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MAPPING AND ANALYSIS OF RIVER NETWORK MODIFICATION AS A FACTOR OF FLOOD RISK IN THE BLANICE RIVER BASIN

J. Langhammer, M. Matoušková: *Mapping and analysis of river network modification as a factor of flood risk in the Blanice river basin.* – Geografie–Sborník ČGS, 111, 3, pp. 274–291 (2006). – Anthropogenic modifications of river network represent a significant phenomenon that influences runoff conditions in river basins, both under normal water level conditions as well as in the period of hydrological extremes. Modifications of watercourses on various levels influence the speed and timing of floodwave progress as well as the potential to efficiently transform the floodwave in the floodplain and to lessen the extremity of the flood event. The paper presents the methodological framework for analysis of historical and current intensity and nature of man-made modifications of river network. There are presented two essential approaches: First represents the analysis of distance data, e.g. the water management maps, historical maps or aerial imagery. The second approach is based on field mapping of various parameters of river network and floodplain modifications. The presented methodologies are applied on the Blanice river basin that represents the core zone of extreme flood in August 2002 that heavily affected the Central Europe. The GIS analysis of results revealed the spatial differentiation of anthropogenic changes in river basin and their potential importance in the context of the flood risk. The results and the applied methodologies are discussed from the viewpoint of their practical applicability and of limitations in terms of data accuracy, availability and reliability.
KEY WORDS: river network transformation - floods - mapping - land-use changes - GIS.

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1. Introduction

Anthropogenic modifications of riverbeds represent a significant phenomenon that influences runoff conditions of river basins, both under normal water level conditions as well as in the period of hydrological extremes. Modifications of watercourses on various levels - ranging from interventions in the stream route geometry to presence of artificial steps in its longitudinal profile and to modifications of the riverbed or modifications of the riparian zone, influence markedly the speed and nature of water runoff from the river basin during floods. They affect especially the speed of the flood wave progress, the possibility of its efficient transformation, they alter the timing of concurrence of flood waves from various parts of the river basin, and last but not least, they contribute in various extents to the character of damages incurred to property, infrastructure, as well as the landscape.

The goal of the research presented has been to assess the current condition of modification of the river network and the riparian zone in the Blanice River basin that represents the core area of the extreme flood hitting the Central Europe region in August, 2002. The assessment stems from the combination of two approaches - Field mapping and evaluation of the distance data available. The paper is focused on assessment of the current situation of the watercourse modification and its spatial variability, and on assessing the possibility of using individual data sources to obtain objective sources for complex evaluation of the flood risk and their practical application.

2. Material and Methods

2.1 Current approaches for river network modification assessment

Various approaches can be applied in assessment of the river network modification, allowing obtaining a different type of information on anthropogenic transformation of watercourses and the floodplain; they are based on different methodical approaches and require a specific nature of input data.

Analysis of distance data – maps, digital materials, aerial or satellite images – provides basic information on the time-spatial dynamics of interventions in the river network. Analysis of historical cartographic materials plays an important role here, as it allows evaluating the dynamics of changes of ground-plan courses of the watercourse riverbeds. Concerning the territory of Czechia, it is thus possible to utilize e.g. the maps of military mapping for the territory of the former Austro-Hungarian Empire; these maps allow to evaluate changes in the time horizont of the previous ca. 150 years, a period for which data from regular observation of hydrological and climatic elements are available in numerous regions, at the same time. However, concerning limited accuracy and different level of generalization of the historical map works, the analysis is limited especially to significant watercourses and their main tributaries (Langhammer, Vajskebr 2003). Changes of the river network in the course of the 2nd half of the 20th century are also well documented by aerial images (Matoušková 2003). Accuracy of the materials derived is always determined by accuracy of georeferencing of historical map data as well as by the level of their content generalization (Langhammer, Vajskebr 2003). Data of good quality for the spatial structure analysis of the river network modification are provided by current digital maps, especially the Water Management Maps (WMM) and Map Data of the Agricultural Water Management Authority (Matoušková in Langhammer 2003).

Field mapping, as opposed to distance data, allows obtaining substantially more detailed information on the nature and intensity of human impact on the river network and flood plain. Besides basic classification of the segments as modified and non-modified, it allows to classify the intensity of modification according to numerous parameters – e.g. modification of the riverbed route, of the longitudinal profile, of the watercourse riverbed, utilization of the riparian zone, etc. Methodology of mapping of the watercourses modification stems from the general ecomorphological approaches (e.g. Barbour et al. 1999; Havlík et al. 1997; Landson White 1999; Matoušková 2003, 2004; Niehoff 1996; Raven et al. 1997; Rosgen 1996; Vlček, Šindlar 2002 etc.), however the direct use of these methods is not applicable due to their complexity. The methodology developed for the purpose of assessment of stream modification in regard to the flood risk is thus based on the subset of selected parameters that correspond with specific needs of the evaluation.

2.2 Analysis of river network modification of river network based on distance data

Analysis of the distance data has been focused on assessment of the degree of the river network modification based on available mapping materials and based on performing mutual comparative analysis of different information sources.

The raster form of the WMM 1:50,000 have represented the basic data source, showing segments of modified channels, and at the same time, artificial built channels. Individual WMM map sheets were geo-coded, geo-registered and modified channels were digitised. The degree of river transformation was calculated for the whole catchment's area of the Blanice river and also for 6 sub-catchments on the bases of WMM 1:50,000.

Another source of information was represented by digital map layers of the Agricultural Water Management Authority (AWMA) that contains hydro-amelioration measures performed, as well as related modifications of the riverbeds. Registry of channel modifications and the registry of surface and subsurface drainages were available for this analysis. The mapping materials obtained did not have the character of a geodatabase, which made the assessment analysis difficult. The detail mapping materials 1:10,000 only for a part of the lower course of the Blanice River were available and therefore the analysis was processed only for the selected sub-catchment Blanice V., where the highest degree of anthropogenic modification of the river network has been observed, at the same time.

2.3 Methodology of field mapping of river network modification

Mapping and subsequent evaluation of modification of the watercourses and floodplain in the Blanice River basin has been based on the methodology developed at the Faculty of Science of the Charles University for the needs of research of the environmental changes impact on the course and consequences of floods (Langhammer 2003).

