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Anthropogenic Transformation of River Network in the Otava River Basin

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Abstract

The article is focused on the analysis of effect of the anthropogenic transformation of the river network on the course and consequences of floods. The process is analysed on the example of Otava river basin which is located at the core zone of the extreme floods in August 2002 in Central Europe. The assessment stems from large-scale field mapping of current intensity of transformation of the riverbed, river longitudinal profile, floodplain and the river course. More than 600 km of streams representing the backbone of Otava river basin was mapped using a newly developed mapping methodology allowing integration of the results in GIS and their consequent geostatistical treatment.

The results prove the high intensity of riverbed and floodplain modifications mainly in the agricultural landscape as well as the intensive transformation of longitudinal profile of the rivers. The anthropogenic changes of streams importantly affect the flood course and flood consequences and the experience from 2002 flood in the Otava river basin proves this relation. The mapping methodology presented in the article thus can be used as efficient tool to identify the critical segments of the river network with regard to the flood risk and to improve the flood protection planning process.

Key words: hydrology; floods; river network transformation; flood plains; GIS; mapping

1. Introduction

Anthropogenic transformation of watercourses and flood plains significantly influence runoff process and hydrological conditions of river basins. Human interventions to watercourse routes, longitudinal profiles, river-bed geometry, cross sections, or riparian belt use affect the speed of water runoff, the form of flood waves, flood wave timing in partial river basins, and the overall river basin capacity. Particularly during extreme hydrological events the stream modifications have a significant impact on the flood course, flood wave transformation, retention capacity of affected areas, and flood consequences. A good knowledge and specific assessment of watercourse and flood plain anthropogenic modifications are therefore essential for flood protection planning and landscape management.

The aim of the project was to assess the current state of watercourse and riparian belt anthropogenic modifications in the Otava river basin and to specify their impact on the extreme flood in August 2002 and its consequences. For the data acquisition and consequent geospatial analysis there was developed a new methodology of field mapping. The methodology was tested in the core zone of the 2002 flood and brought important information on spatial distribution and intensity of river network modifications. The results of river network transformation analysis were consequently used in analysis of impact of anthropogenic modification of the river network on the flood course and consequences.

2. Material and Methods

2.1. Methodology

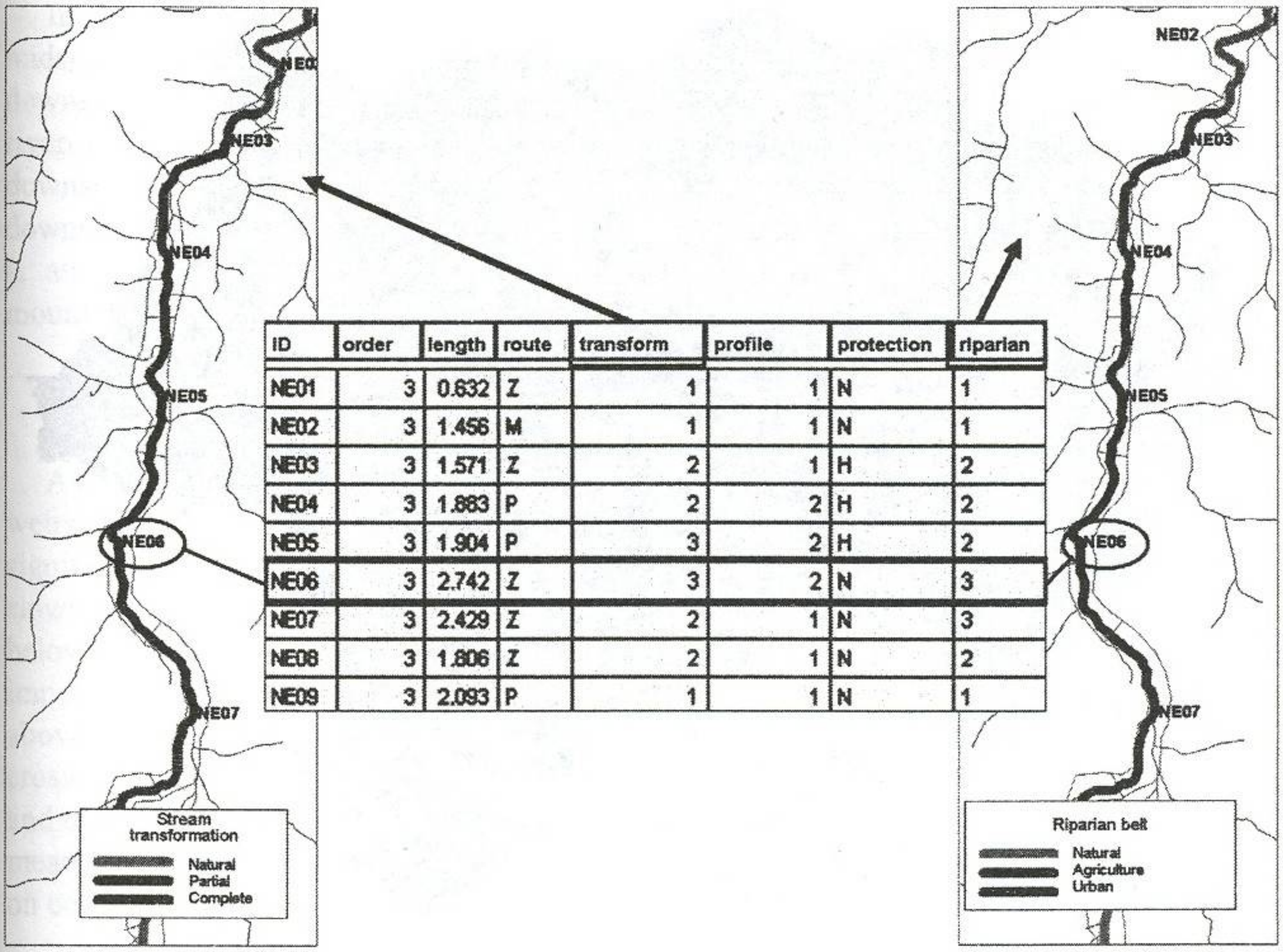
To assess the relations between anthropogenic modifications of the river network and flood consequences, in the framework of the project a new methodology of watercourse and riparian belt mapping was proposed. The methodology was designed to ensure the highest assessment objectivity, transparency, ability to cover large areas within the same time period, results integration into GIS, and to produce information applicable in consequent analysis and modelling.

