COMPARING A HYDRODYNAMIC MODEL FROM FIFTH GENERATION DTM DATA AND A MODEL FROM DATA MODIFIED BY MEANS OF CROSOLVER TOOL

RADEK ROUB[1], MARIE KURKOVÁ[1], TOMÁŠ HEJDUK[1,2], PAVEL NOVÁK[2], LUDĚK BUREŠ[1]

[1] Czech University of Life Sciences Prague, Faculty of Environmental Sciences, Department of Water Resources and Environmental Modeling, Czech Republic
[2] Research Institute for Soil and Water Conservation, Czech Republic

ABSTRACT

Flooding is a natural phenomenon that occurs with varying intensity and at irregular time intervals. Floods are the natural disasters that pose the greatest direct threat to the Czech Republic. They may cause serious critical situations during which not only extensive material damages are incurred, but so too is the loss of human life in affected areas as well as vast devastation of the cultural landscape including environmental damages. The information issued by flood forecasting services about the character and size of flood areas for individual N-year flood discharge events and specific flood scenarios is important for eliminating the potential threats and consequences of such events. Hydrodynamic models provide an adequate image of depths and flow velocities at the longitudinal or cross profiles of the watercourse during a flood event. This is why information obtained from hydrodynamic models occupies a privileged position from the viewpoint of protecting human life and mitigating property damage.

Altimetry data are the basic input into hydrodynamic models. One way to obtain such data is through the method of aerial laser scanning (ALS) from the digital terrain model (DTM). This method is considered one of the most accurate methods for obtaining altimetry data. Its major drawback is however its inability to record terrain geometry under water surfaces due to the fact that the laser beam is absorbed by the body of water. The absence of geometric data on watercourse cross sectional area may perceptibly affect results of modelling, especially if the capacity of a missing part of the channel represents a significant cross sectional area. One of the methods for eliminating this deficiency is sufficiently calculating channel depth by means of software tools such as CroSolver.

This paper deals with the construction of a hydrodynamic model using fifth generation DTM data and compares outputs from this model at various discharges with a model based on the altimetry data modified using CroSolver. Outputs from the two hydrodynamic models are compared using HEC-RAS software with the use of depth estimate data and with the use of the unmodified DTM. The comparison is done on two watercourse reaches with different terrain morphology and watercourse size. A complementary output is the comparison of inundation areas issuing from both model variants.

Our results indicate that differences in the outputs are significant, namely at lower discharges (Q_1, Q_5), whereas at Q_{50} and Q_{100} the difference is negligible with a great role played by the morphology of the modelled area and by the watercourse size.

Keywords: aerial laser scanning (ALS), hydrodynamic model, HEC-RAS, CroSolver, cross profile – floods

Received 22 July 2015; Accepted 18 November 2015

1. Introduction

Hydrodynamic models are used to simulate hydraulic phenomena and are derived from the physical characteristics of flow, namely the laws of mass, momentum, and energy conservation. As to output details and input data requirements, they are divided into one-dimensional (1D), two-dimensional (2D), and/or combined (1D/2D) models (Roub et al. 2015).

The main factor in the creation of hydrodynamic models is input data for developing watercourse computational geometry (Ernst et al. 2010). Requirements for input data differ with respect to the hydrodynamic model used. One-dimensional (1D) hydrodynamic models feature lower requirements for input data as the computing track is formed by channel cross profiles. By contrast, in two-dimensional (2D) hydrodynamic models, a digital terrain model has to be constructed for the entire area in question. An alternative to the above-described models are quasi-2D modelling approaches, which combine the computational 1D or 2D approaches (Lindenschmidt 2008). In the latter, the actual complicated spatial geometry is artificially divided into parts of a branched or ring network composed of several partial models, e.g., the channel and inundation area (Valentová et al. 2010; Valenta 2005).

In the case of one-dimensional modelling, methods used to obtain data on the computational geometry of the watercourse and its adjacent inundation area include geodetic surveying, photogrammetry, ALS, or a combination thereof (Novák et al. 2011).

Geodetic surveying of the channel and adjacent inundation areas of watercourses is the most time- and cost-consuming method to ascertain information about the geometry of watercourses with respect to the size of the surveyed point field (Bharat and Mason 2001). In order to obtain data for hydrodynamic models the topography of watercourse axes is surveyed as is the topography and altimetry of cross profiles and objects on the watercourse. The distance between individual surveyed cross profiles ranges from several tens to several hundred of metres and depends especially on the variability of river channel shape. The surveying should involve the recording of watercourse spatial changeability, namely changes in channel cross sections and changes in longitudinal gradient. The usual distance between cross profiles on streams in the Czech Republic ranges from 50–100 m in built-up areas to 200–400 m outside of built-up areas (Drbal et al. 2012).

Geodetic surveying is also a necessary part of aerial photogrammetry, where it is used for surveying geodetic coordinates and the elevation of ground control points. Ground control points serve to determine orientation and scale and for transformation into the geodetic system. This procedure identifies the captured images with the actual terrain (Pavelka 2009).

Photogrammetry is a scientific discipline falling under geodesy and cartography, which deals with the acquisition of geometric data from image records, i.e., from photographs. Aerial photogrammetry uses two appropriately captured images (stereo-photogrammetry) that show the same area with a certain overlap. Data collection is further limited due to the use of a passive sensor, which is affected by atmospheric processes. Aerial photogrammetry is used for mid- and large-scale collection of topographic and altimetry data with sufficient accuracy and in considerably less time and at lower cost than with the use of geodetic methods. The low time consumption makes it possible to repeat the scanning and hence to keep data up to date (Metodický pokyn [Methodological instruction], 28181/2005-16000).

The third method of collecting spatial data for the construction of watercourse computational geometry in hydrodynamic models is aerial laser scanning. The ALS method is one of the most advanced technologies for harvesting topographic and altimetry data. Aerial laser scanning has been developed for the fast and operative mapping of large areas where standard methods (tachymetry, GPS, photogrammetry) are not sufficient (Dolanský 2004).

The ALS method is based on the principle of laser beam reflection; the precise position of the scanner and at the same time the precise direction of the emitted beam must be known. The principle consists in recording the time between the emission of the laser beam (which is as a rule within the infrared spectrum) and the reception of its reflection. The position of a given point is computed by processing this parameter (Wehr and Lohr 1999; Dolanský 2004; Novák et al. 2011; Oršulák and Pacina 2012). The advantage of this method consists in fast data collection, relatively low costs, and the ability to survey difficult terrain and large areas (Charlton et al. 2003).

Currently a new altimetry survey is being conducted in the Czech Republic with the use of the ALS method. It draws from current altimetry databases that contain data that are already obsolete for certain territorial types, their quality and accuracy adversely affecting the quality of national map series as well as digital geographic databases of the Czech Republic (Brázdil 2009). The goal is to ensure in collaboration with the State Administration of Land Surveying and Cadastre (ČUZK), the Czech Ministry of Agriculture, and the Czech Ministry of Defence a high-quality geographic data infrastructure that would be uniform and standardized for the whole territory of the Czech Republic.

