ANTHROPOGENIC RIVER ALTERATIONS AND THEIR EFFECTS ON THE FLOOD SITUATIONS (BÍLINA RIVER CASE STUDY)

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ABSTRACT

This paper summarizes the results of research focused on the evaluation of anthropogenic impacts on the formation and process of the flood. The HEM-F methodology, partially modified and supplemented by identifying potential risk parts which during the floods could complicate the water convection, was applied on part of the Bílina River. During mapping were evaluated selected reaches of the Bílina River, and determined watercourse characteristics and the degree of anthropogenic river alterations. The conclusions of the research indicate that more than 50% of the river length shows no significant risk factors that could have influence on the development and flood events.

Keywords: flood, risk, HEM-F, Bílina River, river alteration

Received 17 Semptember 2015; Accepted 16 February 2016

1. Introduction

Floods and the related conditions of riverbeds, river banks or floodplain are actually a present theme. Recently several major floods have occurred in the Czech Republic during previous fifteen years. Among the most disastrous were the floods in 1997, 2002, 2009 and 2013. This issue about floods, their effect on landscape and society is actual in the Czech Republic, and is the main area of study for many authors (Brázdil et al. 2005; Brázdil, Kirchner 2007; Křížek 2008; Langhammer 2007b; Patera 2002; Šobr et al. 2008). The most emphasis is on the continuing occurrence of floods with historical and present anthropogenic river alterations (Kopp 2007; Langhammer, Vilímek 2008). The aim of research is to provide protection against the effects of flood events. As an example study results of analysis of relationships between stream direction and the geomorphological effects of floods in the case of the Blanice river basin in the Czech Republic on relationships between river alterations and the geomorphologic effects of floods in riverbeds and on floodplains (Langhammer 2010). The following text summarizes results of survey of anthropogenic activities in the landscape and riverbeds and the origin and course of the flood events (for full data of this research see Jelen 2015). The main objective is to analyze the kinds and grades alterations of floodplain, and evaluate positive or negative effects on floods. This evaluation also includes a methodology of field mapping of those riverbeds alterations. This methodology is based on already published and accepted methodologies of the Ministry of Environment specifically methodology HEM-F (Langhammer 2007a). However, differently of other existing methodologies, it is complemented by sub-elements. This concentrates on mapping a standstill state of the watercourse and identifying barriers to water flow and critical points that could be threatened if the water overflows the riverbed during a flood. The methodology has preventive character in compare with other methodologies (HEM (Langhammer 2007a), MUTON (Langhammer 2007b)) that focuses on mapping the effects of floods. The methodology was tested by mapping section of the Bílina River. This river was intentionally chosen because it is located in the Ústí nad Labem region, which is heavily influenced by anthropogenic activities. Studies have been conducted in the past (Dvořák, Matoušková 2008; Vlasák et al. 2004, Havlík et al. 1997 or Kyselka 2010), which confirmed the significant anthropogenic river alteration. The differences between author's approach and mentioned works will be present in other part of this text.

1.1 Flood formation and process

There are many factors which are influencing the occurrence of the floods. One of the main factors is the weather situation, exactly rainfall (Brázdil et al. 2005). River basin also has its specific properties that contribute to the retention or drainage of water (interception, detention, infiltration, river network volume and the volume of inundations) (Matějíček, Hladný 1999). In evaluating the factors influencing the course and consequences of floods should be considered not only the riverbed but the overall condition of the landscape. It should take into account the soil profile, terrain depression, vegetation and wildlife corridors. Retention and

http://dx.doi.org/10.14712/23361980.2016.9
Jelen, J. – Matějček, T. (2016):
Anthropogenic river alterations and their effects on the flood situations (Bílina River case study)
AUC Geographica, 51, No. 1, pp. 97–111

storage elements on the landscape can have a surface, line or composite character. All of these elements are called the water retention capacity of the landscape (Soukup, Hrádek 1999; Benitob et al. 2008). At present, a lot of money is spent after extreme floods and damage. The most important thing is prevention and the effective use of the landscape and the economic efficiency (compare the cost of flood protection measures and acquired effects). A thorough survey of individual catchment areas and identifying critical places could prevent or mitigate flood damage. Land use along rivers must be adapted to the needs of both industry and agriculture, as well as flood protection (Gilvear 1999). The state legislative should lead the way on preventive measures and financial support as well as research activities to analyze the areas that need flood protection measures.

One of the major interventions on the landscape is the change in land use in catchment area. The most significant changes are associated with intensive farming, which significantly interferes with the character of the landscape. The original natural vegetation (meadows and forests) on cultivated areas is transformed and they lost their natural retention capacity and this accelerates flooding. The retention capacity of forest areas is higher than agricultural areas (Langhammer 2007b). The importance of forests in the watershed has not always been appreciated as much as it is today. In the 1960s it was called "Forestry Hydrology" which began to look at the ecological links within the landscape structure of a basin and noted the importance of forest (Bonell 2002).

