FLOOD MODEL FOR THE BÓDVA CATCHMENT

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Abstract
In term of floods the current area of Hungary has extensively been endangered. Modelling of flood processes – mainly following the hydrological events in the riverbed – has recently been developed. As far as protection dykes provide protection of the inhabited and agricultural areas, the flood models can run with acceptable preciseness. However, when dykes cannot withstand against the increasing load and a dyke burst occurs, fast and efficient protection measures shall be taken in the protected areas.
The dynamic 4D Flood model presented in this paper makes possible a fast modelling of dyke burst occurring in the protected side and spreading of water mass, based on real parameters. For this reason the features of protected area shall be recognised, for example topology of creeks, features of agricultural and inhabited areas, parameters of roads, railways, rainwater drainage, buildings, natural conditions (soil parameters, meteorological characteristics, etc.).
The results satisfy the comprehensive demands of the Directorate General for Disaster Prevention of Borsod-Abaúj-Zemplén County. In case of dyke burst, the completed Flood Model can run the expected events of the next hour in a few minutes. This time is enough for the specialists to bring operative decisions to protect the inhabitants and avoid material losses.

Keywords: Flood, GIS, disaster prevention, 4D model, time factor, DEM, LIDAR.

1. Introduction

Modelling of relief – which is one of the most determining components of landscape forming factors – is becoming more and more important in environmental researches (Verrasztó, 1979, 1993, Moore et al., 1991; Goodchild – Mark, 1997; Burrough – McDonnell, 1998; Longley et al., 1999; Mezõsi – Bódis, 1999; Wilson – Gallant, 2000; Sárközi, 2003; Tóth et al., 2004; Hengl – Reuter, 2007; Peckham – Jordan, 2007; Maune, 2007; Verrasztó – Németh, 2011).

Due to natural changes occurring faster and faster in our environment, new solutions are required in the water reservoir management, for example in treatment of getting more droughty, soil erosion and floods (Verrasztó, 1979; Miklós et al., 1986; Mitasova – Mitas, 1993; Mitasova et al., 1996; Rakonczai, 2002, 2003; Mélykuti, 2007; Samuels et al., 2008;)

Mathemathical researches, development of hardware-, software-, geoinformatics and remote sensing opened new perspectives in modeling of complex environmental processes (Beven – Moore, 1995; Grayson – Blöschl, 2000; Bates – Lane, 2000; Gorokhovich – Sharlow, 2000; Beven, 2001; Soille, 2007; Wu-Li et al., 2007). It is possible to make modelling of hydrological processes with divided parameters, in such a manner that partial processes are summarised from tiny units (cells, grids) of space defined by terrain/creeks.

Data process of digital relief based on model calculations and analysis in hydrological models are purpose of numerous foreign and domestic research works and projects (Telbisz, 2007).

FloodLog project summary

The overall goal of the project is to support the Disaster Management Directorate / Crisis Management Authorities by providing them with a toolset for flood modeling, forecasting the size and location of the affected area and the affected population, identifying relevant objects and human infrastructure in risk, or object needed for handling the crisis, and to develop the logistics framework to better manage the human and natural resources for the crisis management. The specific goals are: Development of a framework and a pilot database for flood modeling in support of the crisis management authority. Development of a pilot framework for the environmental impact assessement of the floods on the soil and the water resources. Feasibility study covering the design of the whole GIS based logistic capacity management and supervisor system. The study deals with all the necessary components of the system that helps Crisis Management Authorities to make effective decisions from the legal background and database elements to the shared and controlled maps of the affected areas and its necessary IT background.

2. Cell- based models

During the development of our 4D Flood Model – in order to optimum modelling of real flow – the combination of several flow algorithms was applied based on the process of combined Stream Burning Technique (Németh – Csikós, 2014).

Algorithms determinig the flow direction are important in term of hydrological modelling. Not aiming at completeness the more important flow algorithms are as follows:

Unidimensional flow

This algorithm determines the spreading direction of flow and delivered material the movement direction between the neighbouring cells and the scattering ratio. In the simpler models, from the eight possible neighbours of a given cell there is only one of largest rise, to which movement is made (Bódis K., 1999; 2007).