2. Methodology

2.1 The underlying data

The basic groundwork was altimetry data from the fifth generation DTM of the Czech Republic. The data were provided by the State Administration Land Surveying and Cadastre (ČÚZK) and delivered in the S-JTSK coordinate reference system and the Baltic Vertical Datum after adjustment in ASCII coding and formatted with X, Y, and H values.

Data on N-year discharges were taken from the Registration Sheet of Crier Profile no. 127 for the Otava River and no. 182 for the Úhlava River (Tab. 1).

Tab. 1 Flow volumes corresponding to N-year discharges.

Site	N = year discharges Q_n [m³/s]				
	Q_1	Q_5	Q_{10}	Q_{50}	Q_{100}
Otava R.	146	300	394	680	837
Úhlava R.	36.7	82.4	111	201	250

2.2 Description of the study areas

The hydrodynamic models were constructed for two watercourse reaches with different terrain morphology and stream size. The first site of interest was a reach on the Otava River in Písek and the second one was a reach on the Úhlava River in Přeštice.

2.2.1 The Otava River site

The Otava River site is represented by a reach of 2,224 m in the cadastral area of Písek municipality. The reach is delimited by river km 22.4–24.6 and was divided into a total of 20 cross profiles (Fig. 1). The selected stream reach is situated in the central and north-eastern parts of the town

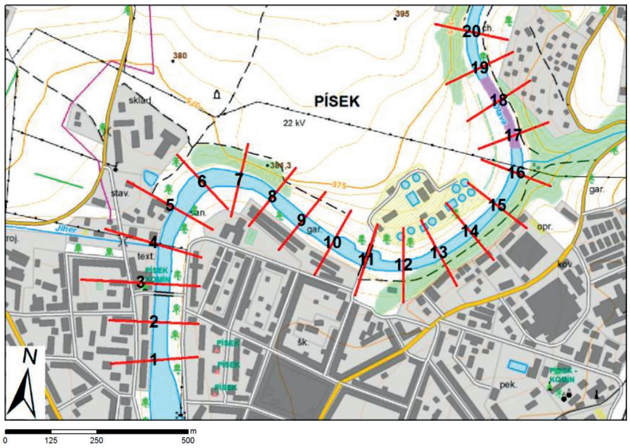


Fig. 1 Localization of cross profiles on the Otava River reach.

The Otava River is a third order stream and a left-bank tributary of the Vltava (Moldau) River, originating at the confluence of the Vydra River and Křemelná River in the Šumava Mountains near Čeňkova Pila. In the selected stream reach, the Otava River already indicates typical lowland features with an average top width of about 35 m. The average annual discharge in this section is 23.4 m^3/s and the average annual water level height is 90 cm (ČHMÚ 2015a).

2.2.2 The Úhlava River site

The second concerned site is a 1,280 m reach of the Úhlava River situated in the cadastral area of Přeštice. The reach is delimited by river km 30.5–31.7 and was divided into a total of 13 cross profiles (Fig. 2). The Úhlava River is a watercourse smaller than the Otava River, and its average annual discharge is 5.51 m^3/s (ČHMÚ 2015b). Terrain morphology is very specific with the entire right-bank side lying very low, and therefore extensive spills can be expected when the stream overflows its banks.

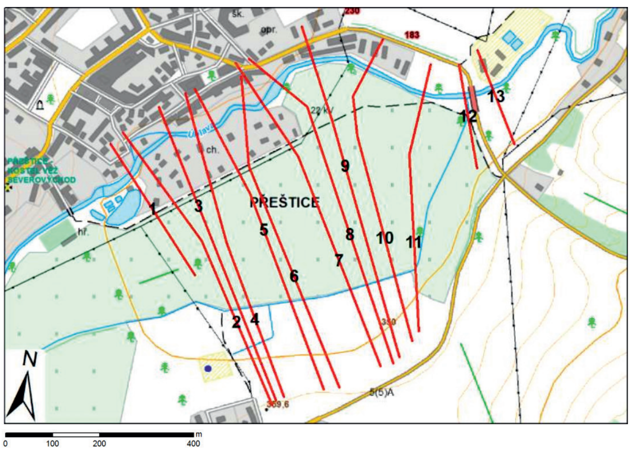


Fig. 2 Localization of cross profiles on the Úhlava River reach.

2.3 CroSolver Toolbox

As during ALS the laser beam does not penetrate the water's surface, the real shape of the channel is neglected, which may considerably distort the results of hydrodynamic modelling (Podhoranyi and Fedorcak 2014). The CroSolver (Cross section Solver) tool was developed to resolve this problem; it is available in two variants: CroSolver as a library of functions in the R programming language (Roub et al. 2012b) and as the CroSolver Toolbox consisting of Python scripts for use in ArcGIS (Roub et al. 2015).

The basic computing diagram of the tool is shown in Figure 3. During pre-processing, cross profiles are constructed first based on the specified distance between the profiles and watercourse width; the distance between the profiles affects the details of the results. The depth is then determined based on other channel parameters at the time of ALS, such as discharge, channel roughness coefficient, slope gradients, water surface smoothing distance, and the selected method for determining depth (Roub et al. 2015).

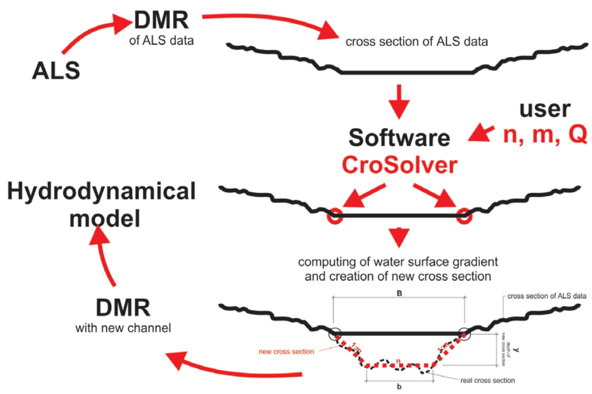


Fig. 3 The basic working scheme of CroSolver software (CroSolver 2014).

In the next step, the constructed cross profiles are prepared for depth computation. The constructed cross profiles are two-dimensional only. The extreme points of the cross profiles should characterize the contact points of the water surface and channel bank. Because we are searching for a point that is as close to the water surface as possible, it holds that such a point has the lowest height. Thus, a search radius for this point must be entered into the software. The tool will find the lowest point in the search field and will return its height and position vertical to the cross profile. A point defined in this way characterizes a point on the bank slope at the water surface.