The main principle of the methodology is the splitting of the watercourses into individual segments where is assessed the level of anthropogenic modifications according to predefined parameters. The delimitation of the segments is based on the principle of homogeneity in at least of one of the observed parameter. The length of the segments may vary according the level of watercourse and floodplain heterogeneity. The individual segments indicated on maps are marked by unique codes to ensure their identification in further processing. The values of parameters are recorded in uniform forms. Delimited segments and the corresponding values of monitored parameters are digitised and subsequently integrated in the GIS environment to allow consequent treatment and analysis.

Anthropogenic modifications of river network were monitored in terms of five key parameters: watercourse route, longitudinal profile, river-bed, riparian belt, and flood control measures resulting in the following potential states of watercourses and flood plains (see Tab. 1).

Tab. 1 Assessed parameters of river network transformation

Parameter	Environment	Status
Watercourse route	Watercourse	Straight / Sinuous / Meandering / Braided / Branched
River-bed modifications	Watercourse	Unaffected / Partially modified / Completely transformed / Pipelined
Longitudinal profile modifications	Watercourse	No steps/ Steps under 50 cm / Steps of height 50–100 cm / Steps higher than 100 cm
Flood control measures	Flood plains	None / Active measures (flood control dykes) / Passive measures (polders, oxbow meanders) / Ponds and water bodies
Riparian belt	Flood plains	Natural vegetation (meadows, wetland, forest etc.) / Agricultural areas / Scarce settlement / Intensive urbanisation



ID	order	length	route	transform	profile	protection	riparian
NE01	3	0.632	Z	1	1	N	1
NE02	3	1.456	M	1	1	N	1
NE03	3	1.571	Z	2	1	H	2
NE04	3	1.883	P	2	2	H	2
NE05	3	1.904	P	3	2	H	2
NE06	3	2.742	Z	3	2	N	3
NE07	3	2.429	Z	2	1	N	3
NE08	3	1.806	Z	2	1	N	2
NE09	3	2.093	P	1	1	N	1

Fig. 1 The principle of mapping and assessment of the river network modifications

The intensity of the watercourse route modification, riverbed modification and longitudinal profile modification was assessed for each segment of the river course as a whole. Riparian belt modifications and flood control measures were recorded separately for left and right banks. Individual segments were accompanied by explicatory notes that completed the mapping results with data uncovered by a standard classification, but important for documentation of the impact of river-bed or riparian belt modifications on the flood course and consequences. The methodology can be generally applied in assessing river basins sensitivity to flood risks in areas with different physicogeographical conditions and different intensity of human impact.

2.2. Study Area

The methodology was applied in the Otava river basin in the framework of a research of the impact of landuse changes on the 2002 flood course and consequences (see Langhammer, Vilímek, 2005 in this volume).

The mapping has covered 610 km of watercourses representing the backbone of the hydrographical network and was completed by segments affected by significant flood consequences. Field mapping was performed by some 20 workers and the whole area was

Fig. 2 The Otava river basin and its subcatchments

covered approximately within 90 days. Mapping results were digitalised on the basis of the digital watercourse lines from the ZABAGED geodatabase. The data from individual subcactchments were cross-checked for correctness and consistency of assessment results to ensure their applicability for assessment of the whole river basin.

3. Results

3.1. Watercourse Routing Modifications

River-bed modifications seem to be the most distinctive indicator of watercourse transformation. While interventions into the geometry of watercourse profiles (particularly profile reinforcement) may not be evident in the course of time, route rectification is a direct proof of performed modifications even after decades.

River system shortening has a significant impact on water runoff acceleration during floods leading to a faster progress of flood waves. River-bed shortening accelerates water flow in rectified tracks and increases a flood wave slope intensifying devastating effects in affected areas. River network shortening is often accompanied by simultaneous deepening of the riverbed profile aiming in increase of riverbed capacity. Despite this the total water volume in the whole river segment may decrease which may be critical during the extreme flood events.

In the Otava river basin, the highest number of rectified segments is located on midstream and downstream river segments in agricultural areas. River basins of the downstream Blanice and midstream Otava river is rectified in more than 40% of total river length. Remaining sub-basins of the midstream and downstream Otava and downstream Volyňka have more 30% of the river length with rectified segments. In downstream areas, where watercourses tend to natural meandering the rectification is attributable to anthropogenic activities. To the contrary, straight segments in mountainous areas are mostly induced by geomorphology.

3.2. Longitudinal Profile Modifications

Anthropogenic modifications of the longitudinal profile comprise artificial steps and weirs changing the longitudinal profile of the river-bed. In terms of the water flow, they significantly affect flow dynamics above and below the step. Afflux above the steps slows down the flow and results in broader flood spill in the flood plains. On the contrary, below the steps the water flow is accelerated. During floods, regulatory structures are impeding the geomorphologic effects of the flood, i.e. erosion and accumulation. Afflux above dams causes overflow accelerating material sedimentation and leads to intensive erosion under weirs. Only weirs designed with an adequate water-surface elevation and the crest at a right angle to the stream are affected relatively less. Weirs situated in meanders or in an oblique direction towards the water flow lead to intensified erosion on concave banks.