Deterministic 8, D8

The flow down is directed from a given cell to any of neighbouring cells, which has the largest slope (O'Callaghan – Mark, 1984). Applying this method on a relief model the cells of raster obtained can generally bear nine values and the values have two different meanings depending on the given application.

The cell value means the number of the neighbouring cells flowing in the cell; if the cell value is 0, it is a flat area without flow where no flow down is found, or a mountain peak or a mountain crest being in special situation at the border of catchment area is the upper starting point of flow down network. If the number of neighbouring cells flowing in the cell is 1,2,3,...7, , it means that cell is an intermediate point of the flow accumulation network, but not sure it has outlet. The value 8 indicates a cell being in a lower situation than its environment, no flow is found. The flowing direction out of the cell is coded. The coding is software dependent, for example PCRaster23, LDD (Local Drain Direction) map values follow the numeric keyboard arrangement of the computer, ESRI (Environmental Systems Research Institute) geoinformatics analysing software Arc/Info, ArcView, ArcGIS provides the possible eight directions based on local places of binary system (Jenson – Domingue, 1988). Some models (for example SAGA 24, CCM 25, HEC-RAS), follow individual logics when giving value.

Rho8

The algorithm adds a stochastic component to D8 model. The direction of flow down is determined based on unintentional variant, which is dependent on the cells exposition and difference of direction of two neighbouring cells (Fairfield – Leymarie, 1987). In this way the torsion of D8 model can be reduced by direction.

Multiple flow direction

In most cases a simple flow accumulation model produced by D8 algorithm is enough for hydrological modelling, however, it is not true, for example to material transport, pollution migration modelling. Full volume of the moving material is transported from a cell not to another, neighbouring cell, but it is distributed among the surrounding cells, even one part remains in place.

Three-directional flow

The flow is distributed among the direction of three neighbouring cells, cell falling in the closest direction to exposition of the central cell and two neighbouring cells. The model gives the method of distribution by a numeric estimation scheme. (Braunschweiger Digitales Reliefmodell, Bauer et al., 1985). The Multiple Flow Direction (MFD-FD8) algorithm applying all the eight neighbouring flow directions derived form the D8 model is a two-dimensional flow model (ESRI TIN, ESRI GRID 1994.). There is flowing from a cell to each surrounding cell of lower position, the quantitative distribution depends on the rise and length of slopes (Freeman, 1991; Quinn et al., 1991).

D∞- Deterministic Infinity

The deterministic infinity (D∞) model recommended by Tarboton (1997), determines the flow direction of a given cell on an infinite scale between 0-360 degrees. The material movement is distributed between the first two neighbouring cells falling in the direction, proportionally to flow angle.

In term of hydrological modelling the best results were obtained on the basis of Tarboton's D∞ „derived vector method" (Tarboton, 1997; Beven, 2001) and "combined flow algorithm" described by Quinn and partners (Quinn et al. ,1991; Beven, 2001).

Flow Tracing Algorithms

Among the methods, modelling the flow directions and potential material movement the flow-tracing algorithm is applied in practice by DiGeM software.

Kinematic Routing Algorithm, KRA

KRA estimates the surface of each cell of the relief (terrain) model by a plane best fitting on the four corner points of the cell and determines its direction (exposition). Similarly, as following the path of a ball rolling down from a given surface, it records different directions as staight sections, and makes modelling of direction between the inlet and outlet of the cells (Lea, 1992). In this manner the result can represent – similarly, like the exposition of slope – infinitely many values, but similarly to D8 model, it keeps unidimensional nature (Costa-Cabral – Burgess, 1994).

DEMON - Digital Elevation Model Network

Similarly like KRA, the DEMON algorithm searches the flow route based on the directions of slopes' explosition, but flow is not simply happened in a line, but in a two-dimensional, tubular bed consisted of several cells, from which an impact matrix is plotted to modelling of material flow and distribution (Costa-Cabral – Burgess, 1994). The model represents well the flow accumulation properties combined with material transport (Gruber – Peckham, 2007).

