Hydrodynamic and water quality model using GIS techniques

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SUMMARY

In Hungary, fractional characterisations of trans-border surface waters and actual high resolution maps are not available at present. At the same time these are needed for the evaluation of contaminant transmission and the determination of ecological water quality requirement.

In our research, the digital riverbed model of Berettyó was prepared, which is one of the trans-border rivers of Hungary. By means of this model the hydraulic parameters were calculated under different boundary conditions (water level, discharge) and the transmission processes were modelled.

As results the conceptual model and the water quality risk map were prepared for the Hungarian section of Berettyó River. This map provides solid basis for decision–makers to estimate the consequences of any pollution event in all river section.

KEY WORDS: riverbed model, water quality, GIS

INTRODUCTION

In case of a pollution event the water-quality conditions of surface streams are decisively influenced by the space and time distribution of the water discharge. Thus, one of the crucial elements of the operative interventions is the determination of the dilution rates needed to the values not exceeding the critical concentration by the certain water output of streams (Pregun-Burai, 2004).

The studied Berettyó-Barcau which is one of the border rivers of Hungary and Romania, that has an approximately 80 km Hungarian section with occasional havaria pollution (Bíró-Tamás, 2003). The greater part of the watershed of the investigated river is situated in Romania (Figure 1).

The computer-aided applications - integrated GIS-water quality modelling (WQM) - make the strategic managing of complex water quality problems possible (Somlyódi, 2000).
Such task is the mapping, past-time analysis or the different-time predictions of the different hydraulic events of streams with various flood-plains.

The critical point of model integration and the precondition of applicability of the result is the accurate field surveying. This study presents the conceptual model and the prepared risk map of the Hungarian section of Berettyó River.

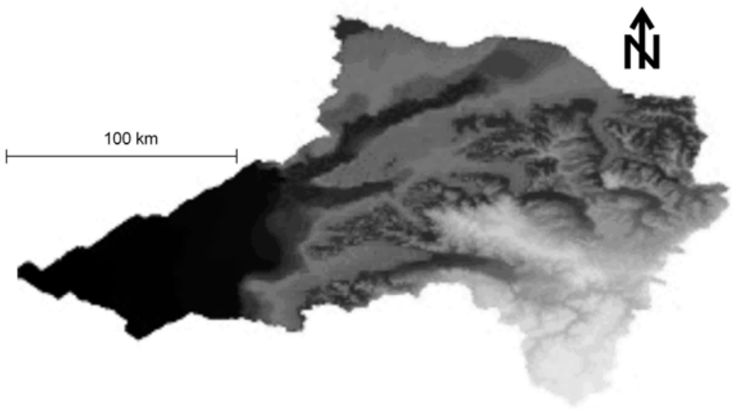

Figure 1: DTM of the Berettyó-Barcau River's watershed

MATERIAL AND METHOD

The conceptual model consists of three hierarchical development stages: 1. Preparation of GIS-based virtual riverbed model, 2. Hydrodynamic model 3. One-dimensional surface water quality model.

The original analogue river cross-section maps (148 sections) were updated by detailed field surveying (Figure 2.). The survey locations were measured by geodesic GPS. Then roughness factors determined by field assessment were related to different water depths.

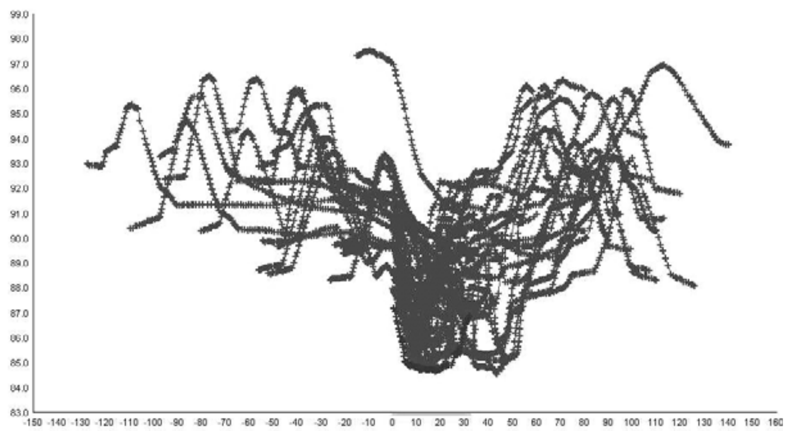

Figure 2: Cross sections

Based on these data the virtual riverbed model was prepared in ArcGIS environment (Figure 3.). The correct structure of morphological profile ensures the further development of hydrodynamic model.