The methodology has been designed to allow assessment of the connections between individual aspects of anthropogenic modification of the river network and floodplain, and the course and consequences of floods. The extent of the indicators evaluated has been chosen in such a manner so that the mapping allows to obtain the necessary spectrum of information, and at the same time, so that it allows for rapid advancement of mapping in the field and processing of the large territory in the time period needed. The methodology is based on integration of the results with the GIS, representing geostatistical assessment of the results, as well as, however, their usage as input data for further applications. The spectrum of evaluation indicators has been selected in such a manner so that the methodology can be used in general geographic and hydrological conditions of Czechia.

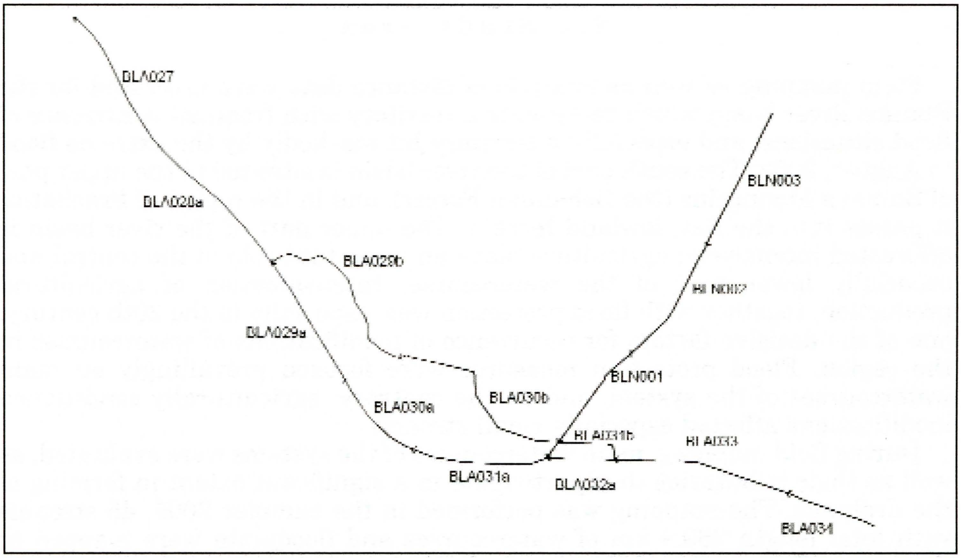

Fig. 1 – Principle of dividing the watercourses in partial segments and their linkage to database records by means of a unique identifier of individual segments.

For the mapping purses, the watercourses are divided in segments of variable length (Fig. 1). Borders of the segments have been chosen in such a manner so that the watercourse segment obtained is homogeneous as for one of the key parameters at least: The riverbed route, modification of the riverbed, landuse of the riparian zone. Borders of the segment are marked in the map, while a typical segment length is 100-500 meters.

A unique indicator has been assigned to individual segments, allowing distinguishing even complicated hydrographic structures. Intensity and nature of modification in individual parameters is evaluated for every segment together with the given segment code, stored in a form, and subsequently transferred to the database. Using the segment identifier, the map elements are linked to database records, and they allow for further geoinformatic processing.

Modification of the watercourses and the floodplain is evaluated in five main indicators, while every indicator is divided internally within the scale of categories, pursuant to the intensity of anthropogenic modification (Langhammer 2004):

– modification of the stream route
– modification of the watercourse riverbed
– modification of the watercourse longitudinal profile
– utilization of the riparian zone
– presence of flow obstacles in the floodplain.

Supplementary indicators are added to these basic ones, evaluating e.g. the nature of flood protection, the retention potential of the floodplain or the course and consequences of floods.

In mapping of large areas, systematic training and supervision of the mappers as well as a transparent digitising method, checking, and processing of the results, play a key role. These operations help to eliminate inaccuracies caused by different approach of individual mappers, as well as errors in processing and interpretation of the results.

2.4 Study area

Field mapping as well as analysis of distance data were processed for the Blanice River basin which represents a territory with frequent occurrence of flood situations, and especially a territory hit markedly by the extreme flood in August, 2002. The south part of the river basin is situated in the upper part of Šumava Mountains (the Bohemian Forest), and in the region of Prachatice it passes into the flat, lowland terrain. The upper part of the river basin is afforested intensively; agriculture plays an important role in the central and especially lower part of the watercourse. Intensification of agricultural production, together with flood protection was, especially in the 20th century, one of the decisive factors for occurrence of modifications of watercourses in the region. Flood protection measures were focused prevailingly on main watercourses of the system, and on the contrary, agriculturally conditioned modifications affected especially small streams.

During field mapping, main watercourses of the systems were evaluated, as well as their tributaries that participate in a significant extent in forming of the drainage. The mapping was performed in the summer 2005; 45 streams with total length 289.9 km of watercourses and floodplain were mapped at this time. These watercourses were divided in 918 segments representing elementary units for which individual aspects of anthropogenic modification and manifestations of the flood were assessed.

3. Results

3.1 Analysis of river network modification based on distance data

3.1.1 Modification of the river network based on the Water Management Map

The primary output is represented by the map of anthropogenic transformation of the river network of the Blanice River basin, see Figure 6, and furthermore, by subsequent assessment of the river network modification in selected sub-catchment, see Figure 7. The total length of the watercourses based on the digital layer WMM 1:50,000 amount to 1035.5 km. The length of river reaches modified by human intervention, based on the analysis WMM 1:50,000, is 264.3 km. Average degree of anthropogenic transformation of the river network reaches 25.5%. Approximately one fourth of watercourses in the Blanice River basin are modified.

Significant regional differences in the extent of river modification were identified. Relatively low proportion of river alteration was recorded on the upper course of the Blanice, especially in the area of its right-sided and left-sided tributaries. An exception is represented only by the right-sided tributary Zbytinský potok (the Zbytinský Brook), in the river basin of which extensive hydro-amelioration measures have been taken. Channels have been straightened, deepened and fortified by quarried stones or concrete prefabricated materials. Furthermore, modifications of the channel were performed in the main course of the upper Blanice at the turn of the 19th and 20th centuries, however, these modifications have not brought any significant change of the course or character of the channel, and it is possible to identify them in the present landscape with difficulty only.