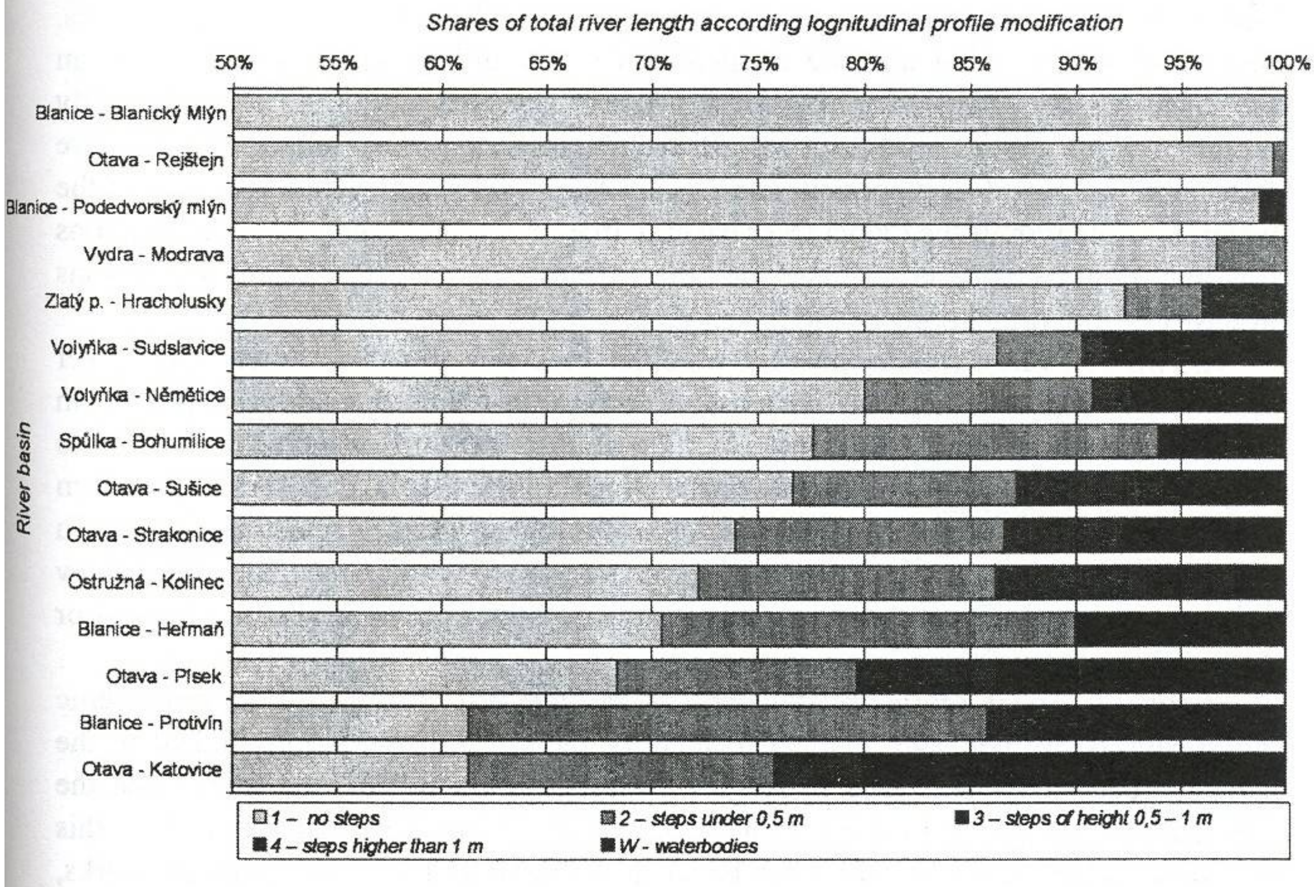


Fig. 3 Watercourse longitudinal profile anthropogenic modifications in river basin subcatchments

In the Otava river basin, we identified in total 337 steps out of which 169 were weirs. The highest number of artificial steps in absolute terms was found on the Volyňka river (60), Otava (54), Ostružná (39), Spůlka (37), and Blanice (31). In general, steps are concentrated in midstream and downstream areas. In terms of frequency, the highest amount of steps in the river-bed was found on the Spůlka river where we counted 37 steps on a 9-km track, and on the Nezdický stream, Volyňka, Ostružná, and Losenice. All of the watercourses are located in the main area affected by the 2002 flooding.

Findings of such a high concentration of artificial steps in midstream and particularly downstream areas of the river basin are confirmed by results of assessment in the main balance river basins. The highest number of modifications was identified in the downstream and midstream Otava and Blanice river basins, where the percentage rate of watercourses with longitudinal profile modifications was close to 40%, on the Otava river down to Písek or Strakonice, on the Blanice river down to the Heřmaň profile, and on the Ostružná river. To the contrary, mountainous areas of the Otava, Blanice and Vydra river basins are almost free of any modifications, the percentage rate of modified segments being lower than 5% of the whole watercourse length.

3.3. Anthropogenic Modifications of River-Bed

The term "river-bed anthropogenic modifications" applied in the presented methodology covers anthropogenic interventions into the river-bed geometry and river bank or bottom reinforcement by a foreign matter leading to roughness changes. Results of the mapping indicate intensive river-bed anthropogenic modifications in the most of Otava river basin. Out of 610 km of assessed length, 43% are currently modified while partial modifications affect 26% of watercourse length and 16% are fully modified; 0.1% is pipelined, and 2% are lakes and ponds. Although 55% of the watercourse length in the Otava river basin is free of any anthropogenic modifications it is important to take into account the huge differences in watercourse modifications intensity in individual parts of the river basin.

The highest rate of anthropogenic modifications was found on downstream river segments in agricultural areas. In absolute terms, the highest rate was detected in the downstream Blanice river basin reaching almost 100% of observed watercourses length. Extensive modifications however affect also the Otava mid and downstream areas, Ostružná and Spůlka basins, and the Volyňka and Blanice midstream areas. To the contrary, the headstream areas of the Otava river basin (Blanice and Vydra) show only minimum modifications and more than 80% of their length are in a natural or almost natural state.

Important aspect of the field mapping was the classification of anthropogenic modifications by their age, namely to identify the fresh modifications linked to the damages caused by the flood in August 2002. Results can be used to provide the feed back for mapping in other parameters. However, the informative value of this parameter is limited by the time gap between the flood and the field mapping works, and by the progress of reconstruction works. Although the mapping was performed

Fig. 4 Reconstruction of river bank pavement damaged by the flood. The river segments located under the weirs were frequently points of intensive erosion and accumulation as result of the flood in August 2002 (Photo J. Langhammer, 2003)

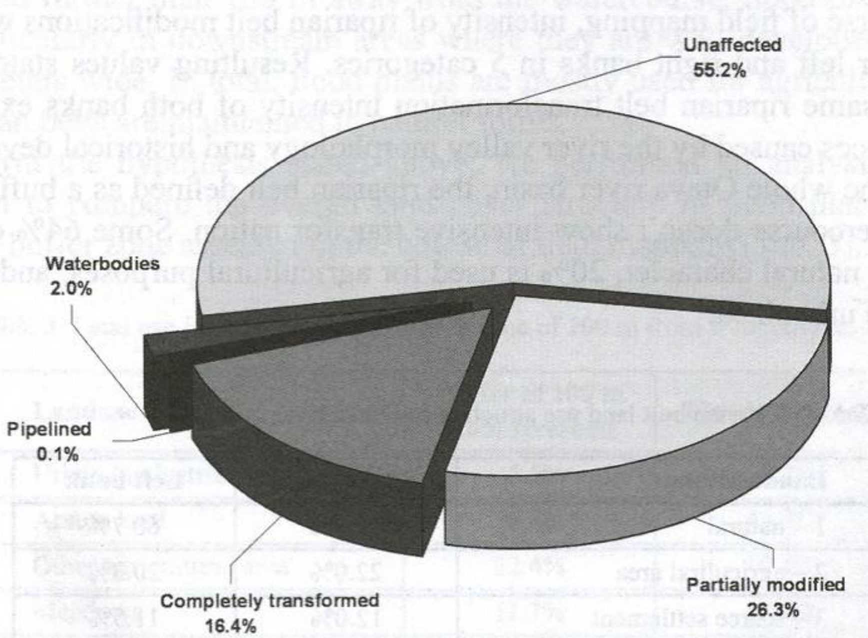


Fig. 5 Anthropogenic modifications of the river bed in the Otava river basin

8 months after the flood, many of the damaged structures were not still repaired due to focus on priority reconstructions in urban areas and infrastructure and thus they are not appearing in results among the fresh riverbed modifications.