The computation of watercourse channel depth is based on pre-processing data and on the characteristics of the watercourse channel. The computation is carried out for steady, uniform flow using the continuity equation and the Chézy formula with the calculation of flow rate coefficient according to Manning:

$$Q = v\,S,$$
$$v = C\,\sqrt{(R\,i)},$$
$$R = S/O,$$
$$C = R^{1/6}/n,$$

where Q is discharge ($m^3 s^{-1}$), S – cross-sectional area (m^2), v is flow velocity ($m s^{-1}$), C – flow velocity coefficient, ($m^{0.5} s^{-1}$), i is water level gradient (–), R is hydraulic radius (m), n is Manning's roughness coefficient (–) (Roub et al., 2015).

2.4 Construction of the digital terrain model in ArcGIS

The fifth generation DTM data were delivered in ASCII coding stored in *.xyz format. Therefore, it was necessary to convert them into a shapefile first (namely a point layer) in ArcGIS using the 3D Analyst extension's "ASCII 3D to feature class" function. Subsequently, a digital terrain model was constructed from the point layer in TIN format. The resulting TIN model of the Písek site is shown in Figure 4.

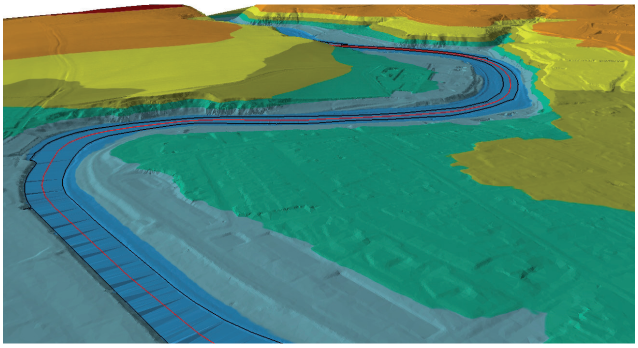


Fig. 4 3D display of the Písek site digital terrain model.

2.5 Creation of geometry with the HEC-GeoRAS extension

One of basic inputs into the HEC-RAS program is the geometry data of a watercourse. It is formed primarily by the watercourse axis, embankment lines, and cross profiles with altimetry data. All input data were created in ArcGIS using the HEC-GeoRAS extension, which allows the direct export of data in the form applicable for HEC-RAS.

In the case of the Otava River, cross profiles were automatically distributed with minor manual modifications so that the profiles do not cross one another and characterize watercourse geometry as realistically as possible. For the Úhlava River, asymmetric profiles had to be constructed with respect to the large inundation area on the right bank of the watercourse. The profiles were plotted manually and wrapped to prevent their crossing.

A 3D layer of cross profiles was constructed using the "RAS Geometry – XS Cut Line Att. – All" function. Thus, the attribute table of cross profiles was filled (namely the stationing added), and a layer was created of cross profiles with the altimetry information taken from the digital terrain model.

2.6 Determining channel depth by means of CroSolver Toolbox

The input layer into the CroSolver tool is the stream axis vectorized against the flow direction. Another input is the DTM stored in the *.txt text format. Data from the State Administration of Land Surveying and Cadastre (ČÚZK) were provided stored in *.xyz format, and therefore it was necessary that they be stored in the required format first. The actual process of calculating depth consists of three steps.

In the first step, a set of watercourse input axes had to be chosen as did parameters for dividing the watercourse into individual polygons, i.e., the distance between cross profiles and average width of the watercourse. For the Otava River the distance between profiles was set at 80 m and watercourse width at 30 m. For the Úhlava River, these figures were 60 m and 15 m, respectively.

In the second step, the output file from the previous step was entered (either as a text file or as a shapefile) and the DTM stored in the *.txt format. In both cases, the radius for finding the lowest point was set at 10 m.

In the third step, the input to be entered was the output from the previous step and optional parameters, including the method of depth computation, discharge, Manning's roughness coefficient, slope gradient, and minimum distance for water level calculation (Table 2). The discharge value entered was the actual value measured at the time of data acquisition by ALS.

Tab. 2 Parameters chosen when determining depth.

Parameter	Otava R.	Úhlava R.
Method of calculation	by gradient	by gradient
Discharge [$m^3 s^{-1}$]	15.2	3.612
Roughness coefficient [–]	0.033	0.026
Slope gradient 1 : m [–]	2	2
Min. distance for water level calculation [m]	100	100

2.7 Hydrodynamic model construction in HEC-RAS

The freely available HEC-RAS program was used, which allows for one-dimensional calculations of steady and non-steady, non-uniform flow and sediment transport (movable bed), as well as the modelling of temperature changes in flowing water. In order to assess whether it is possible to use hydrological surveying for the creation of flow geometry, a steady flow calculation was used. The calculation of steady flow is based on a calculation of non-uniform water flow in the stream channel in sections. The program can divide the cross section into the actual stream channel (i.e., the effective area of flow), and the left and right inundation zones. Determining water surface profiles with HEC-RAS is based on a one-dimensional method using Bernouilli's principle. Energy losses are calculated by friction loss using Manning's equation, while local losses are expressed with contraction and expansion coefficients. Areas that are more hydraulically complex such as overfalls, confluences, bifurcations, bridges, and culverts are dealt with using modified equations of movement.

Two models were constructed for the two sites in HEC-RAS 4.1.0, which differed only in their input geometry data. The entered discharge, roughness, and boundary condition values were identical. Values entered for the Otava River were as follows: channel – 0.033, left bank at the first three profiles where a smooth concrete wall occurs – 0.026, remaining banks with mainly grasslands – 0.03. Roughness values chosen for the Úhlava River were as follows: channel – 0.026, banks with grasslands – 0.027.

The upper boundary conditions were given by N-year discharges Q_1, Q_5, Q_{10}, Q_{50} and Q_{100}. Critical depth was selected as the lower boundary condition, where the program computes a critical depth for each profile and other data need not be entered. The models were simulated in the subcritical flow regime.

In the case of the Úhlava River, geometry data had to be additionally modified. Considering the great similarity between fifth generation DTM data and the width of cross profiles, the number of points exceeded the maximum value (500 points) in some profiles. In such profiles, the excessive points had to be filtered off with geometry data editing (Fig. 5).

Other modifications were necessary on the Otava River, where the "levees" option had to be selected (Fig. 6). HEC-RAS models flooding in the cross section based on altitude but does not consider obstacles that water has to overcome first. The stationing and altitudes of needed points were inserted into the cross sections.

This measure was not used on the Úhlava River due to its terrain morphology. Based on the exploration of the DTM and aerial photographs of the area, spilling was considered over the entire surface since terrain roughness was low and sparse.