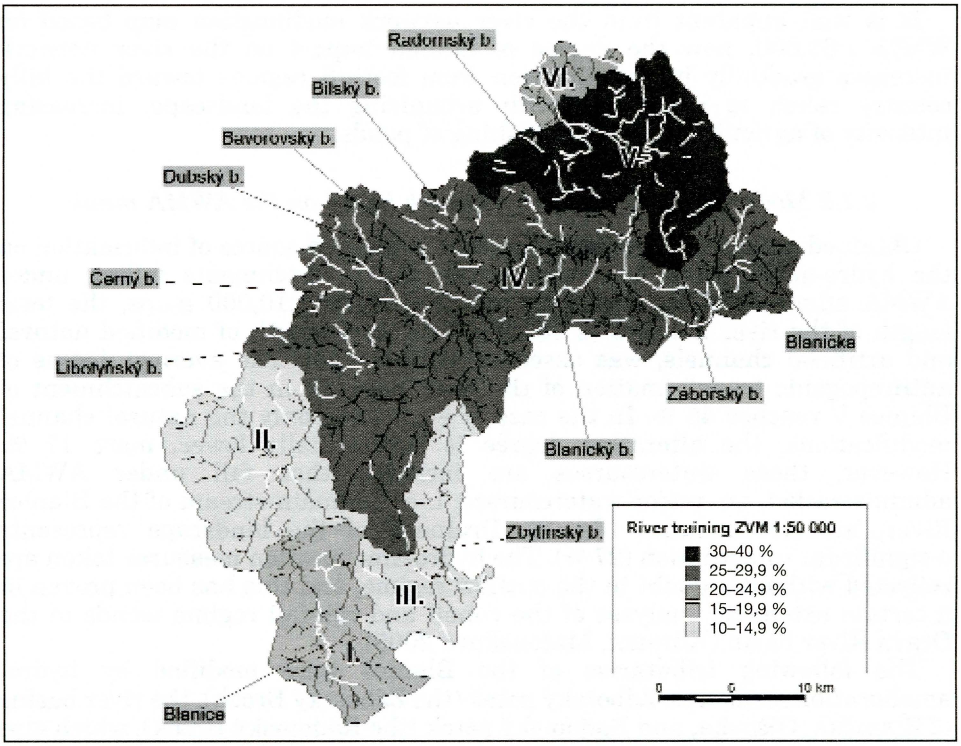

Fig. 2: – The channel modification in the Blanice River basin. Source: WMM (ZVM) maps 1:50,000.

Tab. 1 – The river network modification in the Blanice V. subcatchment. Source maps of the AWMA 1:10,000.

Blanice V.	Watercourse modifications	Drainage	Total modifications	Length of the river network
Length (km) % modification	32.18 17.77	49.09 27.10	81.27 44.87	181.13 100.00

A marked degree of anthropogenic transformation is shown on the middle course of the Blanice River, especially its left-sided tributaries: the brooks Libotyňský potok, Dubský potok, Černý potok, and Bavorovský potok. Further downstream, higher level of modification of right-sided tributaries can be seen, as well in the river basins of the brooks Blanický potok, Radomský potok, Zábořský potok, and Blanička. A high proportion of modified reaches is shown on the lower course of Blanice itself, which is related to the technical flood protection measures.

Furthermore, the river training was studied from the viewpoint of sub-catchments. Six sub-catchments were delimited within the Blanice River basin.

The highest degree of the river network modification (D) has been achieved on the lower and middle course of the Blanice River (Blanice V., D = 40 %, Blanice IV., D = 27 %), see Fig. 2. On the contrary left side tributaries, i.e. the subcatchments II. and III., show lover degree of modification (D = 12%), see Tab. 1.

It is well apparent from the river network modification map based on WMM 1:50,000, how the degree of human impact on the river network increases gradually in the direction from foothill regions toward the hilly country relief, in connection with urbanizing the landscape, increasing intensity of agriculture and establishing of ponds.

3.1.2 Modification of the river network based on the AWMA maps

Obtained mapping materials represent a detailed source of information on the hydro-amelioration measures performed in catchments falling under AWMA administration. Based on the ZABAGED 1:10,000 maps, the total length of the river network is 181 km. The total length of modified natural and artificial channels, was assessed to be 81 km. The average degree of anthropogenic transformation of the river network in the subcatchment of Blanice V reaches 45 %. In the case of evaluating only the natural channel modifications, the alteration degree is substantially lower, mere 17 %. However, those watercourses are included that fall under AWMA administration, i.e. major watercourses, i. e. the main stream of the Blanice River, are not included (fig. 3). Drainage of the landscape represents a significant intervention (27 %). The hydro-amelioration measures taken are reflected without a doubt in the outflow regime, and this has been proven in a certain extent by analyses of the runoff and rainfall regime trends in the Otava River basin (Kliment, Matoušková 2005).

The following tributaries of the Blanice were modified by hydro-amelioration measures: Zábořský potok (the Zábořský Brook), the river basins of Blanička, Olšovka, and Radomský potok (the Radomský Brook), which also

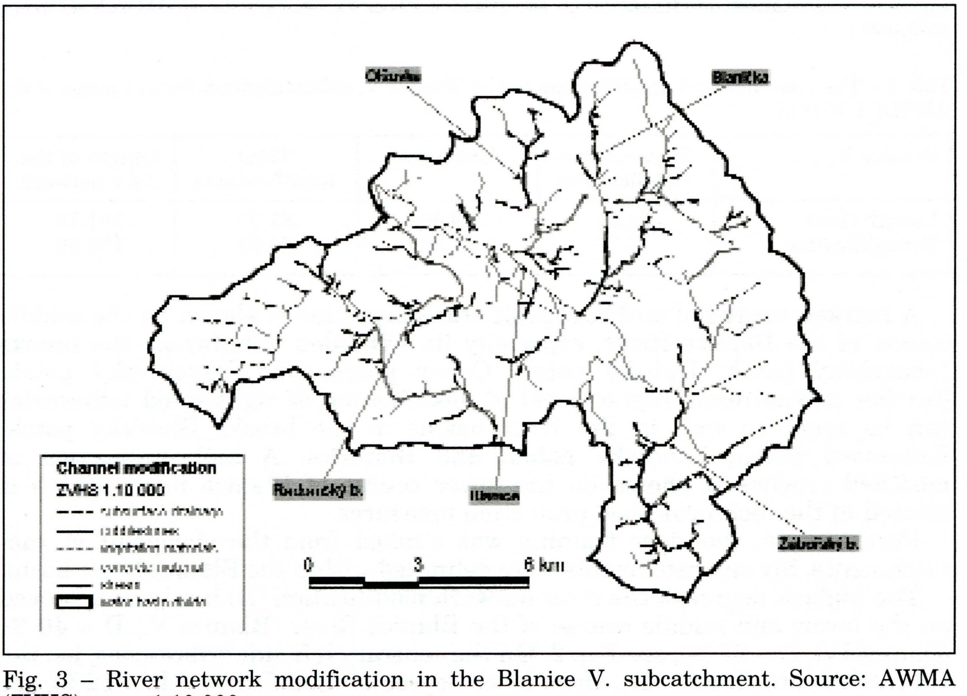

Fig. 3 – River network modification in the Blanice V. subcatchment. Source: AWMA (ZVHS) maps 1:10,000.

