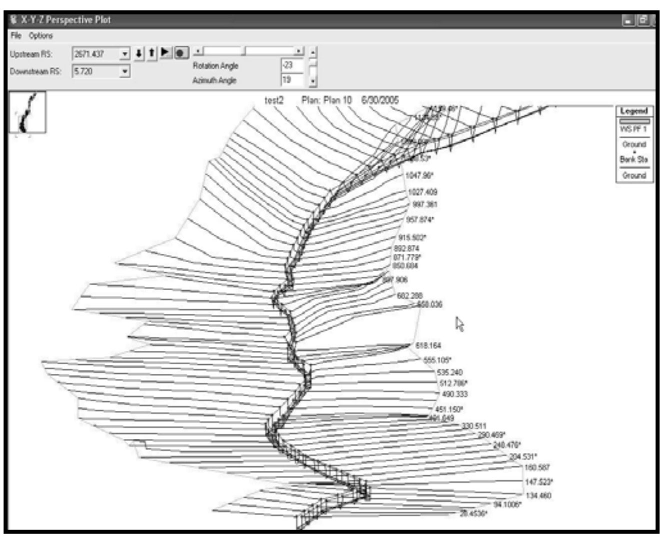


Fig. 9. Three-dimensional representation of Usturoi Valley

In the following figure we can see a three-dimensional representation of Usturoi Valley, when it is crossed by a regular debit. You can easily see there is no overflow at this amount of water (figure 9).

The program also generates a great view for each section. We can see the water level for each cross-section.

Along our valley there are two types of cross-sections, some with artificial dikes and the others with natural dikes.

When the results were ready and when we saw that there is no overflow at the regular amount of water we started to compute the program for bigger debits. After many risks scenarios we reach the conclusion that the critical debit for Usturoi Valley is 6 m^3/s.

At this debit we can see that there is overflow. The water leaves the valley bad in three different locations, starting from the downstream to the upstream, at 50 meters downstream from The Art High school, near the Zoo Garden and near the first Usturoi Chalet.

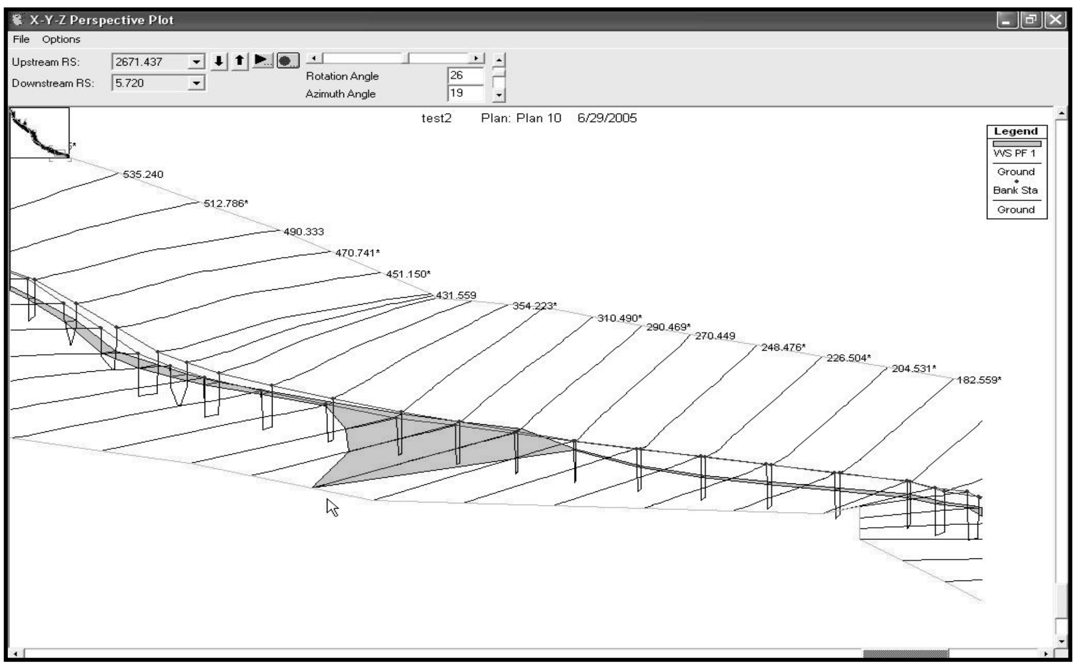


Fig.10. The overflow area in the lower part of the basin, near the Zoo Garden

CONCLUSIONS

After this entire hydrodynamic model was completed we obtained a hydrological risk map, which can be part of the entire environmental risk map, for the studied area.