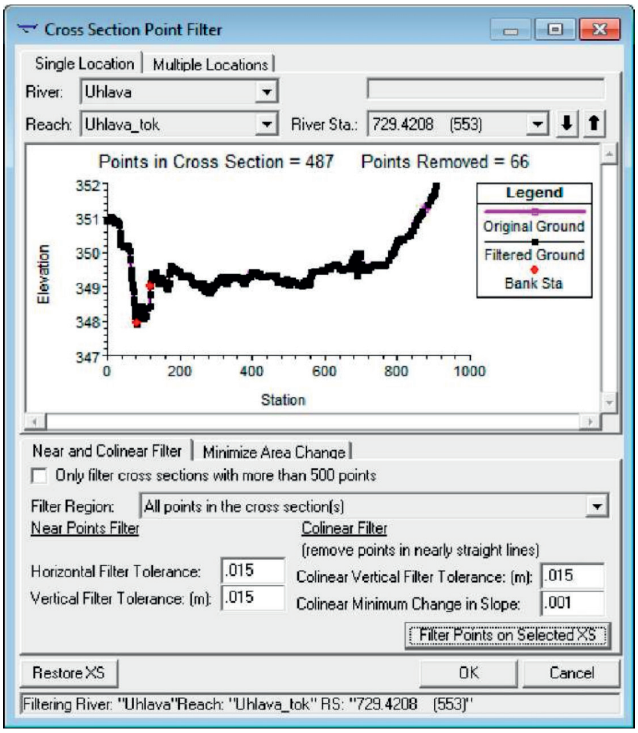


Fig. 5 Filtering off points in cross profiles.

3. Results

Results are presented in the form of graphic comparisons of three output characteristics from the HEC-RAS models:

a) water surface elevation,
b) cross sectional areas,
c) top width.

For comparison, the course of values along the entire longitudinal profile is illustrated as are the average values of differences in the characteristics of all cross profiles for the respective N-year discharges. Average deviations were calculated by subtracting the value of the models with and without depth computation. In addition, inundation areas derived from each model were compared. Summary charts include plotted results for the channel without

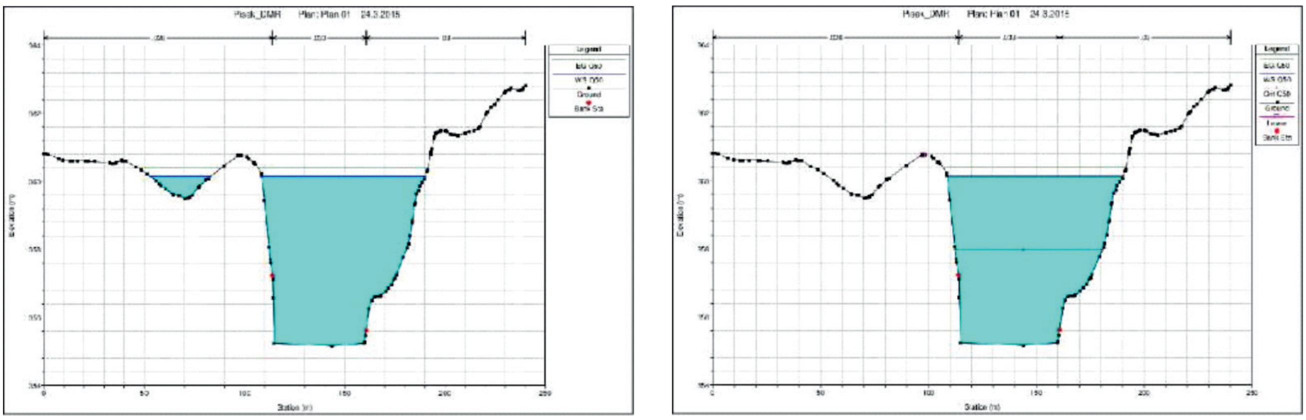


Fig. 6 Comparison of models with/without the "levee" option. (a) Result without using "levees". (b) Result using "levees".

depth calculation (fifth generation DTM) and with depth calculation (CroSolver).

3.1 Evaluation of the Otava River site

Figure 7 shows an example of watercourse channel depth determined by using the CroSolver software as compared with an untreated profile from the fifth generation DTM data. The only difference in geometry apparently occurs only in the channel while the inundation area and surroundings do not change in the process.

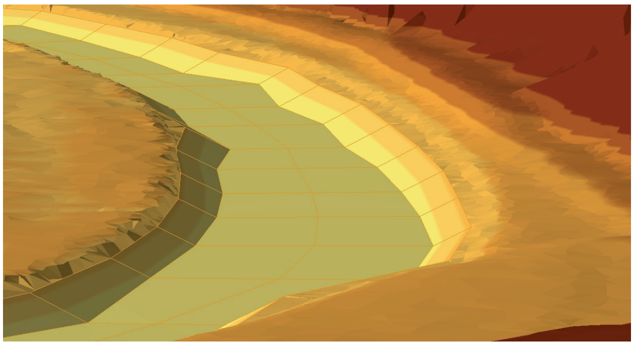


Fig. 7 Example of profile with calculated depth as compared with a profile without depth calculation.

3.1.1 Comparison of water surface elevations

It follows from Figures 8 and 9 that the difference between water surface elevations for the watercourse channels with and without depth calculation steadily decreases. At some discharges we can even see a phenomenon when the fifth generation DTM result corresponds to a different N-year CroSolver result (for example, a fifth generation DTM–based model for Q_5 gives nearly identical results as a depth-calculated model for Q_{10}).

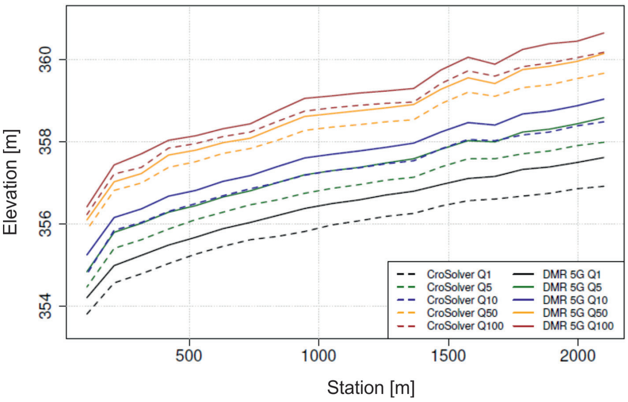


Fig. 8 Comparison of water surface elevations along the longitudinal profile at individual discharges.

3.1.2 Comparison of cross sectional areas

In cross sectional areas the trend is less clear (Fig. 11). The difference in the cross sectional areas gradually decreases at first, being generally insignificant, and the cross sectional area from the depth-calculated model at Q_{50} is even larger than that from the non-depth-calculated model. A shift in Q_{100} can be explained based on Figure 10, where a sudden increase of the area of two cross sections is obvious in the results based on the fifth generation DTM. These deviations were caused by the watercourse overflowing at given places in the non-depth-calculated model and by the subsequent spill, which significantly changed the shape of the cross sectional area. An example of the spill difference at the specific profile is shown in Figure 12.