corresponds with the analysis performed based on WMM 1:50,000. The oldest river alteration were performed in the period of 1926–1938, namely at the lower course of the Radomský potok and in the Blanička River basin. The modifications concerned a fortification of the riverbeds by cobblestones. Further modification was performed in the 60ies of the 20th century, especially within the catchments Zábořský potok and Olšovka. Concrete materials represent the prevailing type of the fortification. Other channel alteration occurred in the 70ies and 80ies, specifically in the river basins of Olšovka and Blanička. Concrete prefabricated materials were applied mostly. Subsurface drainage was generally performed in linkage to the performed modification of channels in the 60ies – 80ies in the river basins mentioned above.

3.2 Analysis of river network modification based on field mapping

Field mapping of stream and riparian zone modification provided information on the current intensity and spatial differentiation of anthropogenic transformation of the river system of the Blanice River basin. The following was assessed as fundamental modification parameters: Modification of the stream route, modification of the longitudinal profile, and modification of the watercourse riverbed. Mapped indicators, individual categories of modification, and results of evaluation of their participation in the total length of the river network under assessment are summarised in Table 2.

3.2.1 Modification of stream route

Analysis of the stream route modification confirmed a significant share of anthropogenically modified segments in the total length of the river network, as well as strong spatial differentiation of interventions in the ground-plan course of the riverbeds, shown by the analysis of historical changes of the Blanice river network (Langhammer, Vajskebr 2003).

Segments with artificial straightening of the riverbed are found over 40.6 % of the river network length under assessment, while, together with sinuous segments where anthropogenic influence can be expected, as well, they represent more than 75 % of the total length of the river network.

Meandering segments, important for potential usage for transforming the flood wave in the floodplain, are found on 17.4 % of the watercourses length. However, out of this length, only a small part of the segments is usable for passive flood protection. This concern, especially in the lower part of the watercourse, often left meanders, separated from the watercourse by flood protection dykes that prevents their usage as retention area in the event of increased water levels (Fig. 4).

Tab. 2 – Degree of river network modification in subcatchments of the Blanice River basin based on WMM 1:50,000

Subcatchment	Modification (%)
I.	16.2
II.	11.2
III.	11.8
IV.	26.8
V.	39.6
VI.	23.5

The analysis of transformation of the watercourses riverbed route indicates considerable variability of the modification intensity among individual parts of the

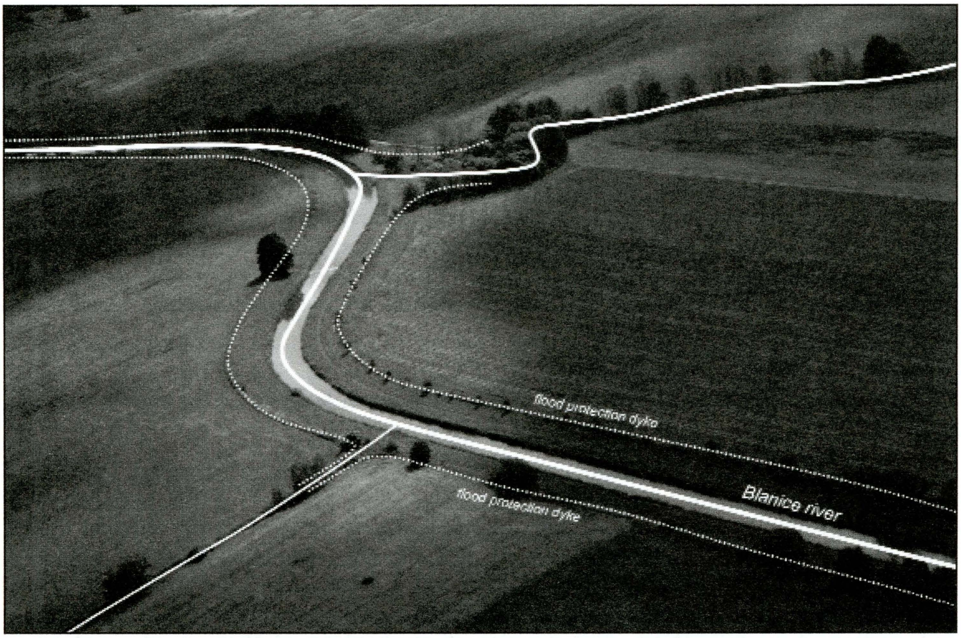

Fig. 4 – Straightened stream of the Blanice River on the down course with flood protection embankments. Flood protection dykes protect here the agricultural land and thus impede efficient usage of the retention potential of the flat floodplain. Photo J. Langhammer 2005.

Tab. 3 – Assessed categories of river network modification and their share on the total lenght of the river network. Data: Field mapping, 2005

Stream route modification	%	Longitudinal profile modification	%	Riverbed modification	%
1. Braided	0.4 %	1. Segment without modifications	70.4 %	1. Natural (without signs of modifications)	46.2 %
2. Branched	1.6 %	2. Naturally low levels in the riverbed (0-50 cm)	16.5 %	2. Vegetation consolidation of the shore	13.7 %
3. Meandering	17.4 %	3. Naturally high levels in the riverbed (above 50 cm)	0.5 %	3. Shore consolidated by wooden round timber	0.3 %
4. Sinuous	35.2 %	4. Low weir (0-1 m)	7.2 %	4. Shore consolidated by non-consolidated stone material	9.3 %
5. Naturally straight	4.9 %	5. Weir in steps, slide	0.7 %	5. Shore or bottom consolidated by quarry stone – levelling material	6.4 % 6.4 %
6. Artificially straightened	40.6 %	6. High weir (above 1 m)	3.2 %	6. Shore or bottom consolidated by semi-vegetation blocks	3.6 %
		7. Dam	1.5 %	7. Shore or bottom consolidated by concrete	18.5 %
				8. Continuous consolid ation of the shore as well as the bottom by concrete	0.7 %
				9. Pipelined stream	1.3 %