An important aspect of land use is the way of farming in a floodplain. If it is used incorrectly, in terms of flood control, significant damage can occur during floods. For example, when the land is transformed into an arable agricultural area the natural retention properties are lost and water erosion arises. Built-up parts of the floodplain sustain many times more material damage than areas left to develop naturally with natural vegetation. The mitigation or aggravation of the consequences of floods depends on the passage of the flood wave and its transformation on the way through the floodplain. If the floodplain is in good environmental condition it can slow down the runoff and reduce the speed of the wave. If these areas are revitalized it is important that the management of the watercourse and its floodplain are sensitively connected (Newson 1992). Revitalization should be taken as a single disturbance. It is a single river system interference which lead to near-natural condition of the floodplain. Rivers systems can respond very quickly to revitalization while gaining better resistance to other floods (Kopp 2007; Schumm 1994).

The studies of land use changes indicate that the positive aspect of flood prevention is a long-term decrease of arable land and increase of the forested areas in the headwater catchment areas, which contribute to the natural retention capacity of the landscape. The risk factor is the increase of built up areas (Bičík et al. 2008).

Urbanized and industrialized areas have lost most of their natural vegetation and thus their ability to retain water. Flood protection is ordinarily based on technical elements. Sewerage systems in urbanized areas have almost no retention capacity and the runoff is accelerated. Also, in the past, rivers were subjected to many anthropogenic alterations. Some of them could be described as highly insensitive to the natural environment (Langhammer 2007b). The developing mining industry was responsible for some of the major interventions into river network over the last two centuries. The most striking example is the mapped Bílina River, which due to mining brown coal in the Most basin had to be transformed several times and in some places the watercourses still flow through a conduit.

Floods also effect the actual condition of the riverbed and their degree of human influence. For increased capacity are the riverbeds countersunk. The extreme case is a flow through a conduit to passing through an industrialized area, urban area or under roads. The main objective of these measures is to let water flow through a built-up area as quickly as possible, which is only possible up to the capacity of the riverbed (or conduit). When the limits are exceeded, water overflows into the surroundings and damages property. Reinforcing the shore and bottom with artificial materials can reduce the roughness of the channel and increases the rate of flow velocity. Floods in those sections lead to an increase in the slope of the flood wave, a higher state of water levels at the peak and increased destructive power of the water flow (Langhammer 2007b).

2. Study area (description and characteristics of the Bílina River)

The Bílina River is a relevant watercourse in northwest Bohemia. It rises in the Ore Mountains on the eastern slopes of Kamenná hůrka, northwest of Jirkov. The total catchment area is 1,082.47 km^2, channel length 81.96 km. From the source, in Klínovecká uplands, the river flows across the Most region to Ústí nad Labem, where is the left tributary of the Elbe River. The Bílina River flows through one of the most industrialised areas of the country. The riverbed of the Bílina River has been adapted and transformed many times in the past and was one of the most polluted waterways in the area (Dvořák, Matoušková 2008). The original channel was changed mainly due to mining activities in the area of Most and the Bílina region. The natural hydrological regime only remains in parts of the stream before reaching the Jirkov waterworks (Štefáček 2008).

Among the interesting facts about the Bílina River is the three water conduit from the Ohře River into the Bílina River. They are called the "Podkrušnohorský přivaděč", Industrial water conduit and the Nechranice industrial Ohře–Bílina conduit. These systems are used to supply the area with water and protect local coal