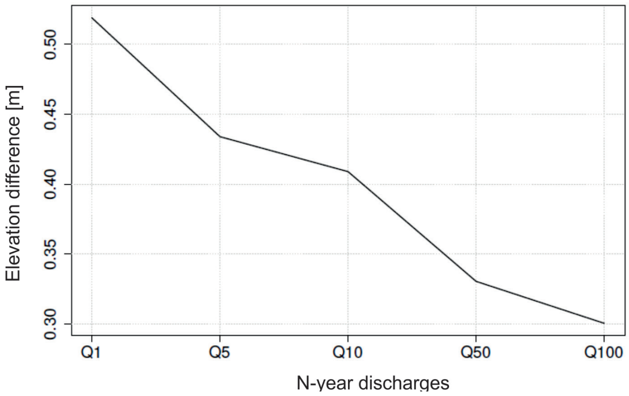


Fig. 9 Average deviation of elevations at individual discharges.

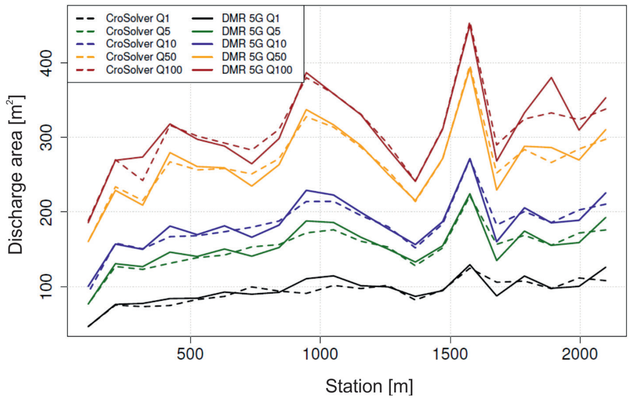


Fig. 10 Comparison of cross sectional areas along longitudinal profile at individual discharges.

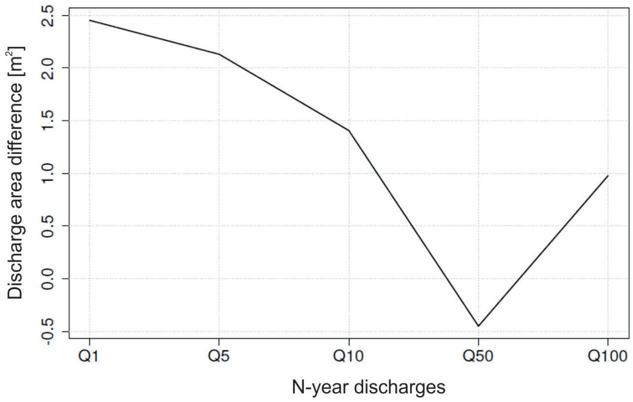
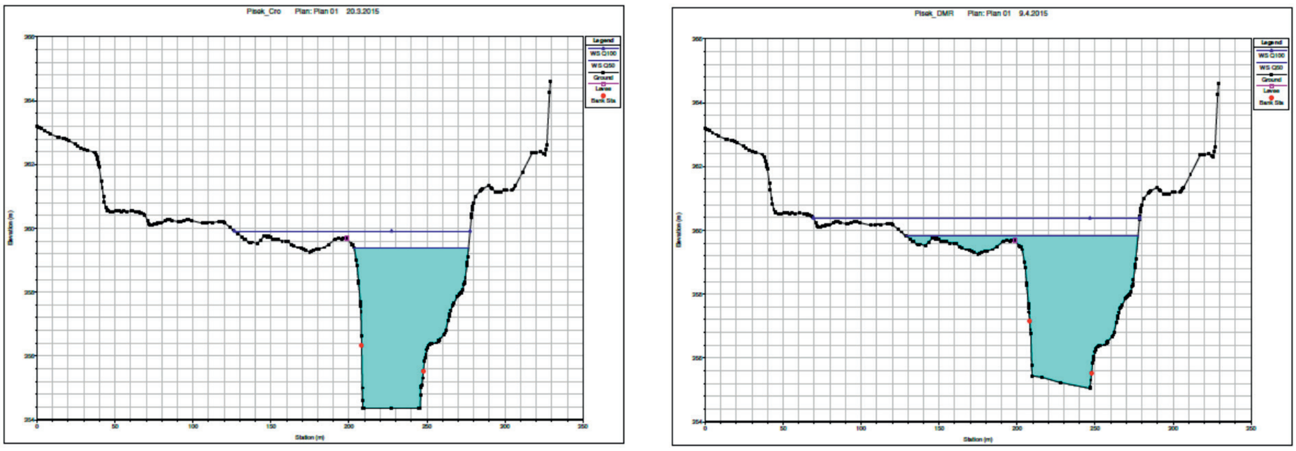


Fig. 11 Average deviation of cross sectional areas at individual discharges.



a) CroSolver

b) DMR 5G

Fig. 12 Comparison of spills at profile no. 3 – Q_{50} and Q_{100}.

3.1.3 Comparison of top widths

Top width significantly depends on terrain morphology. Due to different spills, average differences are distorted (Fig. 14). The situation is similar as in the case of cross sectional areas. The result can be better seen in Figure 13. Top width difference is apparently pronounced namely at lower discharges (Q_1, Q_5, and Q_{100}), whereas the course is practically identical on a greater part of the reach at Q_{50} and Q_{100}. Exceptions are several cross profiles where larger spills occurred into the inundation area in the fifth generation DTM–based model, and hence an abrupt growth of top width difference was recorded (Fig. 12).

3.1.4 Comparison of inundation areas

Inundation area Q_1 was chosen to illustrate differences in spill. Figure 15 shows that differences in the inundation area were minimal even for the lowest discharge for which all monitored characteristics exhibited the greatest differences between the depth-calculated model and the non-depth-calculated model.

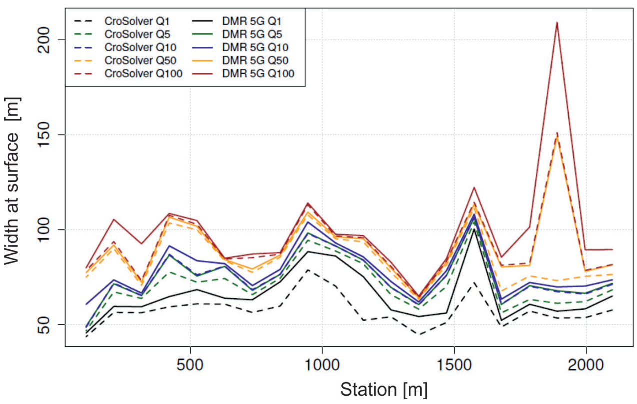


Fig. 13 Comparison of top width along longitudinal profile at individual discharges.

3.2 Evaluation of the Úhlava River site

Figure 16 depicts the longitudinal profile of the studied reach of the Úhlava River. It provides a typical example of terrain morphology in the given locality. An extensive inundation area stretches along the right bank.