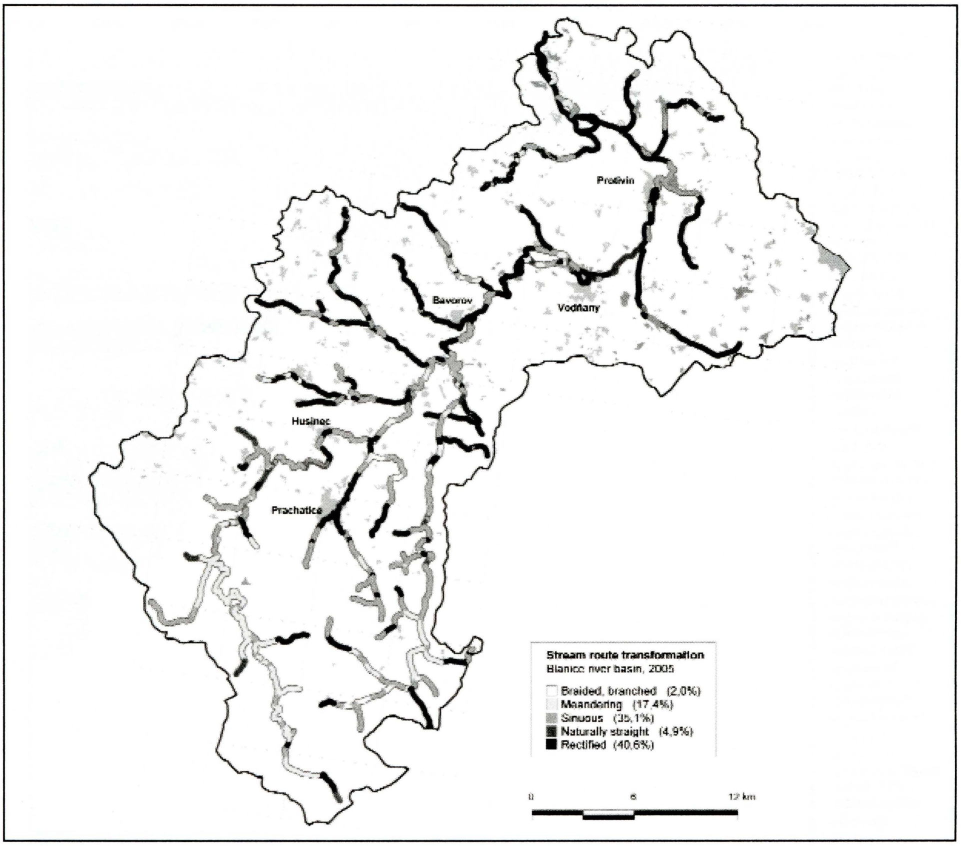

Fig. 5 – Modification of the stream route based on field mapping. Percentage values give the share of the stream length with the given degree of modification of the stream route. Data: Field mapping 2005.

river basin, among individual watercourses as well as among individual watercourse segments. Main watercourses of the river system - Blanice and Zlatý potok - just like their main tributaries, show high variability of modification in individual parts of the river basin - while in the upper watercourse part, virtually natural watercourses are found with a minimum amount of interventions, the route in the lower part of the watercourse is modified considerably in long segments. The highest intensity of modification can be observed on small watercourses in the lower river basin part, in the agricultural region where changes of the stream route geometry are often apparent along the entire length of the watercourse (Tab. 3, Fig. 5).

3.2.2 Modification of longitudinal profile

Modification of the longitudinal profile, i.e. presence of natural or artificial steps in the riverbed, affects significantly the nature of the flow. In flood situations, places of change in the longitudinal profile accelerate erosion as well as accumulation processes, and they thus usually represent centres of increased destructive effects of the flood (Křížek, Engel 2003).

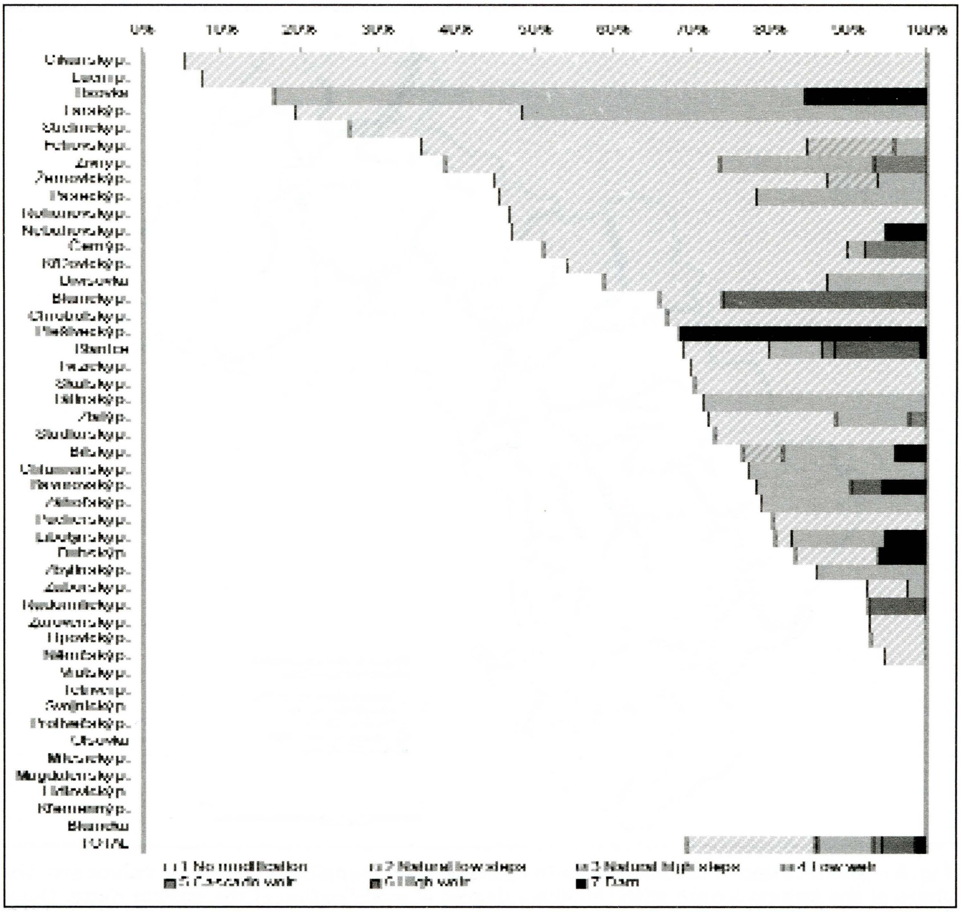

Fig. 6 – Structure of the stream longitudinal profile modification in the Blanice River basin. The percentage values show the share of length of segments with a given degree of modification within the watercourse. Data: Field mapping 2005.