3.4. Riparian Belt Modifications and Land Use

The character and intensity of riparian belt anthropogenic modifications have a significant impact on the runoff wave transformation during floods and the overbank spill. Flood plains with adequate land cover have an extraordinary potential to transform flood waves and increase retention capacity of the runoff area thanks to their overall volume. Flood plains thus represent a highly important element for the flood control.

The optimal land cover of flood plains to preserve their positive effects on flood wave's transformation is permanent grassland combined with wood species. However, due to good accessibility and almost no terrain diversification, flood plains are often used intensively for agriculture, settlement, industrial areas and transport lines which result of loss of their natural transformational capacity. In addition, when flooded, the agricultural areas become a source of material transported by erosion and accumulated in downstream areas. During floods, road embankments cutting through flood plains change their discharge profile and block water flow causing intensification of local damage.

During the 2002 flooding, water fully filled almost whole flood plain profiles on midstream and downstream river segments, mainly in the Otava, Blanice and Volyňka rivers and their tributaries. The water levels there often raised even several meters above the floodplain ground (see Fig. 6). Intensity and structure of flood plains land use thus were important factors affecting the course of floods, flood wave transformation and overall flood consequences.

In the course of field mapping, intensity of riparian belt modifications was assessed separately for left and right banks in 5 categories. Resulting values stated in Tab. 2 indicate the same riparian belt transformation intensity of both banks except certain local differences caused by the river valley morphology and historical development of the area. In the whole Otava river basin, the riparian belt defined as a buffer of 100 m from the watercourse doesn't show intensive transformation. Some 64% of its length preserves the natural character, 20% is used for agricultural purposes, and 16% of the total length is urbanized.

Tab. 2 Riparian belt land use structure in Otava river basin

Landuse class	Right bank	Left bank
1 – natural	60.3%	60.7%
2 – agricultral area	22.0%	20.3%
3 – scarce settlement	12.0%	11.5%
4 – urbanized area	4.4%	5.1%
W – waterbodies	1.3%	1.2%

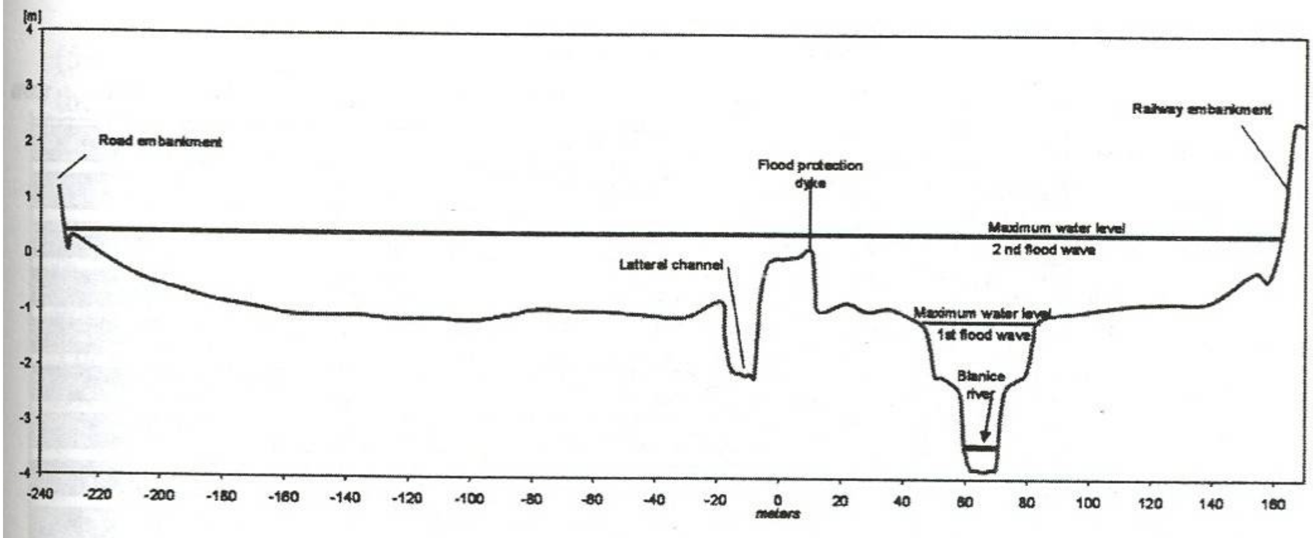


Fig. 6 Cross section of the Blanice river at Protivín

With respect to the regional differences, the highest percentage of modified zones in watercourse riparian belts was found around the Otava, Blanice, Spůlka and Zlatý brook downstream segments. Riparian belts around mountainous watercourses are often formed by natural areas in more than 75%. In total natural riparian belts represent 60%, which is positive in terms of transformational effects of flood plains.

However, stated values of riparian belt usage intensity differ significantly from the assessment results for the whole flood plains. The flood plain land cover analysis made on the basis of the CORINE land cover geodatabase indicates a significantly higher share of agricultural land in flood plains than showed by the results of the riparian belt structure mapping. The overall agricultural land share in flood plains of assessed watercourses exceeds 60% and arable land accounts almost for 45%.

Such variations are caused by differences in delimitation of the riparian belt and flood plains area and in assessed land cover categories. While mapped riparian belts aren't located further than 100 m away from the watercourse, flood plains are much broader particularly in downstream areas where they are well developed and several hundreds meters wide. In total, flood plains are mostly used for agricultural purposes while riparian belts are maintained in natural forms.

To confirm the hypothesis stated above, we performed an analysis in the GIS environment to compare the overall land cover structure in flood plains and in the 100 m wide buffer zone assessed in the course of field mapping (Tab. 3).