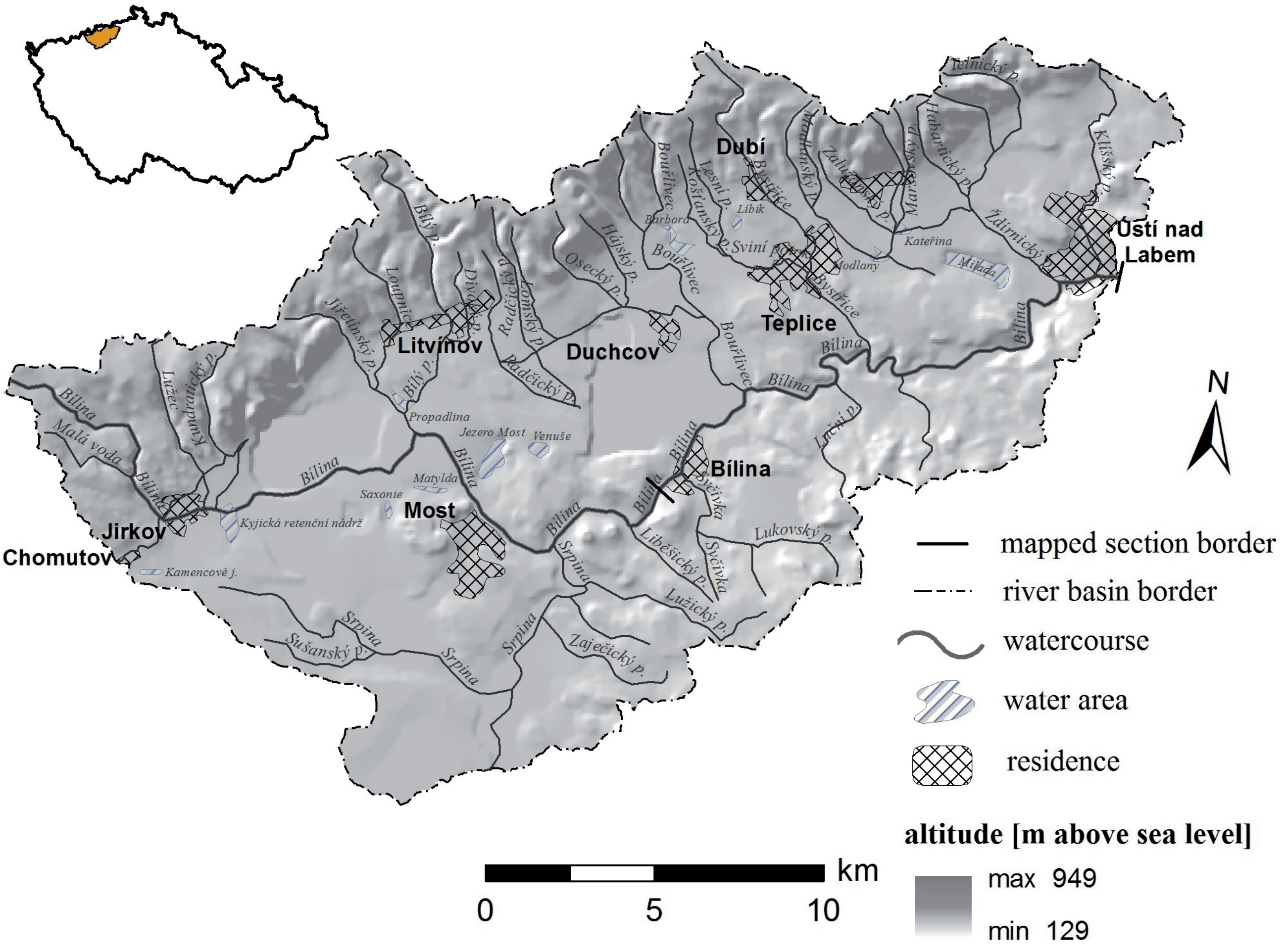

Fig. 1 The Bílina River basin.

mines from flooding. Water is also transferred through Počerady power station, which draws water from the Ohře River, and drain the waste water into the Srpina River, a tributary of the Bílina River. The system for transferring water from the Ohře basin to the Bílina basin is the largest in the Czech Republic. In the long term coal mining is expected to decline in the region and in a few decades the open mines should become flooded. The water for this purpose will be drawn primarily by the indicated penstock. For example, flooding the ČSA mine near the town of Most (the start is planned for 2020) should create the largest mining lake in the Czech brown coal districts, which will have an area of over 1,500 hectares (Simon et al. 2005). Another rarity is the Ervěnický corridor, with an up to 170 metres high embankment in places between Jirkov and Most. It is on part of the Bílina River where water is transferred to the conduit. The four steel pipes cover a distance of 3.5 kilometres with a total capacity of 10 m^3 sec^{-1}. There is also the road and railway line, linking the city of Chomutov and Most. The Bílina River's conduit will be the world's unique technical solution that will serve its purpose for over 25 years. As it is located at the dump, which is constantly falling (from the beginning to the laying of the hopper declines of several metres are expected), it was chosen instead of an open steel conduit channel (Hladný, Němec et al. 2006). In the future, after the mining pits are flooded and areas reclaimed the conduit will be removed and the river will return to its natural state of an open channel.

When assessing anthropogenic transformation, the rate of reduction of the length of the main stream is evaluated by comparing historical and contemporary maps. Over the past 80 years the Bílina watercourse has been reduced by nearly 3.9%. The most significant changes occurred in the area between the towns Most and Jirkov. The watercourse was increased between the discharge Ervěnický corridor and the Most corridor, where the Kopistská dump originated (Dvořák, Matoušková 2008).