In the Blanice River basin, segments of the longitudinal profile modifications represent a minority in the river network length. More than 70 % of length of the segments does not show traces of modification in the longitudinal profile, however, there are substantial differences between individual watercourses (Fig. 6). Modifications of the longitudinal profile are usually accompanied by straightening of the watercourse, when artificial steps compensate changes in the water level declination and speed of flowing in the straightened segments.

Artificial steps in the riverbed are concentrated spatially especially in the lower part of the Blanice River basin. Lower segments of Blanice and Zlatý potok and their tributaries show modifications of the highest intensity. Watercourses in the mountain part of the Blanice River basin show minimum modifications, on the contrary - the proportion of modified segments with artificial steps in the part of the river basin does not exceed 5 % of the aggregate watercourses length.

3.2.3 Modifications of riverbed

Anthropogenous modification of the watercourse riverbed affects the condition of the flow in the riverbed under normal as well as under extreme water levels. Interventions in the watercourse riverbed are leading, according the material used, into reduction of the riverbed hydraulic roughness, and consequently into increase of the flow velocity.

Modification of the watercourses riverbeds was evaluated separately during mapping for the right and left river bank, in categories summarized in Table 2. For the overall evaluation the modification level in the given segment was evaluated as the highest modification intensity value recorded for the right or left bank of the given segment.

There are remarkable regional differences in the Blanice river basin, as for intensity and nature of modification of the watercourses riverbeds. In the river basin as a whole, there is a marked high proportion of non-modified segments along the total length of the river network assessed - the total of 46.2 % and together with the slight modification forms they represent 60 % of the entire river network length.

Segments with the highest transformation intensity, i.e. segments with the riverbed partially or completely consolidated by concrete including tubing, represent more than one fifth of the whole river network length. Such a high proportion of intensively modified segments of watercourses is not adequate to the nature of the land use. Share of the segments in urban or industrial areas, where intensive modification may form part of flood protection measures, does not exceed 5 % in the river basin. A considerable part of the intensive modifications of the watercourses riverbeds, especially in the case of small watercourses, is a result of agricultural ameliorative measures from the second half of the 20th century. From the viewpoint of the current view of management of watercourses as well as needs of complex flood protection, this manner of watercourses modification is obsolescent, and revitalization modification could represent a suitable solution for a number of such watercourses.

Besides the nature of the riverbed modification, the watercourse modification structure, i.e. alternation of modified and non-modified segments, is of extraordinary importance for water flowing during a flood and for the nature of the consequences. Long modified segments increase the flowing speed and when passing into non-modified segments, especially at places of bends or meanders, acceleration of erosion and accumulation manifestations occurs. From the viewpoint of flood protection, pipelined segments and culverts represent an element with extraordinary risk, as these elements become blocked by materials drifted by the flood, with subsequent destruction of the respective structure and formation of the secondary flash-flood wave (fig. 7).

4. Discussion

Comparison of results of the watercourse modification assessment obtained from the field mapping and analysis of distance data is difficult in respect of the different nature of input data and methodology of their acquisition. In spite of that, it is apparent that the results are comparable as for the basic parameters.

First, this is a confirmation of results of the watercourse changes analysis from historical mapping materials (Langhammer, Vajskebr 2003) with

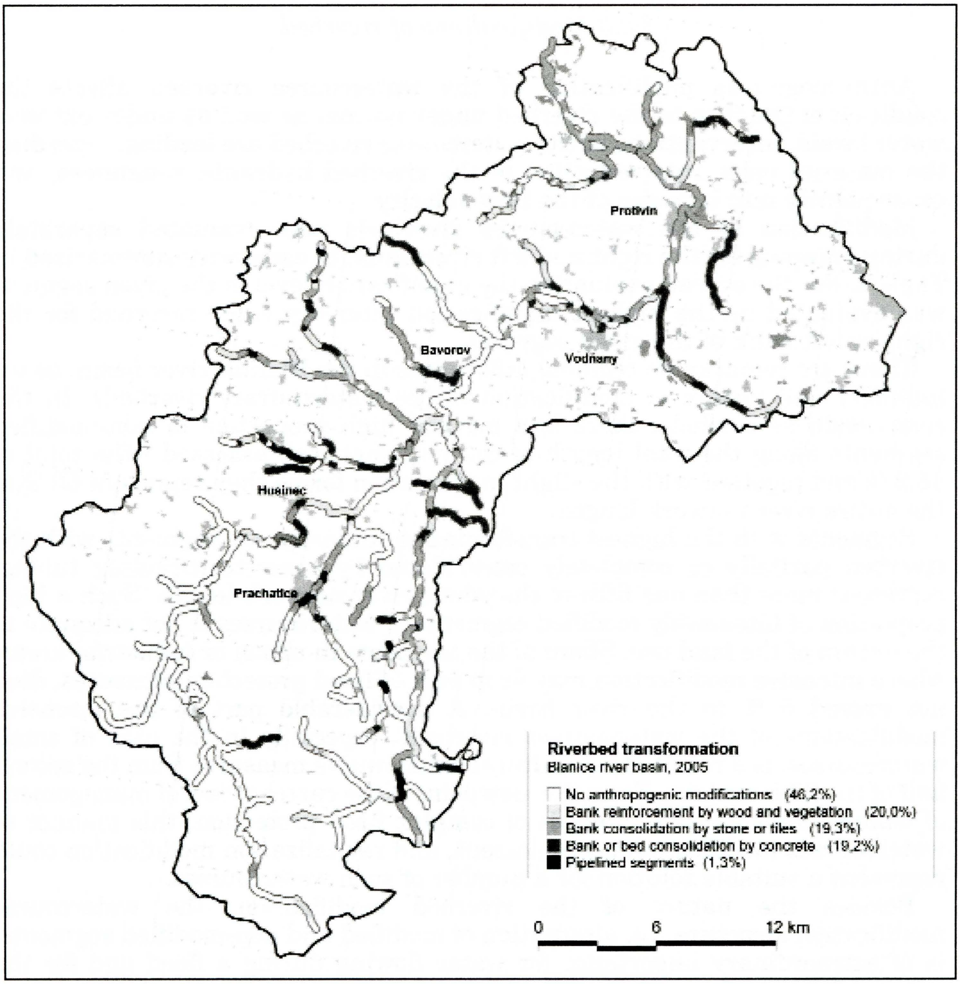

Fig. 7 – Modification of watercourses in the Blanice River basin. Data: Field mapping 2005.

results of field mapping. Segments identified as straightened based on assessment of the historical watercourse changes show signs of modifications of the stream route in field mapping, as well.