Tab. 3 Land use in flood plains and buffer zone of 100 m from watercourses

Landuse class	Buffer of 100 m from riverbed	Floodplain total
Urban / industrial area	5.5%	8.2%
Arable land	25.5%	43.7%
Other agricultural area	22.4%	19.4%
Meadows	11.3%	15.9%
Forests	32.1%	11.4%
Water and Wetlands	3.2%	1.3%

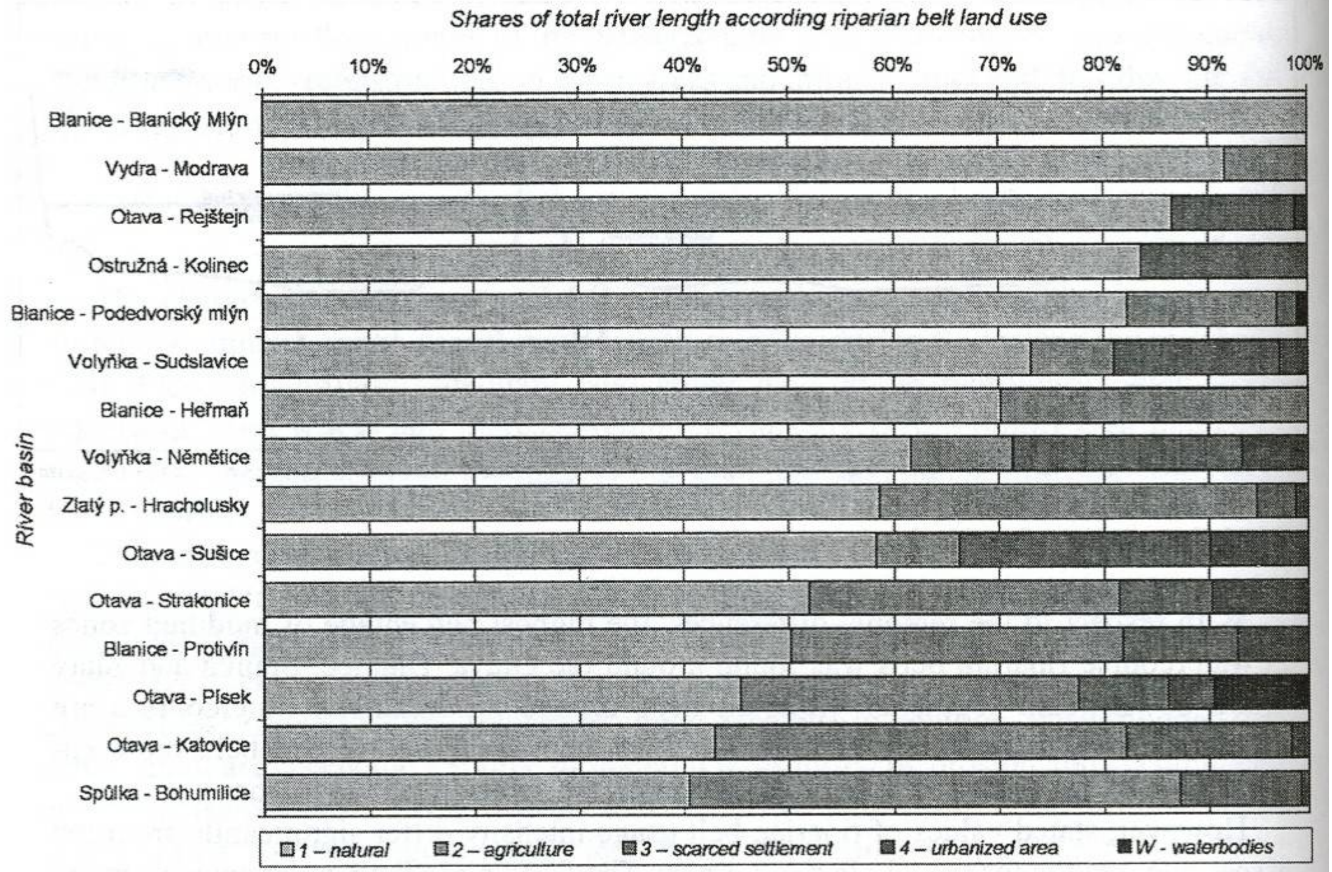


Fig. 7 Riparian belt land use in the Otava river basin by individual subcachements

The riparian belt structure identified through field mapping resembles the structure defined on the basis of remote data applicable to the buffer zone 100 m from watercourses. The greatest differences appear in the category of zones of nature-like characteristics. The analysis of supporting data shows that the mapping staff extended this category also to areas classified in the CORINE database as "Areas with prevailing agricultural land use with additional natural vegetation" and "Complex systems of cultures and land allotments". In the course of field mapping with different land use classification categories, such areas can be identified as zones of nature-like characteristics. It's necessary to define categories of riparian belt modifications in more specific terms to avoid confusion between individual categories and to facilitate results comparison with remote data.

3.5. Flood Control Measures

Mapping proved the presence of active flood control measures barriers in flood plains, mainly dykes and mound, in downstream areas – on the downstream Blanice river around Vodňany and Protivín, on the downstream Volyňka river, and on the midstream and downstream Otava around urban zones.

In the whole Otava river basin, the active flood control measures like barriers and mounds are located in 10% of watercourse length. The highest percentage of watercourse segments with flood control barriers was found on the downstream Blanice

(59%), Otava down to Sušice (23%), the midstream Blanice and downstream parts of the Otava where the share of flood control mounds in the flood plains exceeds 10% of the total length.

Passive flood control features are very scarce. Polders and oxbow lakes allowing safe water spill during floods and effective flood wave transformation were identified only in 1.6% of river length. Most of them were abandoned meanders of artificially rectified watercourses, in the whole Otava river basin there was not found any controlled polders. The highest percentage of natural retention spaces was detected in the downstream Blanice river basin (13.6%), on the Zlatý stream (4.6%), and on the midstream Otava (4.2%). The length of segments with passive flood control features doesn't reach 1% of the total length in any of the partial river basins except the downstream Otava (2.6%) and Ostružná (2.1%).

Passive flood control measures are scarce due to intensive use of flood plains dominated by arable land. Arable land covers 45% of the total flood plains acreage and jointly with other agricultural land represents 64% of flood plains. Meadows and pastures, the typical flood plain land cover, represent only 16%, forests 11%, wetland and water areas 1.4% of the total flood plains acreage.