The hydraulic analyses were made by the WSPRO module of 7.0 hydrodynamic software of Surface Water Modelling System (SMS, 1997; Tamás et al, 2002).

The low water discharge, as limit factor of the ecological water requirement was the initial condition. The purpose of this modelling stage was the characterization of the extreme hydrologic conditions.

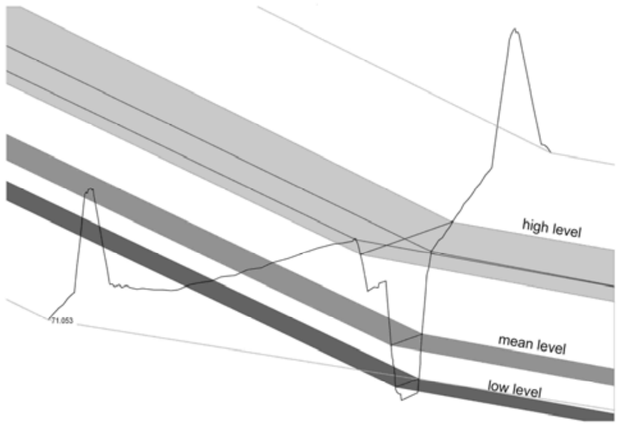

Figure 3: Different probability of the water levels at a cross section on the Berettyó River

The last stage of the whole model was the calculation of the following processes:
dilution, dispersion, sedimentation, biological degradation to run the one-dimensional surface water quality model.

RESULTS

The prepared vector based virtual GIS model precisely determines the vertical and horizontal topographical conditions which provide the basic data for the hydrological analysis.

This evaluation focused on the calculation of those parameters that needed for the determination of concentration changes derived from the pollution distribution processes: water surface elevation, wetted perimeter and area, hydraulic radius, width of the water surface and mean water velocity (Figure 4.).

On the basis of the results derived from the hydraulic analyses the values of the dispersion coefficients were determined for all sections (Figure 5).

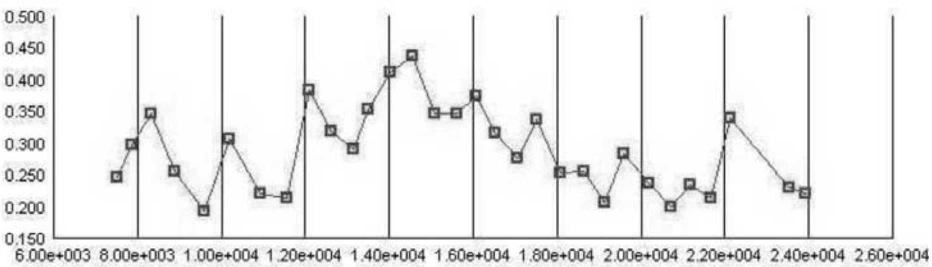

Figure 4: Water velocity distribution along the Berettyó River

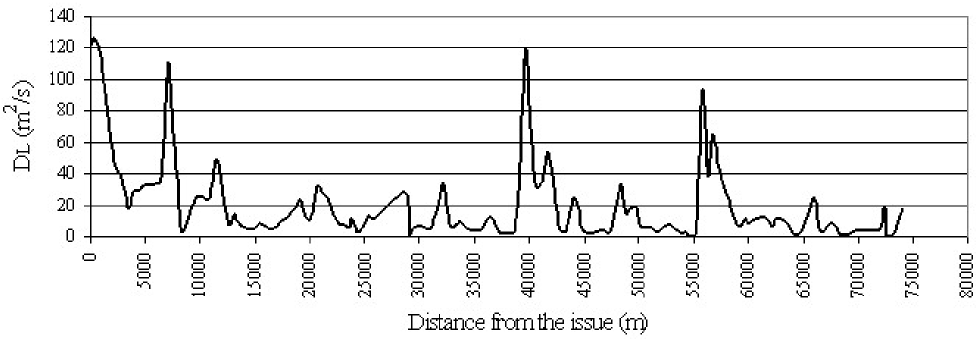

Figure 5: Dispersion coefficient (D_L)in the length-section of the Berettyó River.