Comparison of the degree of anthropogenic transformation from the Water Management Map analysis also corresponds with findings from the terrain investigation, both from the viewpoint of the whole river basin of Blanice, as well as in comparison of regional differences. Accurate comparison of the values obtained is not possible in respect of varying scales of the used topographical maps and methodology; in spite of that, the results show identical relationships as for basic categories of modification.

Therefore, usage of distance mapping and data materials can be recommended as the fundamental data source for identification of anthropogenically affected segments of the river network, and for assessment of overall values of modification intensity of individual river basins. For accurate assessment of the nature and intensity of the modifications and identification of critical segments, in respect of possible affecting of the course and consequences of floods, it is necessary to use field mapping. Specifically focused field mapping provides the accurate data that can be used both to evaluate the current state of the river network transformation, as well as the data for further analysis, like, for example, hydraulic modelling or geostatistical assessment. As for practical application of assessment of anthropogenic modification of the river network, it is necessary to stem from limits given by individual methodical approaches, availability, and nature of the data used, and the exacting character of their acquisition.

Analysis of modification of the watercourses and the floodplain based on field mapping offers possibilities of assessment of a large amount of aspects of the river network anthropogenic transformation, together with further indicators, such as, for example, evaluation of the course and consequences of floods. Experience from mapping of the watercourses and river network modification within medium-sized river basins shows that for practical usage, it is important to fulfil the following conditions:

- precise formulation of the assessment goal and definition of the corresponding mapping parameters and categories
- ensuring of the assessment objectivity in field mapping methodology
- ensuring of data consistency obtained from multiple mappers
- choice of a suitable data collection technique and sound preparation of materials for mapping
- choice of suitable results processing technology
- balancing of the proportion between the informative value of the data obtained and the exacting character as far as time and costs are concerned of their acquisition
- ensuring of broader usability of the results obtained and compatibility of the information obtained with general standards.

Formulation of the assessment goal, and definition of suitable indicators and the structure of mapped parameters, represents a key condition for successful acquisition, analysis, interpretation, and usage of the watercourse modification data. For the specific purpose of assessment, it is desirable to pay attention to selection of only those indicators that are relevant for the resulting evaluation, and selection of those categories that can provide the information needed. Input data of non-suitable structure may make proper assessment and interpretation of the results more difficult or impossible. Parameters not used in the assessment moreover markedly extend the time needed for field mapping as well as digitising of the results, and they thus results in higher costs of the mapping. If a more extensive region is the subject of assessment, a key condition to obtain reliable data is represented by preserving the consistency of assessment of multiple mappers. The decisive role is played by sound preparation of ground materials, training of the mappers, their supervision, and checking of the results.

The present dynamic evolution of geospatial technology allows the usage of new tools for field mapping. This applies mainly to the usage of handheld devices equipped with mobile GIS applications like e.g. ESRI ArcPad. Experience from field testing of these mobile technologies however shows that in case of mapping with complex set of assessed features these tools offer lower flexibility in routine usage compared to traditional procedures, require specialized training technical help for mappers, prove sensitivity to atmospheric conditions, and are considerably more demanding as far as the financial costs are concerned.

Informative value of the source data represents a significant limiting element for assessment based on distance data. The informative value is influenced by the differing nature of various data sources, as well as by the degree cartographic generalization. The data obtained from WMM 1:50,000 capture modification of the major watercourses and their tributaries. The AWMA database records channel modifications of small and middle-sized catchments and drainage measures that fall within the AWMA administration. As for modification of individual tributaries, both of the mapping sources match. In order to perform overall balance of modification of the river network in the entire Blanice River basin, the assessment applied based on WMM 1:50,000 provides good informative value. The analysis performed in the scale 1:10,000 makes the information more accurate, and at the same time, it allows to perform basic qualitative assessment of the river network modification, i.e. assessment of the channel fortification and their age. A disadvantage is represented by the fact that AWMA maps do not have the character of a geodatabase. It must be also mentioned that the analysis performed does not take into account anthropogenic modifications performed in the longitudinal profile of the watercourse, i.e. slope modifications and building of weirs and water reservoirs.

5. Conclusions

The Blanice River basin can be termed as a region where the river network has been remodelled in a significant extent. A relatively high degree of modification is present here, especially on middle and lower courses. Marked spatial differentiation of intensity of anthropogenic interventions in the river network is characteristic in individual parts of the river basin as well as between individual watercourses assessed. In general, it can be stated that from mountain and foothill regions toward middle and lower courses, the degree of modification of the river network increases. This is clearly related with the growth of agriculturally cultivated areas and urbanized areas. The highest degree of modification of the river network was recorded in the lower part of the Blanice River. The main cause is represented by flood protection and hydro-amelioration measures in the landscape. The majority of the hydro-amelioration was performed in 1960-1980. Concrete materials and cobblestones represent the prevailing type of fortification of the riverbeds. It follows clearly from both analyses that the degree of anthropogenic modification of the river network reaches more than 40 % on the lower course of the Blanice River. Such remodelling of the river network has changed the flow regime, and especially has an influence on transformation of flood waves. Moreover, the high intensity of channel modification in a number of segments, especially in the area of the flat floodplain in the lower course of the Blanice River, represents an obstacle for efficient usage of the natural retention and transformation potential of the floodplain for the needs of passive flood protection (Janský 2003).

The methodologies used for mapping of channel modification and of the riparian zone, and the distance data analyses applied on the Blanice River basin, have shown the possibilities as well as limits of their usage. The results have confirmed that analysis of anthropogenic transformation of the river network represents a significant tool both to evaluate the intensity of affecting the environment, as well as to provide valuable information to assess vulnerability of the territory by the flood risk and identification of risk elements in the river systems.

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S h r n u t í

MAPOVÁNÍ A GEOINFORMATICKÁ ANALÝZA UPRAVENOSTI TOKŮ A ÚDOLNÍ NIVY JAKO FAKTORU POVODŇOVÉHO RIZIKA

Antropogenní zásahy do koryt toků představují významný fenomén, který ovlivňuje odtokové poměry zasažených povodí jak za normálních vodních stavů, tak v období hydrologických extrémů. Úpravy toků na různé úrovni – od zásahů do geometrie trasy toku přes

přítomnost umělých stupňů v jeho podélném profilu až po úpravy vlastního koryta či úpravy příbřežní zóny, při povodních výrazně ovlivňují rychlost a charakter odtoku vody z povodí. Jedná se zejména o rychlost postupu povodňové vlny, možnost její efektivní transformace, změnu časování souběhu povodňových vln z různých částí povodí a v neposlední řadě přispívají rozdílnou měrou k charakteru vzniklých škod na majetku, infrastruktuře i krajině.