Because of the fact that the valley bed suffers many morphologic changes it has to be monitored from time to time and all the changes have to be added to the program.

We have to mention the fact that besides the graphic results these two models, WetSpa and HecRas also generated tabular results, which helped us to do a good river management.

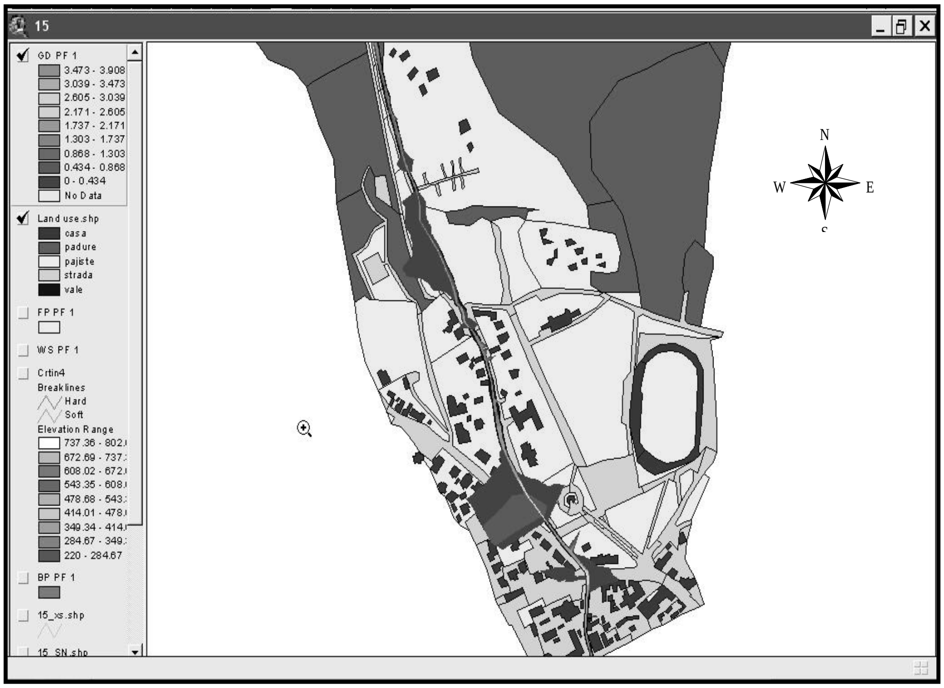


Fig.11.Program capture representing the overflow areas overlap on the land use map

By this work we tried to show to people that a good river management can be done, that these models can give us real results, they are not some toys and that if you really want to do something you can do it.

Bibliography

[1]. **Jan Corluy**, *The WET-SPA Modeling Applications*. 2003, Budapesta. 26pg.

[2]. **De Smedt, F**., 2001. WetSpass: a flexible, GIS based, distributed recharge methodology for regional groundwater modelling. In: H. Gehrels et al. (Editors),Impact of Human Activity on Groundwater Dynamics. IAHS, Wallingford, pp. 11-17.

[3]. **Istvan Zsuffa**: (Water Resources Center VITUKI – Budapesta), *The HEC-RAS modeling example-Lecture.* 2003, Budapesta. 78pg

[4]. **Geza Jolankai** (Water Resources Center VITUKI – Budapesta), *Description of work for the Tisza River Project*. Articol, Budapesta, 2001. 38pg

[5]. *HecRas User's Manual.US Army Corp of Engineers* CPD-68 HEC-RAS, River Analysis System, User's Manual, Jul 95,176 pp.

[6]. **Liu, Y.B.** WetSpa: Documentation and User Manual, Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel.2004 132pg.

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