Stream Burning Technique

The combined algorithms represent the pattern of flow network and flow accumulation in more realistic manner than D8 model, but, of course, the result always strongly depends on the quality of original relief, terrain model (ESRI TIN, ESRI GRID 1994). The D8 eight-directional basic flow accumulation model was also applied in our combined hydrological model, because adequate evaluation of values derived from the detailed relief resulted a higher accuracy of hydrological prognosis (Watson et al., 1998).

A vectorial database was available for the 4D Flood Model in good quality, which was obtained from generally accepted LIDAR point set and included the river and protected areas. The trace and flow direction of Bódva were applied with burning into the relief when elaborating the united flow network of entire area. (Hutchinson, 1988; Maidment, 1996; Sole – Giosa, 2008). On the expanded gently sloping relief sections (in case of cell blocks of same value) the flows were directed to lowest cell being at the zone border and on the shortest route (Soille et al., 2003), in this way the blocking effect of non-flowing areas derived from topography could be prevented. In order to achieve adequate accuracy and efficiency it was necessary to have a vectorial database obtained from reliable LIDAR point set.

Among others, the River Routing Network method was applied to prepare a global river routing network with resolution of half degree (Renssen – Knoop, 2000) and united European River Network Model with resolution of 1 km, with application of GTOPO30 relief model and vectorial river database of various source (Hiederer – de Roo, 2003; Sanders et al., 2005). To prepare a SRTM-based (Shuttle Radar Topography Mission) Pan-European river-and water catchment database, with basic resolution of 100 metres, an adaptive process was used, based on relief model analysis (Hensley et al., 2000; Hennig et al., 2001; Rodriguez et al., 2005, 2006; Vogt et al., 2007; Reuter et al., 2007a, b;).

In divided water catchment areas with high difference of level, the route of the upstream watercourse can be obtained from the relief model with acceptable accuracy, while on the downstream section the burning technique is practical to apply. The European level models are less sensitive for information obtained from the relief (Grayson – Blöschl, 2000), therefore they provide sufficient results for global tasks and wide-scale solutions.

3. Characteristics of Bódva catchment area, former floods

Bódva takes its source in the Slovakian-Ore Mountain (Gömör-Szepesi-Ore Mountain), at the foots of Mt. Nagy Csükerész (1187 m), its total catchment area is 1727 km^2 (Fig. 1.), of which the Hungarian area is 851 km^2.

Bódva is a relatively small watercourse of North Hungary with hectic water volume. The borders of Bódva catchment area in Hungary are the country border in north, Cserehát Mountains in southeast and Borsod-Hills in southwest.

The border of the catchment runs from the terraced hills surrounding the Bódva through the Rudabányai-Mountain to Galyaság and Aggtelek-Karst. From the country border to Perkupa, Lower-Hill at Torna is situated on the right bank of the river and limestone mountain peaks emerging from the sediments of Pannonian age on the left side surrounding the valley. It flows into Sajó river at Boldva. (Holocén Nature Preservation Association, 2013).

In 2009 a flood flowed down in the region, which exceeded the water level of 100 years. Then permanent flood was formed in 2010, which exceeded the previous year’s record.

The flood of the Hernád-, Sajó- and Bódva-rivers caused serious problems in Hungary and Slovakia by afflicting several settlements and directly affecting ten thousands of people (Fig. 2.). The natural disasters in the past few years drew attention to the importance of the prevention and preparedness for flood hazards in the upstream area of the river, in Slovakia, but mostly in the downstream areas, in Hungary. A project coordinated by the University of Miskolc completed a model that physically simulates the floods of the Bódva river and their effect on the natural environment and society.