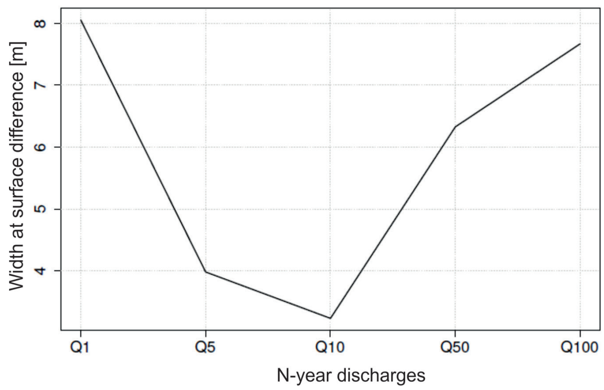


Fig. 14 Average top width deviation at individual discharges.

Fig. 15 Comparison of inundation area at discharge Q_1 at the Otava River site.

3.2.1 Comparison of water surface elevations

Figures 16 and 17 indicate that a significant difference in water surface elevations was observed namely at Q_1. At this discharge, overflowing occurred only in the non-depth-calculated model, and the channel modified with CroSolver still had sufficient capacity for handling this discharge. At Q_{50} and Q_{100}, the difference in water surface elevation was already negligible.

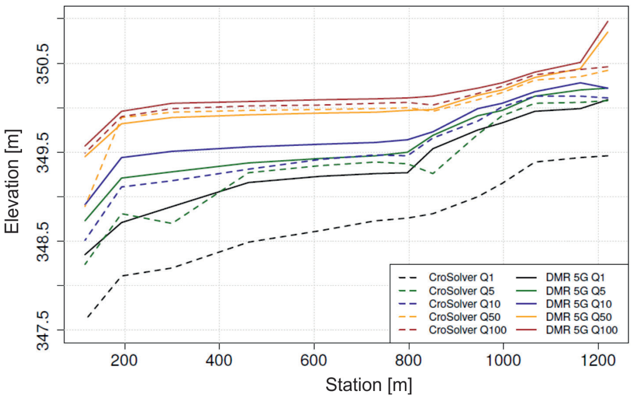


Fig. 16 Comparison of water surface elevation along the longitudinal profile at individual discharges.

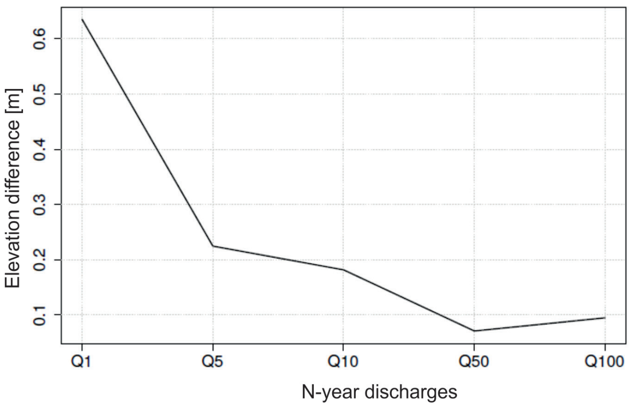


Fig. 17 Average elevation difference at individual discharges.

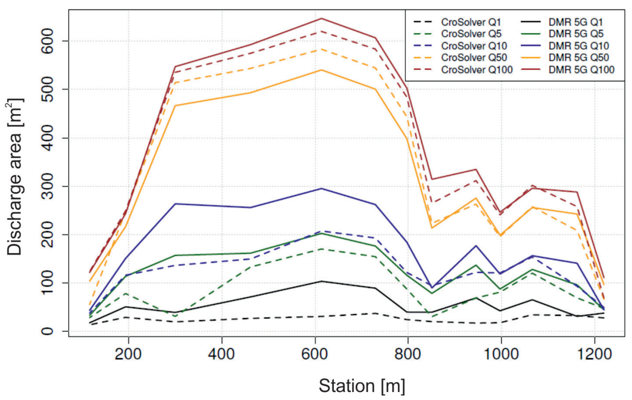


Fig. 18 Comparison of cross sectional areas along the longitudinal profile at individual discharges.

3.2.2 Comparison of cross sectional areas

Considering the rugged terrain and extensive spill, the cross sectional area was considerably variable here. Figures 18 and 19 show the ambiguous results for this characteristic.

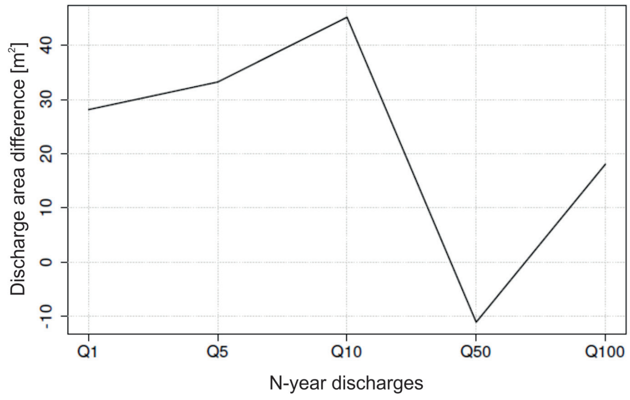


Fig. 19 Average deviation in cross sectional areas at individual discharges.

3.2.3 Comparison of top widths

The resulting top widths reflect once again the mode of water spill into the inundation area. Figures 20 and 21 show that differences in the top widths gradually dwindle up to Q_{50} and Q_{100}, where the courses of top widths are practically identical for the two model options.

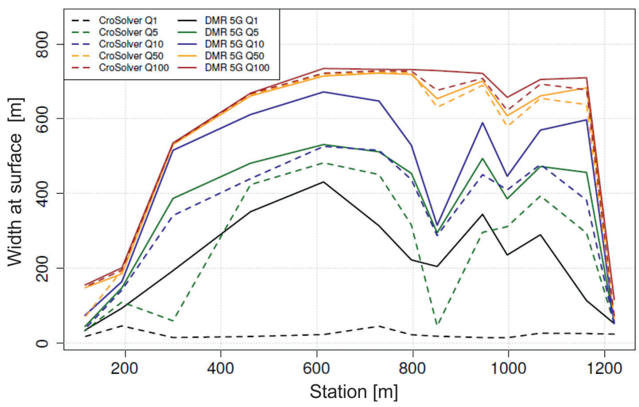


Fig. 20 Comparison of top widths along the longitudinal profile at individual discharges.

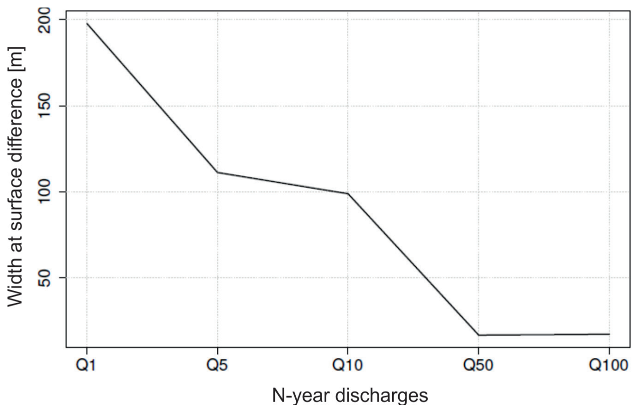


Fig. 21 Average deviation of top widths at individual discharges.