Příspěvek představuje metodický rámec pro hodnocení antropogenní upravenosti toků na základě dvou základních přístupů, vycházejících z analýzy distančních dat a z terénního mapování. Analýza distančních dat vychází z analýzy GIS historických a recentních kartografických podkladů, jaké představují např. historické mapy či ortofoto snímky. Pozornost je věnována zejména těm datovým podkladům, které vzhledem ke kartografické kvalitě umožňují více či méně realistické srovnání se stávajícím stavem. Takovými podklady jsou na našem území např. mapy 2. a 3. vojenského mapování Rakousko-Uherské monarchie či mapy Stabilního katastru, které umožňují analýzu vývoje jednotlivých prvků krajiny v posledních cca 160 letech. Jako další datový vstup pro hodnocení dynamiky změn v podrobném měřítku jsou diskutovány ortofoto snímky, umožňující zachytit změny krajiny od 30. let 20. století, tj. včetně nejdynamičtějších fází vývoje zahrnujících období kolektivizace a intenzifikace zemědělství i změny po roce 1990.

Terénní mapování naproti tomu umožňuje zachytit změny v krajině v nejvyšší míře detailu a především v parametrech, které není možné odečíst nebo odvodit z distančních podkladů. Jde zejména o hodnocení intenzity a charakteru antropogenní upravenosti říční sítě na úrovni trasy toku, podélného profilu, příčného profilu, břehové vegetace či využití příbřežní zóny či identifikaci potenciálních překážek proudění při povodni. Výsledky mapování upravenosti toků a příbřežní zóny je možné díky integraci v GIS vyhodnotit společně s informacemi odvozenými z distančních podkladů či popisujícími jiné aspekty hodnoceného procesu.

Oba přístupy - hodnocení na základě distančních dat i na základě terénního mapování, jsou aplikovány na konkrétním příkladu povodí Blanice ležící v jádrové oblasti extrémní povodně, která v srpnu 2002 zasáhla oblast střední Evropy. Autoři se zde zaměřují na vyhodnocení současného stavu upravenosti říční sítě a její prostorové variability a zároveň diskutují možnosti a limity praktického využití jednotlivých přístupů a zdrojů dat pro získání objektivních podkladů pro komplexní hodnocení povodňového rizika a jejich praktickou aplikaci.

Výsledky provedených analýz ukazují, že povodí Blanice představuje území, kde byl významně přemodelován charakter říční sítě. Setkáváme se zde s relativně vysokým stupněm upravenosti, především na jejím středním a dolním toku. Charakteristická je výrazná prostorová diferenciace intenzity antropogenních zásahů do říční sítě v jednotlivých částech povodí i mezi jednotlivými hodnocenými toky. V obecné rovině lze konstatovat, že od horských a podhorských oblastí směrem ke středním a dolním tokům stupeň upravenosti říční sítě roste, což zcela jednoznačně souvisí s nárůstem zemědělsky obhospodařovaných ploch a urbanizovaných území. Největší upravenost říční sítě byla zaznamenána na dolním toku Blanice. Hlavní příčinnou jsou protipovodňová a hydromeliorační opatření v krajině. Většina hydromelioračních úprav byla provedena v období 1960-1980. Převládajícím typem opevnění koryt jsou betonové prefabrikáty a kamenná dlažba.

Z obou analýz jednoznačně vyplývá, že stupeň antropogenní upravenosti říční sítě dosahuje na dolním toku Blanice více než 40 %. Takovéto přemodelování říční sítě, má nepochybně vliv na charakter odtokového režimu a především na transformaci povodňových vln. Vysoká intenzita upravenosti koryt toků navíc v řadě úseků, zejména v oblasti ploché údolní nivy na dolním toku Blanice, představuje překážku pro efektivní využití přirozeného retenčního a transformačního potenciálu údolní nivy pro potřeby pasivní protipovodňové ochrany.

Použité metodiky mapování upravenosti koryta toku a příbřežní zóny a analýzy distančních dat, aplikované na povodí Blanice, ukázaly možnosti i limity jejich využití. Výsledky potvrdily, že analýza antropogenní transformace říční sítě je významným nástrojem jak pro hodnocení intenzity ovlivnění přírodního prostředí, tak poskytuje cenné informace pro hodnocení zranitelnosti území povodňovým rizikem a identifikaci rizikových elementů v říčních systémech.

Obr. 1 – Princip členění toků na úseky a jejich propojení s databázovými záznamy.
Obr. 2 – Upravenost toků v povodí Blanice. zdroj. ZVM 1:50 000
Obr. 3 – Upravenost říční sítě v dílčím povodí Blanice V. Upravenost koryta: podpovrchová drenáž, dlažba, vegetační opevnění, beton, tok, rozvodnice

Obr. 4 – Napřímené koryto Blanice na dolním toku s protipovodňovými valy. Povodňové hráze zde chrání zemědělskou půdu a brání tak efektivnímu využití přirozeného potenciálu ploché údolní nivy. Foto J. Langhammer 2005.

Obr. 5 – Upravenost trasy toku na základě terénního mapování. Procentuální hodnoty udávají podíl délky toku s daným charakterem upravenosti na celkové délce hodnocené říční sítě. Data: Terénní mapování, 2005. Upravenost trasy toku: rozvětvený, divočící (2,0 %), meandrující (17,4 %), zákruty (35,1 %), přirozeně přímý (4,9 %), napřímený (40,6 %)

Obr. 6 – Struktura upravenosti podélného profilu v povodí Blanice. Procentuální hodnoty udávají podíl délky toku s daným charakterem upravenosti na celkové délce hodnocené říční sítě. Data: Terénní mapování, 2005

Obr. 7 – Upravenost koryt toků v povodí Blanice. Upravenost koryta toku: bez úprav (46,2 %), vegetační zpevnění a dřevěná kulatina (20,0 %), zpevnění břehu lomovým kamenem nebo kamennou dlažbou (19,3 %), zpevnění břehu nebo dna betonem (19,2 %), zatrubnění (1,3 %). Data: terénní mapování, 2005.

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