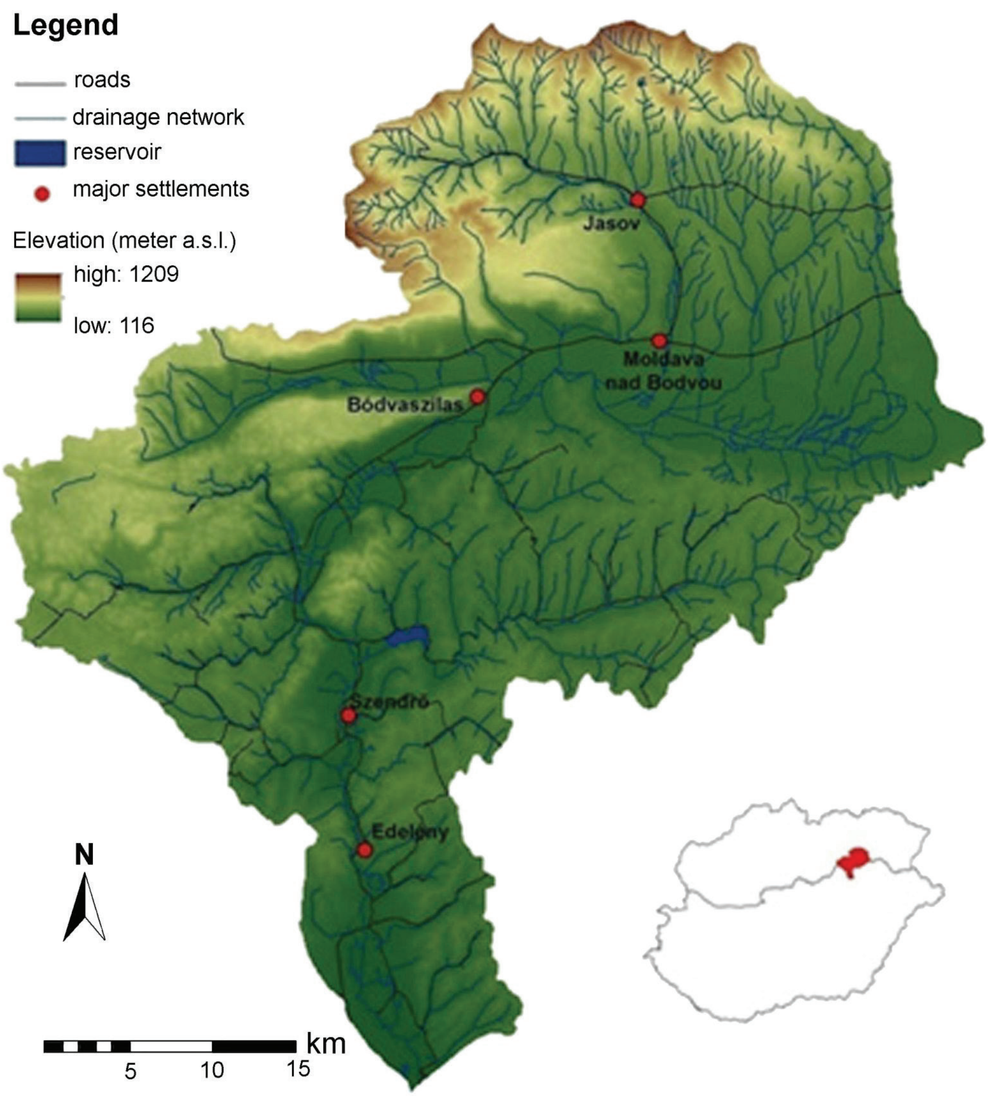

Fig 1. Bódva catchment area

4. Methodology

Studying the landscape by the relief conditions have determining role on the hydrological, geomorphological and ecological processes, so application of relief models has proved experience in the mentioned fields of science (Verrasztó, 1979; 1993; Moore et al., 1991; Hoggan, 1997; Burrough – McDonnell, 1998; Longley et al., 1999; Wilson – Gallant, 2000; Hutchinson, 1988; Jones, 2004; Peckham – Jordan, 2007; Hengl – Reuter, 2007; Németh – Csikós, 2014).