3.2.4 Comparison of inundation areas

A simulation of Q_1 was chosen for illustration. Figure 22 shows the difference in spills caused by the sufficient retention capacity of the channel in the model with calculated depth channel as compared with the insufficient channel capacity in the non-depth-calculated model. In the other variants, the difference was not so conspicuous due to the fact that bank overflow occurred also in the non-depth-calculated model.

Fig. 22 Comparison of inundation areas at discharge Q_1 at the Úhlava River site.

4. Discussion

This paper deals with the synthesis of data from hydrological measurements and ALS, which provide an alternative to the use of geodetic measurement data for hydrodynamic modelling. One of outputs is the assessment of the possibility for using ALS data in water management, while the development of specialized tools such as CroSolver attempts to eliminate errors in ALS-based input data for hydrodynamic modelling.

The main source of error when using the unmodified DTM derived from ALS data is neglect of the submerged part of the watercourse channel by which the size of the cross sectional area and the wetted perimeter in particular are affected.

It should be pointed out however that even the use of geodetic surveying itself may pose some problems, such as, for example, cross profiles of insufficient capacity or a too large distance between the cross profiles. When using the cross profiles from the DTM, these deficiencies can be easily eliminated; however, the use of geodetically oriented data requires, for example, additional elongation of the cross profile or cross file interpolation directly in the modelling software (HEC, 2010). These procedures may introduce errors into the computation.

Errors can also be introduced by using the CroSolver tool. Based on a sensitivity analysis, Roub et al. (2015) confirm that CroSolver is sufficiently robust in regards to input parameters (slope gradients, roughness coefficient). One of the disadvantages of this software however is the impossibility of choosing the schematic shape of the watercourse channel cross section.

The tool currently uses trapezoidal schematization. Nevertheless, this shape cannot characterize natural channels. Podhoranyi and Fedorcak (2014) inform that the influence of the shape used for schematization on the results of modelling has not been clearly demonstrated so far. Complications can be brought also by objects along the watercourse, with which CroSolver currently cannot work satisfactorily. On the other hand, Roub et al. (2015) expect the tool's accuracy to improve along with the improving accuracy of DTM input data.

Other sources of error include inaccurately measured discharge used in determining depth with the software. Moreover, the ALS-based digital terrain model is very heavy in terms of data volume, and this factor may prove to be limiting in working with a large area. In this respect, it would be possible to reduce appropriately the use of TIN without impairing its accuracy (Roub et al. 2012a).

5. Conclusion

This paper aims at a comparison of outputs from hydrodynamic models based on two computational geometries: (1) cross profiles obtained from the DTM based on fifth generation DTM data and (2) cross profiles obtained from the DTM including watercourse channel depth calculated using the CroSolver tool.

The above-mentioned results indicate that outputs from the hydrodynamic model based on the fifth generation DTM are – as expected – overestimated compared with the model with calculated depths. These differences are most apparent at lower discharges (Q_1 and Q_5) on both studied reaches. In contrast, differences at Q_{50} and Q_{100} are negligible. These are corresponding results considering the fact that a lower influence of discharge reached during ALS (used for determining depth) was assumed at higher modelled discharges.

The differences were obvious when comparing the two monitored sites. While the differences of all characteristics on the Otava River were relatively insignificant with respect to the watercourse size, the differences on the Úhlava River were greater. This was due to the effect of terrain morphology as the deeply incised Otava River channel does not practically allow spill into the inundation area, whereas the Úhlava River floods nearly its entire inundation area after bank overflow. Thus, the significance of the CroSolver tool is best demonstrated in the inundation results as well as where thanks to depth calculation a sufficient channel capacity can be expected for handling the required discharge.

The results of our work demonstrate that the CroSolver tool has high potential for use. Further research could be focused on comparing the models with calculated depths directly with models based on geodetic measurements, possibly with the readout of discharge measured at the time of scanning. At the same time, a more extensive comparison of the influence of watercourse morphology and size on resulting differences when using the CroSolver tool would be useful.

Acknowledgements

The results reported in this text were obtained with the support of the Czech Technology Foundation, programme Alpha, project TA04020042 – New technologies bathymetry of rivers and reservoirs to determine their storage capacity and monitor the amount and dynamics of sediments and BV II/2-VS, project VG3VS/229 – "Geographical information systems to support crisis situations and their conection to the automatic warning systems".

REFERENCES

BHARAT, L., MASON, D. C. (2001): Application of airborne scanning laser altimetry to the study of tidal channel geomorphology. ISPRS Journal of Photogrammetry and Remote Sensing 56, 100–120. http://dx.doi.org/10.1016/S0924-2716(01)00041-7

BRÁZDIL, K. (2009): Projekt tvorby nového výškopisu území České republiky. Geodetický a kartografický obzor 55(7), 145–151.

CROSOLVER (2014): CroSolver for ArcGIS, Nástroj CroSolver pro práci v prostředí ArcGIS, Ver 1.0 – Manual, online: http://fzp.czu.cz/vyzkum/software.html, cit. 9. 3. 2015.

ČHMÚ (2015a): Evidenční list hlásného profilu Písek, online: http//hydro.chmi.cz/hpps/hpps_prfbk_detail.php?seq=307230, cit. 18. 2. 2015.

ČHMÚ (2015b): Evidenční list hlásného profilu Přeštice, online. http//hydro.chmi.cz/hpps/hpps_prfbk_detail.php?seq=2505279, cit. 7. 3. 2015.

DOLANSKÝ, T. (2004): Lidary a letecké laserové skenování. Acta Universitatis Purkynianae, 99, Studia geoinformatica. Univerzita J. E. Purkyně v Ústí nad Labem.

DRBAL, K., ŠTĚPÁNKOVÁ, P., LEVITUS, V., ŘÍHA, J., DRÁB, A., SATRAPA, L., HORSKÝ, M., VALENTA, P., VALENTOVÁ, J., FRIEDMANNOVÁ, L. (2012): Metodika tvorby map povodňového nebezpečí a povodňových rizik. Ministerstvo životního prostředí, 91 s., online: http://cds.chmi.cz/dokumentace/Metodika_mapovani_2012-03-13.pdf (cit. 24. 3. 2015).

ERNST, J., DEWALS, B. J., DETREMBLEUR, S., ARCHAMBEAU, P., ERPICUM, S., PIROTTON, M. (2010): Micro-scale flood risk analysis based on detailed 2D hydraulic modelling and high resolution geographic data. Natural Hazards 55(2), 181–209. http://dx.doi.org/10.1007/s11069-010-9520-y

HEC (2010): HEC-RAS River Analysis System. User's Manual. U.S. Army Corps of Engineers – Hydrologic Engineering Center – HEC, Davis, CA.