From the point of view of flood protection the current structure of flood plains land use is inadequate. To increase the local retention capacity of the floodplain and effectiveness of flood wave's transformation there would be important to enlarge zones of passive flood control. It would be beneficial to build the polders combining flood control features and use of a natural retention potential. At a low discharge, they work as traditional dykes and at a high discharge they allow water storage in flood plains retention areas.

3.6. Flood Course Obstacles

In conditions of extreme floods the very important effect on resulting consequences has the structure of watercourse modifications and the presence of flood course obstacles in the floodplain. The flood consequences are significantly affected by the structure of anthropogenic modifications of river network, mainly by altering of segments with different intensity of transformation. Long, compact modified sections speed up the flow leading to concentration of erosion and intensive sedimentation hitting the unmodified zones, mainly in meanders and bends. The highest attention should be paid to pipelined segments that despite their short total length pose significant risks of considerable damage due to blockage by material transported by the flood wave. This leads to water accumulation and subsequent break of the temporary dike resulting in a flash-flood with significantly higher destructive capacity of the flood wave than under normal flood progress.

In Otava river basin the Losenice river could serve as an example. Its river-bed is formed mostly naturally with exceptions of 3 pipelined sections that significantly intensified the 2002 flood damages on properties and infrastructure.

Similar effect have flood course obstacles in the floodplain like improperly located or insufficiently designed bridges or culverts. They can induce blockage of the flow by transported material and creation of a temporary dike and after the sudden dam

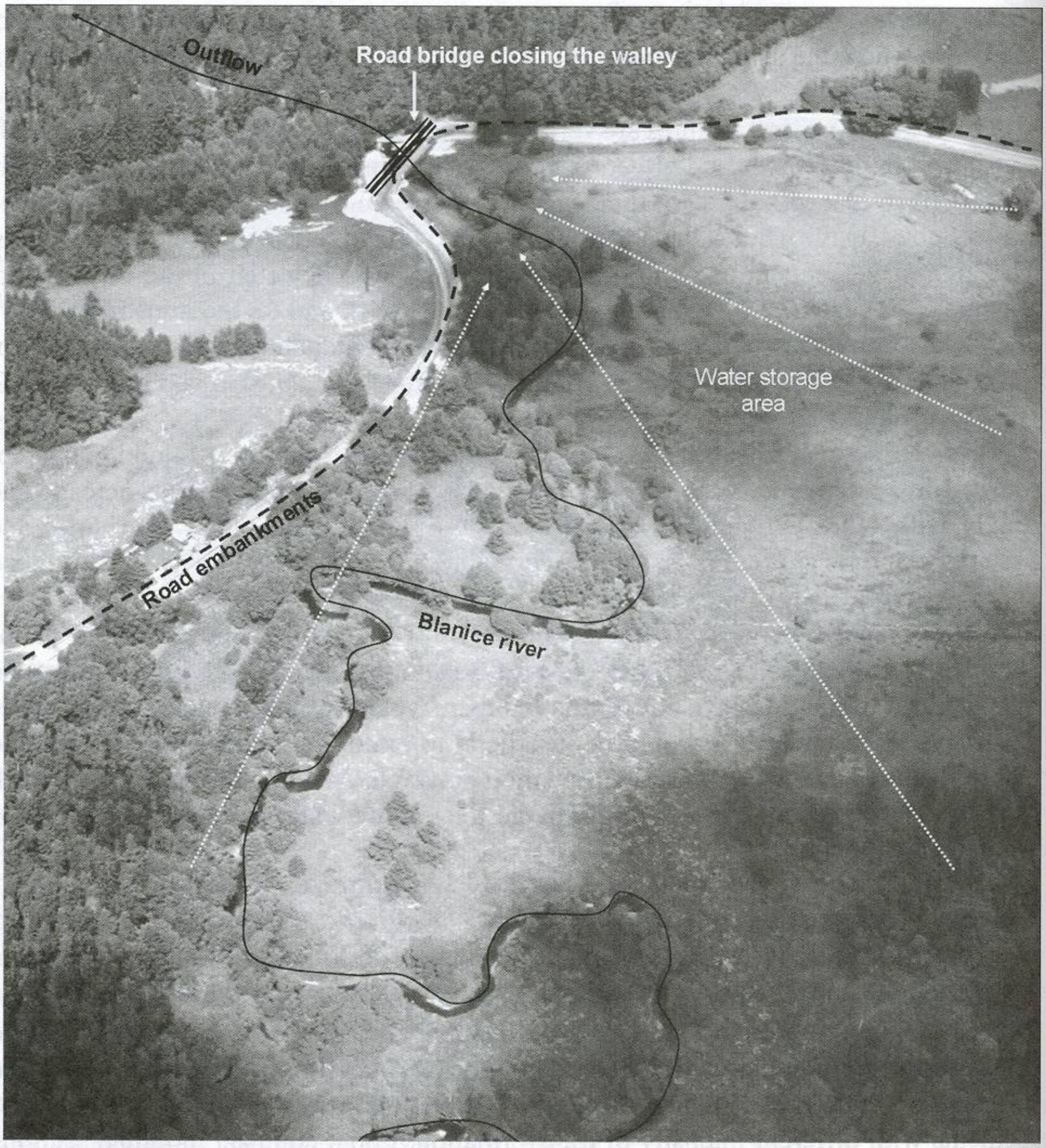


Fig. 8 Improperly located and designed bridge on the downstream Blanice river accelerated the geomorphological effects of the flood (Photo J. Langhammer, 2003)

break the flash-flood can occur. This process could be illustrated by the 2002 flood progress on the upstream Blanice river. The small road bridge closing a large flat valley was blocked by transported material. There was formed a large lake accumulating an enormous volume of water. After the break of the bridge the resulting flash-flood hit the already full dam reservoir located several kilometres downstream and heavily endangered its stability and safety.

4. Discussion

Results of extensive mapping activities indicate that watercourses in the Otava river basin are currently significantly affected by human activities. Although anthropogenic interventions into the hydrological network differ in terms of their characteristics and intensity, they affect watercourses of all categories even in natural or protected areas.

The intensity of anthropogenic transformation of river-beds and riparian belts increases with the overall intensity of land use in the direction from upstream to downstream areas. In the Otava river basin, the most intensively modified river segments are located on downstream parts of the main watercourses in agricultural landscape. Such watercourses show high modification intensity according to all assessed parameters, i.e. routing, longitudinal profile, river-bed, riparian belt land use, and flood control measures.