Studying the catchment area as a unit, relationship between the relief modelling and hydrological modelling, characteristics of various landscape forming factors, natural and environmental events and processes can be analysed (Beven – Moore, 1995; Beven – Kirkby, 1979, Grayson – Blöschl, 2000; Hutchinson – Gallant, 2000; Jordán, 2007, Verrasztó, 2011).

Fig. 2. Bódva flood's pictures 2010

5. Modelling procedure

The methodological basis of our 4D Flood Model development was to create such an unified system that integrates all the important data on the state of the environment; namely, all information about the natural, social and economic factors, especially the environmental indicators, impact sources and impact sufferers. If these data are missing for an area, it is very difficult to simulate the natural processes (such as floods and their technical consequences, or disasters such as dyke burst) in a way that it would support the local, occasional or individual decision-making.

This explains why the exact knowledge of the natural environment was considered the basic requirement for the logistic modelling in the project. As the logistic model cannot be run without understanding the natural components that determine the spatial processes in the environment, it was necessary to build a 4D Flood Model at the beginning. At the same time, the objects to be protected or to be used in the operations also had to be integrated into the system. Monitoring the flood processes requires the availability of a harmonized spatial database for the complete area of the drainage basin in Slovakia and Hungary. The preparation and harmonization of this database was a key element in the project.

The successfully completed project greatly contributes to decision making in disaster management that demands multi-aspects and modern IT solutions. In this way, the efficiency of protection against floods will increase.

The Bódva project with its cross-border cooperation also supports the practical efforts of unifying the European information space (EU COM, 2004).

This geographical information system (GIS) will model, in the drainage basin of the Bódva river, the inundated areas and the potential consequences of floods, and will monitor the local, occasional and concrete consequences of a dyke burst. This GIS-based method can serve as the basis of decision making, sometimes on the minute, on the necessary and possible measures by the disaster management staff.

6. Theoretical basis of the model

Bernoulli's principle defines the forms of energy as (Harro Heuser, 1984; Mark – Aronson 1984; Kertész – Mezõsi 1991; Jenson 1997; Hofierka et al. 2002; Ekenberget et al., 2004; Hengl – Evans 2007; Asselman et al., 2008)

- potential energy,
- pressure energy,
- kinetic energy.

Bernoulli's equation expresses the conservation of energy in fluid flow. This principle states that the forms of energy can transform, but their sum remains constant. The energy in practical engineering is given in the form of specific energy.

$$h_1 + \frac{p_1}{p \cdot g} + \frac{v_1^2}{2g} = h_2 + \frac{p_2}{p \cdot g} + \frac{v_2^2}{2g}$$

$$h + \frac{p}{p \cdot g} + \frac{v^2}{2g} = C, \textit{ constant}$$

h – height location of the fluid particle (height above a given point), m;

$p_{1,2}$ – pressure of the fluid, Pa;

v – velocity of the fluid, m/s;

q –density of the fluid, kg/m^3

g – gravity acceleration, m/s^2

In words, in the case of ideal fluids, the sum of the specific potential, specific pressure and specific kinetic energy of flowing fluid remains constant.

The fluid is considered ideal, if the fluid

- has no viscosity (inner friction),
- is incompressible,
- there is no friction between the fluid and the wall.

Bernoulli's principle can be written for a unit mass of the material:

$$g \,.\, h + \frac{p}{q} + \frac{v^2}{2} = C$$

The model calculates the amount of water flowing from cell to cell. The volume of flowing water is received by the velocity and cross-section. If we consider the total surface of one of the sides of the full water column, then we have to average the flowing velocity, because it will be 0 m/s on the top of the water column, and will be maximum at the bottom:

$$v = \sqrt{2gh}.$$

This means that the velocity changes according to the square root function of the height of the water column. The integer of this function from 0 to 1 is 2/3. In other words, we have to accept the 2/3 of the velocity calculated at the bottom of the water column as the average velocity.

7. Input data for the 4D Flood Model

Characteristics of the area and surface

In case of a dyke failure occurring in the embankment, the water flows on the protected side according to hydrological laws, towards the lower areas, and inundates the embayments. The velocity of the flow is influenced by the relief and several other factors such as the infiltration and/or runoff conditions, surface features, undergrowth, bushes, forest belts, roads, embankments, drainage channels, caves, sinkholes, springs, soils, meteorological conditions (e.g. raining, freezing, degree of saturation) etc.