CHARLTON, M. E., LARGE, A. R. G., FULLER, I. C. (2003): Application of airborne lidar in river environments: the river Coquet, Northumberland, UK, Earth Surface Processes and Landforms 28, 299–306. http://dx.doi.org/10.1002/esp.482

LINDENSCHMIDT, K .E. (2008): Quasi-2D approach in Modeling the transport of contaminated sediments in floodplains during river flooding. Model coupling and uncertainty analysis. Environmental Engineering Science 25(3), 333–351. http://dx.doi.org/10.1089/ees.2006.0192

Metodický pokyn (28181/2005-16000) k zadávání fotogrammetrických činností pro potřeby vymezování záplavových území v souvislosti s aplikací ustanovení § 66 odst. 1 zákona č. 254/2001 Sb., o vodách a o změně některých zákonů (vodní zákon), ve znění pozdějších předpisů, a vyhlášky č. 236/2002 Sb., o způsobu a rozsahu zpracování návrhu a stanovování záplavových území.

NOVÁK, P., ROUB, R., HEJDUK, T. (2011): Využití hydrologického měření při tvorbě hydrodynamických modelů z dat leteckého laserového skenování. Vodní hospodářství 61(8), 297–302.

ORŠULÁK, T., A PACINA J. (2012): 3D modelování a virtuální realita. Ing. Tomáš Kukulenka, Ústí nad Labem.

PAVELKA, K. (2009) Fotogrammetrie 1. ČVUT v Praze, Fakulta stavební, Praha, 200 s.

PODHORANYI, M., FEDORCAK, D. (2014): Inaccuracy introduced by Lidar-generated gross sections and its impact on 1D hydrodynamic simulations. Environmental Earth Sciences 73(1), 1–11.

ROUB, R., HEJDUK, T., NOVÁK, P. (2012a): Využití dat z tvorby nového výškopisu území České republiky metodou leteckého laserového skenování při analýze a mapování povodňových rizik. Geodetický a kartografický obzor 58(1), 4–8.

ROUB, R., HEJDUK, T., NOVÁK, P. (2012b): Automating the creation of channel cross section data from aerial laser scanning and hydrological surveying for modeling flood events, Journal of Hydrology and Hydromechanics 60(3), 227–241.

ROUB, R., URBAN, F., HAVLÍČEK, V., NOVÁK, P., HEJDUK, T., BUREŠ, L., REIL A. (2015): Vývoj softwarových nástrojů CroSolver a CroSolver for ArcGIS pro přípravu výpočetní tratě hydrodynamických modelů. Vodohospodářské technicko-ekonomické informace 57(1), 5–13.

VALENTA, P. (2005): Využití numerických modelů proudění vody v protipovodňové ochraně. ČVUT v Praze, Fakulta stavební.

VALENTOVÁ, J., VALENTA, P., WEYSKRABOVÁ, L. (2010): Assessing the retention capacity of a floodplain using a 2D numerical model. Journal of Hydrology and Hydromechanics 58(4), 221–232.

WEHR, A., LOHR, U. (1999): Airborne laser scanning – an introduction and overview, ISPRS Journal of Photogrammetry and Remote Sensing 54, 68–82. http://dx.doi.org/10.1016/S0924-2716(99)00011-8

RESUMÉ

Porovnání hydrodynamického modelu z dat DMR 5. generace a modelu z dat upravených pomocí nástroje CroSolver

Povodeň je přírodní jev, který se vyskytuje v různé intenzitě a nepravidelných časových intervalech. Povodně představují pro Českou republiku největší přímé nebezpečí v oblasti přírodních katastrof a mohou být i příčinou závažných krizových situací, při nichž vznikají nejenom rozsáhlé materiální škody, ale rovněž ztráty na životech obyvatel postižených území a dochází k rozsáhlé devastaci kulturní krajiny včetně ekologických škod. Z hlediska eliminace potenciálního ohrožení a samotných následků těchto událostí jsou významné informace předpovědní povodňové služby o charakteru a o rozsahu záplavových území pro jednotlivé N-leté povodňové průtoky a konkrétní povodňové scénáře. Adekvátní představu o hloubkách a rychlostech při povodňové události, v podélném či příčném profilu vodního toku, poskytují hydrodynamické modely. Získané informace z hydrodynamických modelů tak

zaujímají výsadní postavení z pohledu ochrany životů i zmírnění škod na majetku občanů.

Základním vstupem do hydrodynamických modelů jsou výškopisná data. Jedním ze způsobů získání dat je jejich pořízení metodou leteckého laserového skenování (LLS) pro tvorbu digitálního modelu reliéfu (DMR). Tato metoda je označována za jednu z nejpřesnějších metod pro získání výškopisných dat. Jejím úskalím je však neschopnost zaznamenat geometrii terénu pod vodní hladinou, a to díky pohlcení laserového paprsku vodní masou. Absence geometrických dat o průtočné ploše vodního toku může citelně ovlivnit výsledky modelování, zejména pokud chybějící část koryta reprezentuje svou kapacitou významnou průtočnou plochu. Jedním ze způsobů odstranění této chyby je dodatečné zahloubení koryta pomocí softwarových nástrojů, jakým je například CroSolver.

Předkládaný příspěvek se zabývá sestavením hydrodynamického modelu s využitím dat DMR 5. generace a porovnává jeho výstupy při různých průtocích s modelem založeným na výškopisných datech upravených pomocí nástroje CroSolver. Jedná se o srovnání výstupů hydrodynamických modelů v programu HEC-RAS při použití zahloubených dat a při použití neupraveného DMR. Srovnání je provedeno na úsecích dvou vodních toků s odlišnou morfologií terénu a velikostí vodního toku. Doplňujícím výstupem je porovnání záplavových území vycházejících z obou variant modelů.

Z výsledků vyplývá, že rozdíly ve výstupech jsou významné především u nižších průtoků (Q_1, Q_5), zatímco pro Q_{50} a Q_{100} je rozdíl zanedbatelný, přičemž velký vliv má samotná morfologie modelovaného území a velikost vodního toku.

Radek Roub, Marie Kurková, Luděk Bureš
Czech University of Life Sciences Prague
Faculty of Environmental Sciences,
Department of Water Resources and Environmental Modeling
Czech Republic

Tomáš Hejduk
Czech University of Life Sciences Prague
Faculty of Environmental Sciences,
Department of Water Resources and Environmental Modeling
Czech Republic

Research Institute for Soil and Water Conservation
Žabovřeská 250, Praha 5 – Zbraslav, 156 27
Czech Republic

Pavel Novák
Research Institute for Soil and Water Conservation
Žabovřeská 250, Praha 5 – Zbraslav, 156 27
Czech Republic
E-mail: novak.pavel@vumop.cz