The survey (May–October 2014) of the hydromorphological characteristics of the selected area using the established methodologies mapped 36.51 km of the Bílina River, between towns Ústí nad Labem and Bílina. The total length of the watercourse is 81.96 km therefore 44.55% of its length was mapped. The mapped section were divided into 36 sub-sections and marked by codes from BIL001 to BIL036. The average length of a section was 1014 metres, the shortest part was 300 m and the longest 3000 metres. The longer sections are mainly in the urban areas and municipalities (3000 metre section in Bílina town), and mostly have homogeneous characteristics. Conversely, the shorter sections are outside built-up areas where there are frequent changes in the characteristics.

3. Overview of the methodologies involved in mapping watercourses alterations

The state of watercourses can be viewed from many perspectives. There are many methodologies for evaluating rivers and their characteristics. This can include monitoring their chemical or ecological properties. Methodologies were created to solve the problems of taking and treating samples (the issue of sampling phytoplankton, fish, biota, macrophytes, etc.). When assessing the ecological status various biological, physical and chemical components should be evaluated; there is a sub-set of methodologies for each category. The list of accepted methodologies is administered by the Ministry of the Environment (MoE[1]).

In diferent countries were developed many methods of ecohydromorphological monitoring. Among the most important pertain LAWA – Field survey (LAWA, 2000) used in Germany. It is based on field survey, rated sections have a uniform length (50–500 m) depending on the width of the riverbed. A total of 25 parameters are evaluated in the 3 zones (watercourse, riparian zone, floodplain). Another German methodology is LAWA – Overview survey. It evaluate the function ability of the river ecosystems. The methodology is based on the use of existing maps and images. Field research has only supplementary character. In total 17 parameters in 3 zones are rated (Matoušková, 2008). Other method is Rivers Habitat Survey, which is used in Great Britain. Characteristics of riverbed, floodplain, riparian zone or green belt and land use around watercourse and anthropogenic transformation are evaluated. The length of the monitored parts is 500 m, evaluated are 25 parameters. This methodology is also used in Italy, Slovenia and New Zealand (Matoušková, 2008).

In the Czech Republic (Faculty of Science, Charles University in Prague) were created another methodologies. The first is EcoRivHab (Matoušková, 2003), which is based on field survey and the using of distance data. The method involves analyzing the hydromorphological characteristics of the watercourse, anthropogenic river alterations, the degree of flow dynamics, water quality and land use in the riparian zone. There are 31 parameters in the 3 zones (riverbed, green belts, riparian zone, floodplain) evaluated. Another methodology is mapping transformations of riverbed, floodplains and flood consequences – MUTON (Langhammer 2007b, 2008). The method was developed for evaluate river basin, riparian zones and geomorphological manifestations of floods. The main objective is not to evaluate ecological status of watercourses but determinate relationship with anthropogenic river alterations and floods consequences.

For this study the most important methodology is monitoring of the hydromorphological components of the landscape. This includes especially the hydrological regime, morphological continuity and flow conditions. The accepted method for evaluating them is HEM – Hydroecological monitoring (methodology for monitoring hydromorphological indicators of the ecological quality of watercourses). This methodology has its own sub-section HEM-F, and in addition to the attached section, is based on mapping the effects of floods (Langhammer 2007a).

3.1 Mapping the anthropogenic alterations of the Bílina River

The anthropogenic alterations and actual condition of riverbed of the Bílina River and its surroundings were mapped from May to October 2014. A methodology that builds on another existing methodology (HEM-F) used for mapping river network was created for the investigation and adjusted according to the needs of the field investigation. The presented methodology was used to determine the specific characteristics and level of anthropogenic riverbed alterations. Its aim is to obtain information of the intensity and character of adjustments of the river channel, its surroundings and floodplains that cannot be obtained from other sources (maps, photographs and satellite images) and continue to identify potentially critical sections that might have a negative effect on a flood, its course and consequences.

For the mapping was used a modified form of methodology HEM-F, from which were discharged mapping the effects of flooding and flood damages. The aim was to identify problematic reaches or sections and generally highlighting potentially endangered objects. The risk is seen as probably experiencing undesirable phenomenon that has negative impacts (e.g. on the lives and health of people, their property and the environment).

The mapping was carried out by a survey from the mouth to the spring, – upstream. The watercourse was divided into sub-sections of various lengths, each was homogeneous in some of the key parameters (naturalness of the floodplain, the use of floodplains, river alterations). Each sections were marked with a unique code and its boundaries, recorded by GPS coordinates and evaluated according to mapped indicators described below. These sections are the basic mapping units and the indicators in them are evaluated for each separate mapping. The aim is to evaluate the extent of anthropogenic adjustment of the riverbed and riparian zone, the observed phenomena are recorded on the field mapping forms, the surveyor selected one (or more) of the options, possibly accompanied by details. 16 indicators that describe the various characteristics of the watercourse and its surroundings, anthropogenic alterations and flood risks were inspect.

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[1] http://www.mzp.cz/cz/hodnoceni_stavu_vod

Tab. 1 Comparison of selected data of single mapping.