The digital terrain model for the drainage basin of the Bódva River is a DEM of 26 x

26 m spatial resolution (layer 1). This layer has been overwritten by a 10 x 10 m spatial resolution DEM for the Hungarian side of the watershed (layer 2). The elevation data had been improved by laser-scanned LIDAR (Light Detection and Ranging) data (layer 3). The height accuracy is 10 cm. The file received in this way contains the elevation data for each square metre on the area of 60,000 x 60,000 metres. The total size of the database is 14.5 GB.

It is not practical to burden the model calculation by such a large amount of data. Therefore, the above mentioned file had been split into 8 x 8 m cells; the area of the cells was obtained by calculating the arithmetical mean. In this way, a two-dimensional cell matrix had been developed of 7300 x 8000 size, which makes the calculation much easier. Using larger cells would lead to data loss, while the smaller ones would only result in more calculation, but would not produce a more reliable description of the surface. It is a basic idea of the model that the cells should have identical size, their surface should be considered smooth, and their elevation should be calculated by averaging.

The database of the model includes a 1 x 1 m resolution DEM describing the close neighbourhood of the river, and vector files of roads and embankments. There are also lakes, reservoirs, caves, streams and canals in the areas endangered by the flooding of the Bódva river. Their location and water level influences the dynamics of floods. An almost empty watercourse or canal can transport large masses of water much faster than a neighbouring field. The mouth of a cave can swallow up even a larger mass of water and then discharge it kilometres away. We should not forget about the state of underground waters either.

It must also be considered that the rising water level of the Bódva river will increase the level of those streams and canals that belong to the Bódva drainage network. Inundation may come not only from the main river, but also from the influent streams. In addition, we should think of other non-fluvial processes that influence the changes of the water mass.

Steady and intensive rains can increase the water level by several centimetres on the floodplain. Even if an otherwise dry area was already soaked thoroughly by intensive rains, the newly arriving water mass cannot infiltrate into the soil. High temperature can increase evaporation. Strong and storm-winds can influence the velocity and direction of water flow. This means that the weather conditions must also be taken into account.

Input parameters

Running the 4D Flood Model needs two input files. They are

- config.ini
- leak.txt

The config.ini contains the data for the examined area. These are the data of the input database: map files, file names, map coordinates, environmental parameters and pre-defined limits of the water level. The program can construct models simultaneously, because the model can be run independently for different areas by using the files, which are distributed in different libraries. In this way, the processes in several areas can be monitored at the same time, which greatly supports the work of the disaster management.

The leak.txt file contains the exact description of a dyke burst: the time of failure (start:0, end: 2880 min), its exact location (row ID: 3632, column ID: 2527) and size (150 cm). The operator of the software continuously fills in the data arriving from the site.

For example – leak.txt

d 2014.09.17. 19:10

0: 2880:3632:2527: 150:0:2

The values above register the start time, the width of the damaged dyke, the height of the collapsed section, and the water level on the riverside of the dyke. The last value indicates the direction of water flow. The