During the water quality modelling stage the research work resulted the concentration values that emerge in an occasional pollution event along a stream in case of low-water conditions. The stream sections between the examined cross sections were considered as spatial resolution units for model processing.

The pollutant concentration values calculated by the model for the different sections correctly simulate the real environmental river conditions. All river sections "react" differently for the same intensity, considered conservative pollution. Among the four main investigated processes the simulation results showed that two phenomena, the advective and dispersive transport processes dominantly affect water quality.

As a boundary condition we considered that the pollution occurs in an instant (havaria) event and the pollutant immediately mixes in the whole cross-section of the water stream.

The value connected to the maximum of the concentration's wave curve was calculated according to the following formula published by Jolánkai (1999).

$$C(x)_{\max} = \frac{M}{A \cdot \sqrt{4\pi \cdot D_L \cdot \frac{x}{v_x}}}$$

where:

$C(x)_{max}$= maximum concentration (mg/l)
M= mass of the contamination (kg)
A= wetted cross-section (m^2)
D_L= dispersion (m^2/s)
x= distance from the inlet (m)
v_x= mean velocity (m/s)

The validation of our model was published by Bíró and Tamás (2003). In this study the authors determined the values of maximum concentrations for all sections in case of a conservative pollutant, 100 m from the inlet source (Figure 6.).

Based on the digital riverbed model and the normalized hydrodynamic parameters water quality risk values were determined and a risk map was prepared, which is shown in Figure 7.

This map provides solid basis for decision–makers to estimate the consequences of any pollution event in all river section. According to the risk map it can be concluded that two sections are critically vulnerable to pollution: issue of the river and high meandering section.

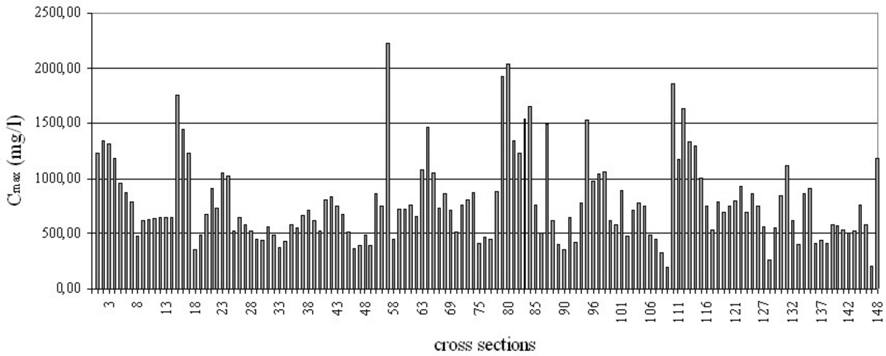

Figure 6: Maximum concentration in each cross-section in 100 m under the inlet *(M=1000 kg)*

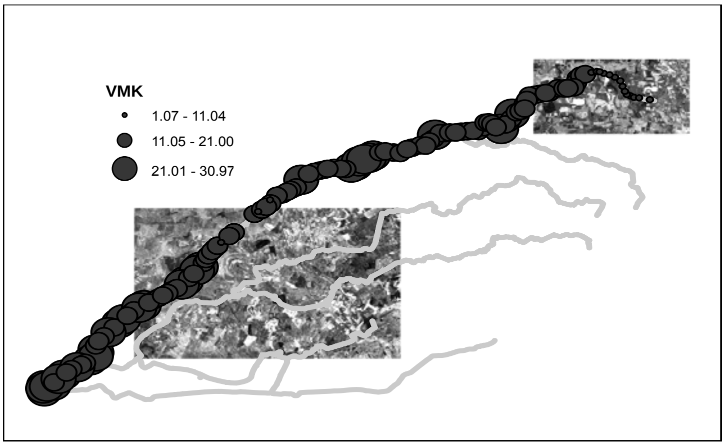

Figure 7.: Water quality risk map based on a developed risk index

This research was founded by Hungarian Scientific Research Found (T47366) and Economic Competitive Power Operational Program (GVOP 3.1.1. 2004.05.0087/3.0.).

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