Mapped reach code (in terms of the present study)	River kilometer	Hydromorphological quality			
		Dvořák (2008)		Kyselka (2010)	Jelen (2015)
		EcoRivHab	LAWA-OS		
BIL001	0.00–0.45	5	5	5	5
BIL017–BIL019	14.28–15.53	4	3	3	2
BIL020	15.35–16.36	3	3	2	1
BIL021	16.36–17.31	3	3	2	1
BIL026	21.46–23.26	2	2	2	2

Note: During mapping hydromorphological characteristic is provided evaluation on a scale from 1 to 5 (1. High, 2. Good, 3. Moderate, 4. Poor, 5. Bad)

Tab. 2 Mapped indicators.

Identifiable information of the section	Morphometry of the river channel, riparian belt, green belt and floodplains	Watercourse alterations and the use of coastal areas and floodplains		Floodplain, the potential risks during floods
section code	the length of the reach (m)	watercourse trajectory	shore purity	floodplain condition
river name	the riverbed width and level	obstacles in the riverbed	riparian vegetation	potential risks during floods
date and time	the width of the floodplain (left + right bank)	depth of the channel	use of the riparian zone	notes
research worker name	the shape of the valley	the bottom structure	use of green belt	
		the bottom substrate	flow type	
		bottom purity	impact on the hydrological regime	

During the field survey have been measured empirical values. Basic features such as distance was determined using a laser rangefinder LEICA, limit points measured sections were recorded by using GPS machine GARMIN. Another data were obtained by direct observation of a qualified appraisal.

3.2 Comparison with already performed studies

In the Bílina River basin was already done a similar field survey. The most important might be considered a studies from Havlík et al. (1997a, 1997b), Vlasák et al. (2004), Dvořák (2008) and Kyselka (2010). Study from Vlasák et al. (2004) builds on earlier studies of river basin Bílina presented in the Havlík et al. (1997a, 1997b) works. There are any ecological studies in witch is on individual profiles computed water flow, evaluated the hydrological flow characteristics, water quality and pollution (including monitoring pollution producers). These studies are applied at intervals of several years, monitor and evaluate changes between measurements. In those studies are evaluated completely different flow characteristics and measurements are only in certain profiles, therefore these studies are not appropriated to compared the results with the submitted work. Dvořák (2008) and Kyselka (2010) concentrate on the evaluation of the Bílina riverbed ekomorfological condition by using different methodologies. Kyselka (2010) used methodology HEM but only on several reacehs of river. Selected reaches are called "priority sections" and they are distributed over all river length, but there are not connected. There are evaluated 31.99 km of watercourse. Dvořák (2008) applied EcoRivHab and LAWA – Overview Survey methods. Selected identical reaches from all of mapping are displayed in Table 1. It can be seen that in some reaches are the same values and in other reaches are better values of hydromorphological quality. Because it was used different methods, we can not say with certainty, that hydromorphological quality was improved or not. All sections which pass through the urban or industrial areas shows the worst results of hydromorphological quality. Unfortunately sections's comparison is quite confused because determining values depend on the researcher's experiences and knowledges.

4. Results

In the following text will be presented partial results of field survey of the Bílina River. For complete and detailed results see Jelen (2015).

4.1 Riverbed width and level

The morphometry of river the channel category is an important indicator of the breadth of the riverbed