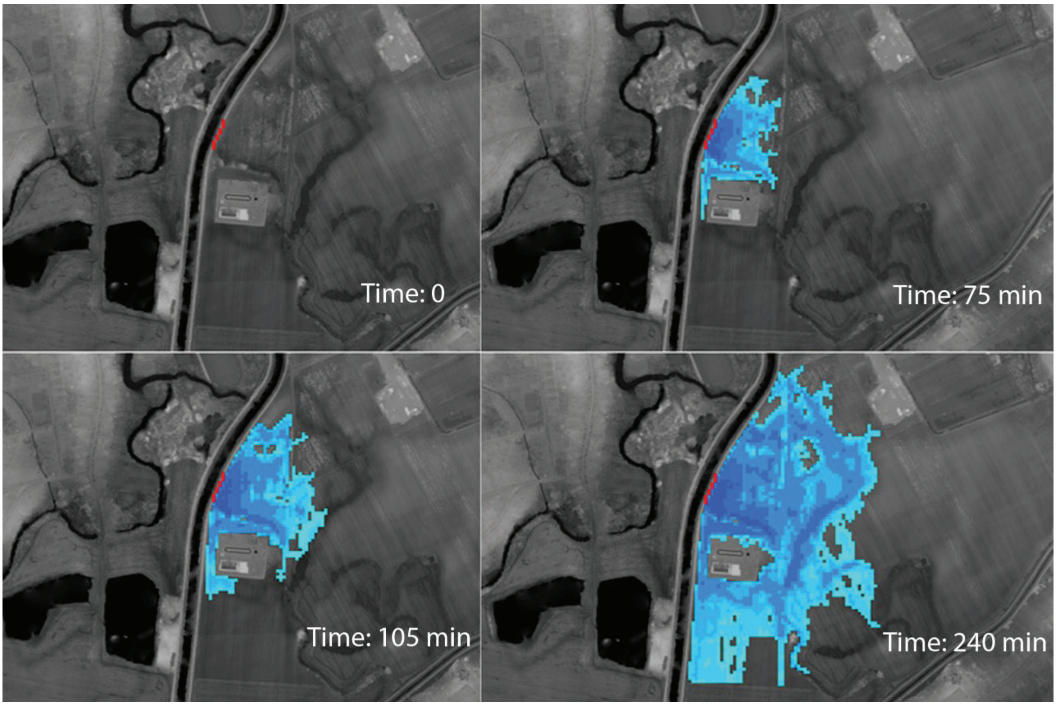

Fig. 3. Polygons showing the flooded area

width and the location can be defined by the combination of measurements by laser tachometer and GPS. The data are registered on mobile tools on site or transmitted by telephone or radio to the operator, who registers the data in the leak.txt file at the flood protection headquarters.

Factors influencing the water flow

The velocity of the floodwater streaming on the land depends on the state of the soil surface, the height and density of vegetation, and the amount of collected deposits. In settlements, the velocity of flow and the amount of additional water can be modified by the buildings, cellars, and ditches along the roads, temporary barriers and dykes. The case is different on the agricultural fields, where there may be few centimetre high crops and 1.5 m high dense vegetation as well. Further, the conditions may change month by month.

For modelling the flood, the streaming water was considered free of eddy currents and stationary (these properties of the stream do not depend on time).

Configuration data

The 4D Flood Model application for calculating the models can be run on various platforms. Therefore, a development environment was choosen (MicroATLAS©) so that the source code should be portable. The model can be run on individual computers, local networks and mobile tools in Linux, Windows and Android operation systems.

The config.ini file contains the predefined water levels (though can be changed in case of need) in centimetres, which serve as limits in the classification of the modelled water levels (for instance, levels 0 to 5 cm, 5 to 25 cm, 25 to 50 cm etc.). Clustering can be set if needed. It is practical to set such water level limits, because further processing of the polygons showing the flooded area produced by the model (Fig. 3.), are needed for decision-making (e.g. the water level limit of rescuing or evacuation).

8. Location and time of dyke burst

The model can be run for testing and planning. However, it is the most useful support tool in crisis situation, when the water begins to flood the fields due to dyke burst.

In the case of danger of inundation, the dykes are continuously monitored. There may be direct indications of an occuring dyke burst, such as dilapidation, fissures, springs etc. When the experts responsible for flood protection sense the dyke burst.

The above mentioned data can change in time, the width of the dyke burst may broaden, the base of the collapsed dyke may sink, and the water level behind the dyke may decrease. These data can be registered in the leak.txt input file of the model. The leak.txt contains the following:

- an identifier, which connects the file and the results given in the output,
- a time mark, date and time of the first event,
- records for each cell.