The obtained results correspond to results of other analysis works performed on assessed watercourses, particularly to the historical river network shortening analysis (Langhammer, Vajskebr, 2006, in this volume), analysis of the geomorphologic consequences of the flood (Křížek, Engel, 2006, in this volume), the assessment of flood control measures in the Otava river basin and analysis of their functionality during the flood in August 2002. The segments that according to field mapping are affected by the highest intensity of anthropogenic modifications correspond to localization of segments affected by the highest rate of historical rectification and the highest intensity of land use anthropogenic changes.

The impact of the watercourse and riparian belt modifications on the flood course and consequences is evident in two aspects – it affects the flood consequences in a close proximity of river network modifications but also the flood progress and damages in downstream areas.

4.1. Impact on Local Level

Anthropogenic transformation of the river system affects the course of floods and consequences in a close proximity to particular modifications and their surroundings only in selected aspects of the modifications. The most significant role has here the modifications of the longitudinal profile and river-bed and the intensity of the riparian belt land use.

Longitudinal profile modifications very strongly affect the intensity of erosion and accumulation processes. Improperly located weirs in watercourse meanders are often spots of massive bank cavings, destruction of regulatory structures, and extreme sedimentation. Field mapping indicated many such cases particularly on the Volyňka and Otava rivers.

River-bed modifications have only a limited impact on the local course of floods. However, the structure of watercourse modifications, mainly the effect of modified and unmodified segments alterations, plays a significant role. Runoff acceleration in modified areas intensifies flood consequences at borderlines with unmodified and mainly meandering zones. The course of floods is decisively affected by pipelined segments due to their jam by material transported by the flood. This leads to water accumulation and subsequent rupture resulting in a significantly higher destructive capacity of the flood wave. Such an effect could be illustrated by the flood development on the Losenice river in August 2002.

The character of the *riparian belt use* becomes a key factor when an over bank flow occurs. The structure of land cover in the area along watercourses and in flood plains is decisive with respect to their flood wave transformation effect and retention capacity. Flood plains covered by arable land may lower the retention potential of such zones. In the Otava river basin, this concerns mainly the Blanice midstream and downstream areas showing an enormous intensity of anthropogenic impact although the local conditions allowing for a more effective natural flood wave transformation in flood plains are very favourable.

4.2. Impact on Downstream

When analysing the impact of riverbed modifications on flood evolution, progress and consequences downstream from the regulations, the most important role is attributed to the effects of watercourse route and river-bed modifications. A special attention should be also paid to flood control measures.

River route modifications, mainly river-bed rectification, accelerate water runoff from river basins. Consequences aren't evident locally, but significantly affect the course of floods in downstream tracks. River system shortening by rectification speeds flood waves and increases their slope. The flood wave acceleration also reduces the time left for warning, evacuation and rescue works in affected areas. During the August 2002 flooding, the influence of rectification in the Otava river basin was limited only to the first flood wave when water mostly didn't spill over protective mounds along watercourses. During the second flood wave inundating whole flood plain areas the impact of watercourse shortening on the flood progress was marginal.

River-bed modifications, involving mainly changes in the cross section geometry and bank and river-bed reinforcement are mostly performed in hand with river routing changes. Their effect is visible particularly in cases of increasing river-bed capacity by river-bed deepening, made mainly for flood control purposes. River-bed deepening may locally prevent overflow of small or medium-scale floods, but generally accelerates water flow and flood wave progress further down in the river basin.

Flood control measures affect the course of floods locally, but may influence also other river segments in downstream areas. In urban areas, property protection is a priority, but the flood progress should be regarded in the context of the whole river basin. Measures increasing the river-bed capacity by deepening or dyke construction along the river-bed should be introduced only after considering their effectiveness and impact on the whole river basin. A special attention should be paid mainly to the balance between the value of locally protected property and potential damage intensification in downstream areas. This applies mainly to upstream and midstream areas where the concentration of properties in potentially affected areas is generally scarce and where the flood waves can be transformed effectively.

5. Conclusion

The application of presented methodology of mapping of anthropogenic transformation of river network in the Otava river basin proved the high level of spatial differentiation of the intensity of man-made changes in the river basin.

The river-beds have been modified with a varying intensity in the total of 43% of the assessed hydrological network length. Individual transformation parameters had different effect on the flooding process during the extreme flood in August 2002. The intensive anthropogenic modifications of riverbed and of the watercourse routing that were found predominantly on down streams helped to accelerate the speed of flood wave and its steepness. For the progress of the flood wave was critical the elimination of natural retention zones in the floodplain that reduced the potential for effective flood wave transformation. The intensive modifications of longitudinal profile had negative impact on flood consequences mainly in cases of inappropriate design and position of structures, their overall impact in the whole river basin was however limited. From the point of view of flood damages played the most critical role the obstacles in the floodplain. The mapping helped to identify the critical elements in the river network system that induced important damages related to the flooding and that should be further analysed.

The intensity of anthropogenic changes of river network in individual parameters in the Otava river basin can be regarded as one of the important factors amplifying the consequences of the extreme flood in August 2002. However the impact of individual measures was mainly at local level and thus the river network modifications cannot be generally considered as the main driving force of the extreme flooding.

The newly developed methodology of mapping of the river network modifications proved its applicability in flood risks analysis. The assessment procedure allows fast collection and objective processing of data from large areas, easy integration into the GIS environment and the subsequent geostatistical analysis. The methodology is helpful mainly due to its ability to identify critical zones in the hydrographical network with respect to flood risks and indicate a natural potential for transformation and retention within the river basin. This is why the methodology can be applicable for broad range of purposes varying from flood protection planning process, gathering data for complex geostatistical and geospatial analysis of river network transformation or preparation of input information for hydrological modelling.

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References

BETTESS, R. and FISCHER, K. R. (1999): Lessons to learn from the UK River Restoration projects. In: Balabanis et al. (eds): Ribamod – River basin modelling, management and flood mitigation. Concerted action – proceedings of the final workshop. European Commission, Luxembourg.

ČHMÚ (2003): Hydrologické vyhodnocení katastrofální povodně v srpnu 2002, ČHMÚ, Praha, [online] http://www.chmi.cz/hydro/pov02/. [Hydrological assessment of catastrophic flood in August 2002, in Czech]

CHENG, J. D., LIN, L. L. & LU, H. S. (2002): Influences of forests on water flows from headwater watersheds in Taiwan. Forest Ecology and Management 165, 11–28.