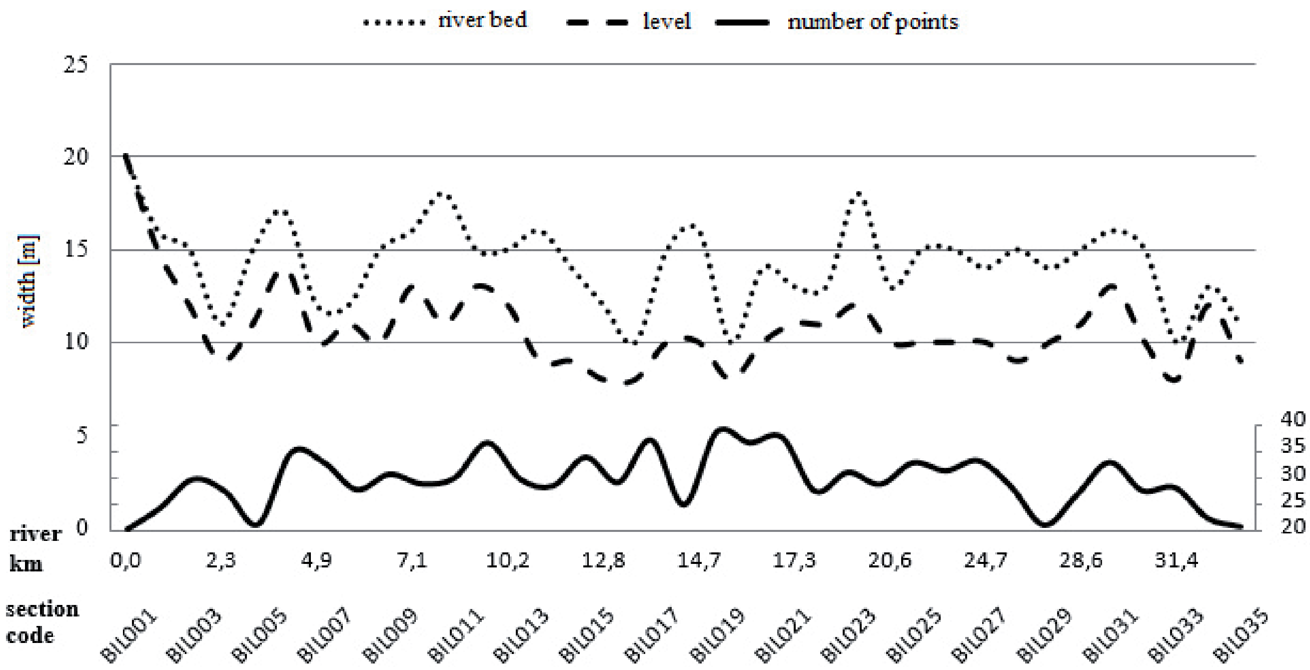

Fig. 2 The riverbed width and level in kilometres.
Note: The water level on 12 April 2014, when the segment was mapped, at the specific station Trmice (river km 3.80) was 1039 mm, with a flow of 3.81 m^3 s^{-1}. During the mapped period from May to October 2014, the level of this station ranged from 1000 mm (lowest status on September 5, 2014) to 1380 mm (highest status on September 20, 2014). The average water level was 1117 mm during the year.

levels and their differences (Figure 1). The figure shows that in areas with the highest degree of anthropogenic influences the riverbed (the urban areas) is the width of the channel and almost on the same level (see the first 1.5 km, which crosses the city of Ústí nad Labem). This means that the riverbed is mostly concreted or otherwise modified. The distance between the curve gradually increases as the river leaves the built-up area. When the water flow passes through less anthropogenically influenced areas, the variability of the riverbed width and level is high. In relatively natural sections the difference can be up to between 5–7 m. These are segments of higher ecological value, natural vegetation and with greater retention potential in cases of elevated water levels.

4.2 The width of the floodplain and flow path

The rate of anthropogenic influence riparian zone could be demonstrated on the floodplain condition. The average width of the floodplain on the left bank was 39 m and the right bank 49 m. These values are reasonable, to keep overflow water from river on the floodplain. But these values, are partially distorted by the fact that in some parts of the river there is none at all because it is an urban area. Because it is necessary to evaluate the individual sections separately. Therefore, the individual sections must be evaluated separately. Other indicators include the flow path and its type. Mapping the reaches of the Bílina River show two main indicators – meandering channel (39% river length) and artificially straightened flow (47% river length). Another occurring type is naturally direct flow which exceeds the limit of 10%. Outside built-up areas the river always meanders. In these parts a parallel with the different widths and channel levels can be found (Figure 1). On the other hand, direct sections are found where the river crosses an urban area or industrial areas, such as Ústí nad Labem. 17.1 kilometres are artificially straightened compared to 14.2 kilometres naturally meandering. This shows that the artificially straightened parts are less than half the total mapped area and more than a third is left in its natural state. The river flows through lots of small towns and villages between the large cities of Ústí nad Labem and Bílina. These are mainly rural settlements where the water flow is regulated only at the core urban area and does not require extensive regulation in the area where flood water could naturally spillover onto the surrounding countryside. There are no major dams or weirs on the mapped parts of the watercourse. The main sections are completely without barriers. One small culvert flow was found due to shift of communications over the watercourse and some low grades and two weirs 1 m high. Over the entire length of the mapped watercourse the longitudinal profile of the flow was very little affected by the construction of dams, weirs, etc. The section could be evaluated as part of the stream with a lower than average incidence of construction because of the unsuitability of the channel for building a large water project (dam type) and the uselessness of these buildings.

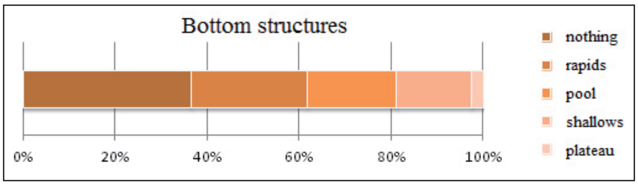

Fig. 3 Bottom structures in the study area.
Note: nothing mean that bottom structures can't be detect, other concepts include the bottom structures, respectively their flow velocity.