Records of files:

1. The start of the cell event (in minute). If 0, then it participates in the model immediately.
2. The end of the event until the cell participates in the model (in minute).
3. Index of cell row.
4. Index of cell column. The index starts from the upper left corner of the area.
5. The decrease of the height of the dyke related to its highest point in cm. If the dyke is 3 meter high above its base on the protected area, and the dyke moves from its place in its full height, then this value is 300.
6. The difference of water level in cm behind the dyke related to the original height of the dyke. If this value is positive, e.g. +20, then the water level of the flooding river is at 20 cm above the highest point of the dyke (e.g., a temporary raising of the dyke could hold it until then). Alternatively, a sudden flood reached the dyke and the water flows over the dyke in 20 cm thick streams. The latter two values may be combined: e.g., 300 + 20 means that the height of the water column on the site of the cell of the dyke is 320 cm. If the value is negative, the flooding water behind the dyke does not reach the highest point of the dyke, though it demolished the dyke; the negative value reduces the height of the water column of the cell containing the dyke.
7. Direction of the flow from the cell: 0 – upwards (north), 1 – to the right (east), 2 – downwards (south), 3 – to the left (west).

The first two values describe the duration of the state of the cell, the next two values give the location of the cell, and the other two values represent the change of the original height (the highest point) of the cell and the height of the water column flowing over the dyke. The registration and compilation of the above mentioned data are executed by the operator program.

9. Time factor

In case of a dyke burst, its parameters, location, time and extent has to be determined, then to forward and register them and start the model. All this procedure may take 10 minutes. After 10 to 20 minutes, the model can provide data for the next 1 or 2 hours after the start of the action. The experts of disaster management will evaluate the data, bring decisions, and give instructions.

The model must be not only reliable, but also fast working. The speed can be increased by optimizing. It was an important objective in the system planning to develop such methods that can speed up the calculations in order to build a reliable system.

10. Output data - polygons

The data generated by the model are classified into categories according to the predefined height limits. Then the data are saved in ESRI shape file format. The index, data and project files needed for the format are all available in a predefined folder. The files can be opened and used in any standard geoinformatic software. The library contains the leak.txt file and the shape files of the respective dykes, therefore the series of events can be traced back for later examinations and analyses.

The polygons showing the flooded area are generated in every ten minutes by default. If needed, the intervals can be much shorter, and the polygons can be refreshed even in every minute.

11. Results and Discussion

The developed decision supporting expert system for Bódva river model the real flood processes at acceptable level via creek/relief model adjusted severel times on the Hungarian section and fine tuning of hydrological –mathematical algorithm. On the Slovakian section - due to missing LIDAR data – however, the relief was not successfully upgraded as required, so the model provides informative data on the upstream section and is able only to support operative decision making in a limited degree.

Originally the system installation was planned to integrate into the inner network of informatics of the Directorate for Disaster Prevention of Borsod-Abaúj-Zemplén County. Due to data security reasons the integration was not possible to realise, so currently the system operates on a high capacity mobile computer applied by the headquarters of the authority.

Sharp testing was performed in September 2014, when a dyke burst was modelled. Basically correct operation of the model was checked. Experts taking part in the test unambiguously confirmed the practical benefits of computerised system in the flood prevention.

Validating of Flood model was not performed because it was not available enough information to verification (meteorology, soil coverage, impacts of underground waters, etc.).

The development achieved its goal because it significantly supports the preventive and operative protection activity of headquarters of defence at Bódva river. The model can be a useful tool for the activity of the Directorate if regional expansion of the system database will be performed on other watercourses of the county, especially on Tisza-, Hernád- and Sajó rivers and their small influents.

The developed software system is able to monitor several events simultaneously. Due to its flexibility, it can be effectively used in the headquarters of defence and in the endangered places by the help of mobile equipment.

Using the results produced by the 4D decision-support expert system in case of a disaster, the intervening official organizations (water directorates, disaster management units, law enforcement bodies, local governments etc.) can have access to all the basic information they may need for rescuing, evacuation, damage prevention, and mitigation of damages. It could be also possible to inform continuously the population through a connected web interface.

The information content (assets to be protected, aspects that influence rescuing, logistic capacities etc.) of the decision-support system can be expanded by adding background maps.

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