HAVLÍK, A., JUST, T. & SLAVÍK, O. (1997): Ekologická studie povodí Bíliny 2. díl – Kvalita vody a produkce znečištění v povodí Bíliny. Praha: VÚV TGM. [Ecological study of Bílina river basin, in Czech]

JANSKÝ, B. (2006): Water retention in river basins. Acta Universitatis Carolinae – Geographica, 38, 2, 173–184.

JUST, T. (2003): Revitalizace vodního prostředí, AOPK, Praha. [Revitalization of water environment, in Czech]

KENDER, J. et al. (2004): Voda v krajině, Praha. [Water in landscape, in Czech]

KONVIČKA, M. et al. (2002): Město a povodeň., Brno. [The city and floods, in Czech]

LANGHAMMER, J. (2006): Geoinformatic Assessment of the Consequences of Extreme Flood in August 2002 in Otava River Basin. Acta Universitatis Carolinae – Geographica, 38, 2, 185–202.

LANGHAMMER, J., MATOUŠKOVÁ, M. (2000): Výzkum kvality vodní složky přírodního prostředí v povodí Berounky, závěrečná zpráva z grantu, PřF UK, Praha. [Water quality research in the Berounka river basin, in Czech]

MAIDMENT, DAVID R., Ed. (1993): Handbook of Hydrology. New York: McGraw-Hill.

ROSGEN, D. L. (1996): Applied River Morphology. Pagosa Springs: Wildland Hydrology Books.

VILÍMEK, V., LANGHAMMER, J., KŘÍŽEK, M. (2003): Posouzení efektivnosti změn ve využívání krajiny pro retenci a retardaci vody jako preventivní opatření před povodněmi, závěrečná zpráva do vlády z dílčí etapy projektu Vyhodnocení katastrofální povodně v srpnu 2002. Přírodovědecká fakulta Univerzity Karlovy, Praha. [Assessment of effectiveness of landscape changes as tool for flood mitigation and improvement of water retention, in Czech]

VLČEK, L., ŠINDLAR, M. (2002): Geomorfologické typy vodních toků a jejich využití pro revitalizace. Vodni hospodarstvi, 2002 (6), 172–176. [Geomorphological classification of strerams and its application for revitalization, in Czech]

VÚV TGM (2003): Vyhodnocení katastrofální povodně v roce 2002, průběžná zpráva o řešení projektu, Praha. [online] http://www.vuv.cz/povoden/main.html [Evaluation of catastrophic flood in 2002, in Czech]

ANTROPOGENNÍ UPRAVENOST ŘÍČNÍ SÍTĚ V POVODÍ OTAVY

Résumé

Antropogenní upravenost říční sítě a údolní nivy je významným činitelem, ovlivňujícím hydrologické poměry povodí. Zásahy člověka do trasy vedení toku, jeho podélného profilu, geometrie koryta a upravenosti jeho příčného profilu či do způsobu využití příbřežní zóny mají vliv na rychlost odtoku vody z povodí, na tvar odtokové vlny, časování odtokových vln z dílčích povodí i na celkovou kapacitu říční sítě. Mimořádný význam má upravenost hydrografické sítě při extrémních hydrologických událostech, jakými jsou povodně. Řada z antropogenních úprav negativně ovlivňuje průběh povodně, transformační a retenční schopnost zasaženého území a tím i celkové následky povodně. Poznání a přesné vyhodnocení míry upravenosti říční sítě a údolní nivy je proto významným podkladem při plánování protipovodňové ochrany, vytváření územního plánu a managementu krajiny.

Článek hodnotí současný stav upravenosti říční sítě a příbřežní zóny v povodí Otavy a ukazuje, do jaké míry se charakter a intenzita transformace říční sítě projevily na průběhu a následcích povodně v srpnu 2002. Vyhodnocení bylo provedeno na základě rozsáhlého terénního mapování, které pokrylo přes 600 km, tvořící páteř hydrografické sítě v povodí. Pro toto mapování byla vytvořena nová metodika hodnocení upravenosti

toků, která byla formulována s ohledem na vliv stavu upravenosti koryta a příbřežní zóny na odtokový proces při povodni, zejména na průběh a transformaci odtokové vlny, rozliv, retenční potenciál povodí, protipovodňová opatření a potenciální škody způsobené povodní.

Mapování a následné vyhodnocení upravenosti říční sítě a příbřežní zóny v povodí Otavy ukázalo, že současná míra napřímení toků zejména v nížinných oblastech pomáhá k akceleraci následků povodně a lze konstatovat, že s výjimkou malých povodní neplní svůj původní účel. Odstranění přirozených retenčních prostor v těchto částech toku snižuje možnost transformace povodňové vlny. Výrazný vliv na následky povodně má přítomnost umělých stupňů v korytě, které představují překážku přirozenému proudění a v místech jejich výskytu je zintenzivněna erozní a akumulační činnost toku. Koryta toků jsou v různé míře intenzity antropogenně upravena na celkem 43 % délky hodnocené hydrografické sítě.

Jako jednoznačně negativní faktor je nutno brát rozšířené intenzivní zemědělské využití údolní nivy i vlastní příbřežní zóny. Orná půda v nivě má nepatrnou retenční kapacitu a neumožňuje účinnou transformaci povodňové vlny. Zároveň působí jako zdroj materiálu pro intenzivní plošnou erozi. Ta jednak poškozuje vlastní zemědělské plochy, zároveň však působí problémy akumulací tohoto materiálu v dolních částech toku včetně intravilánů.

Nová metodika mapování upravenosti koryta toku a příbřežní zóny, aplikovaná na povodí Otavy ukázala, že je vhodným nástrojem pro hodnocení citlivosti území na povodňové riziko. Navržený způsob hodnocení umožňuje při zachování přesnosti hodnocení rychlý postup při mapování i snadné zaškolení pracovníků, kteří terénní mapování provádějí. Rychlé a objektivní zpracování rozsáhlých území, snadná integrace výsledků do prostředí GIS spojená s následnou geoinformatickou analýzou umožňují využití této metodiky i v širším měřítku. Významná je především schopnost odhalit v rámci hydrografické sítě kritická místa z hlediska povodňového rizika a ukázat zároveň na přirozený transformační a retenční potenciál povodí. Tyto vlastnosti předurčují využití prezentované metodiky při přípravě podkladů komplexní protipovodňové ochrany území.

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