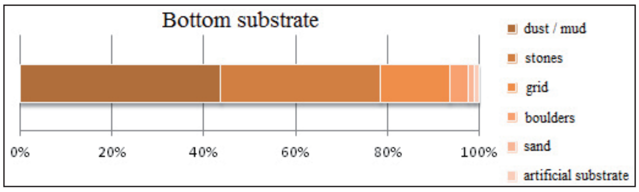

Fig. 4 Bottom substrate in the study area.
Note: bottom substrate is classified according to the grain size (size of the individual parts in millimetre). Dust/mud = 0.002–0.06; sand = 0.06–2; grid = 2–100; stones = 100–200; boulders = > 200, artificial substrate = pavement or concrete.

4.3 Channel depth variability

Other indicators are depth variability and depth of the channel. Where there is low depth variability there is low depth of channel. Depth variability is 60% artificially low, 34% low naturally and 6% in the middle. This corresponds to the partial adjustments of the river channel, but again only a slightly absolute majority, i.e. the remaining 40% is left to develop naturally. Higher values absent because this is the lower part of the medium size flow with a relatively small slope. High variability is found mainly in mountain streams or in meander reaches. The most frequent values of the channel recess are 1–2 m (58%), which is the average value corresponding to the type of watercourse. To help prevent floods it is common to artificially recess the channel to increase its capacity. These adjustments are made mainly in towns and villages, and are used as a substitute for levees. This protection element is only sufficient to limit the values when the volume of the riverbed is exceeded, then the water flows out of the riverbed. In some places this is complemented with, for example, mobile flood barriers (see section BIL001), the city centre of Ústí nad Labem, the site of the confluence of the Elbe and Bílina rivers.

4.4 Bottom structures

The bottom structures and bottom substrates are descriptive characteristics of the actual state of the bottom of the riverbed. The most common structure includes rapids, when it comes to shorter sections with higher speed, outside built-up areas where the bottom is covered with stones. To a lesser extent pools that appear in sections with a slow flow. The bottom substrate is mainly dust/mud, as approximately 50% of the mapped length of the flow is outside the built-up area of vegetation and there is great potential for storing fine dust. In reaches where is stone bottom are the rapids. The rapids are also in reaches where were realized fortification of river banks. After several years stones sunk to the riverbed and create the stone bottom. Indicators mapped the anthropogenic interference with the channel bottom and the tidiness of the shore. More than half length of the river bottom is without alterations – in almost natural state. Unmodified bottom have different flow velocity. Concreted bottom increases the flow velocity through the area. The mapping of the bottom may be distorted by the inability to identify the adjustments due to the riverbed pollution or the water visibility. Alterations is closely related to the neatness of the bottom. For example, if the riverbed has a concrete bottom the banks will be concreted (the mapping indicates bottom casting of 6.01% and 6.69% for banks). Conversely, compared with a modified bottom, the bank is generally more regulated, but more than half of them were very close to the near-natural state (vegetation or stone fortifications). These measures do not prevent water soaking into the surrounding ground and acts favourably in a flood.

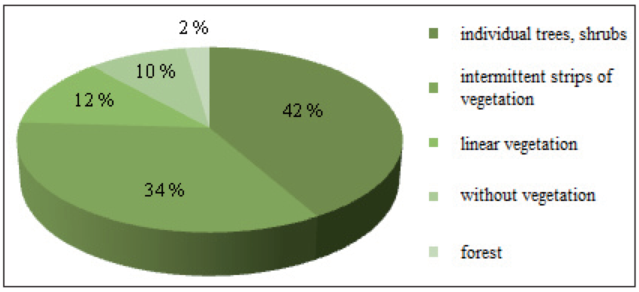

Fig. 5 Percentage types of green belt vegetation in the reporting period.

4.5 Bank vegetation and land use in the riparian belt

Other important factor is absorption of water into the environment, depend on the species composition of the bank vegetation as well as its quality and age. In the mapped area there are mainly individual trees, shrubs or intermittent bands of vegetation. These include especially self-seeded trees. In many sections the stands are not maintained and some may extend up to the watercourse. During floods floating material may become entrapped after hitting these branches or the branches themselves may be broken and act as a barrier in other areas downstream e.g. during the build up to pass under a bridge. This problem should be actively addressed in some sections where there is a high incidence of old trees, extending into the riverbed. In some places the vegetation is left entirely natural, which sometimes prevents continuity along the riverbed. The mapped area is intensively used in the industrial area of the Bohemian Highlands. Therefore, there has been no form of preserved natural forest

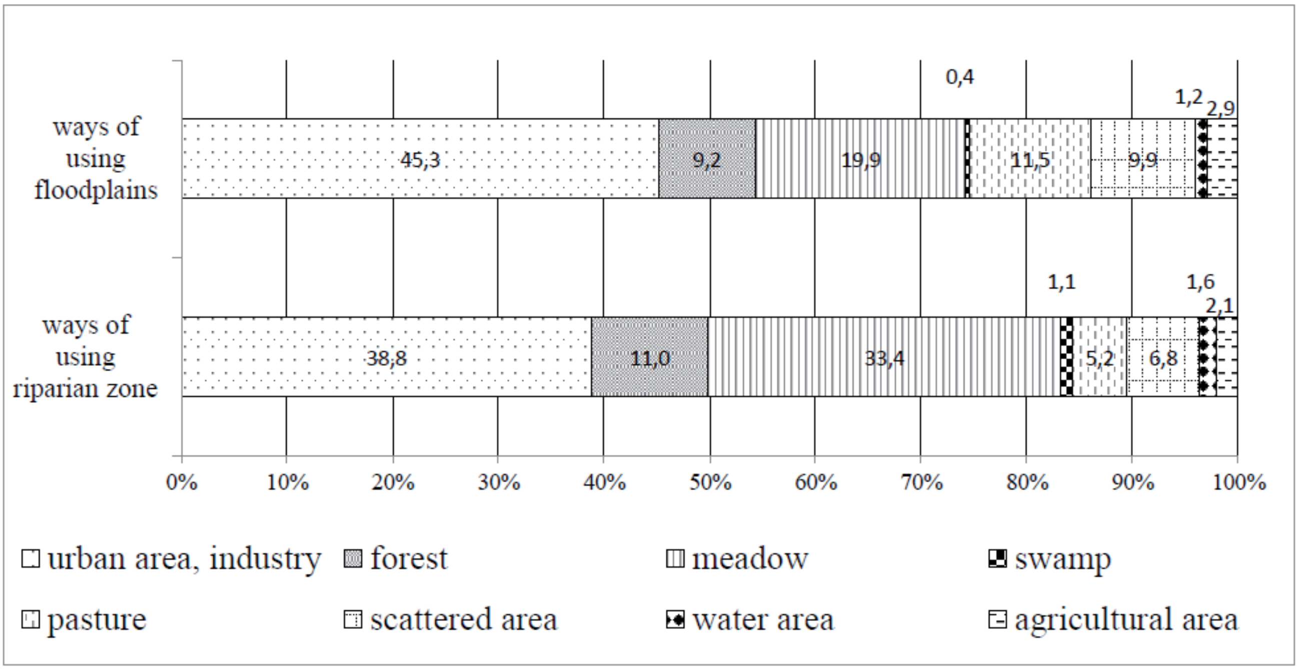

Fig. 6 Percentage of land cover using in the reporting period.

vegetation. Eight main types of use of the riparian zone and floodplains were recorded when mapping the area. All these types of use along both mapped categories correspond to its share. Most are urban and industrial areas. Of the total length of the mapped stream the water flows directly through 17 municipalities, which is over 40% of the length of the flow. More than 30% of the floodplain and over 35% of the riparian zone are used as meadows or pastures. These areas are suitable for the natural overflow of the river at time of increased flood flows, but they do not have such an interception rate as forests, of which there is only about 10% percent in both categories. The mapped area is also suitable for intensive agricultural production in terms of its climatic and geomorphologic characteristics, but the category of agricultural area is less than 3%. The multiple buildings category is also below 10%. These are areas of isolated buildings, especially on the edges of a municipality or outside. These buildings are a particular problem because they are often right near the riverbed, less than 7% in the riparian belt. Therefore they are directly threatened by flood situations.

4.6 Water passages throughout the floodplain

Water passages throughout the floodplain are indicators of mapping structures and objects that may hinder the passage of flood waves at high flow rates. More than half of the floodplain not pass any structures that would prevent the passage of water during an inundation. However, along the route the flow passes through two major potential barriers that are in different places at different distances. The first is the railway line Ústí nad Labem west of (station 5) – Bílina. The railway follows the flow of water through several passes. Some sections go directly along the bank. The track may prevent water overflows on one bank and multiply overflows on the opposite bank. The D8 motorway crosses the Bílina River several times. It is very high above the surface of the water but the bridge pillars extend to it and to its banks, which may act as barriers to the flow. Furthermore, to a lesser extent in some sections there are buildings in the floodplain, for example industrial areas.

4.7 The resulting point evaluation of the mapped sections

In total the 36 sections were analyzed; each section was based on predefined criteria, a specific point value was assigned for each sub-section examined. Only indicators that have a predictable value of the anthropogenic influence on the water flow were included (flow path, obstacles in the riverbed, variability depths, bottom and bank tidiness, green belt, use of riparian zone and flood plains affecting the hydrological regime). The principle of the scoring is that the more characteristic like anthropogenic nature, the fewer points in relation to the suitability or otherwise of these treatments. Natural regions have the largest number of points. In the mapping records the percentage of the occurring phenomena is allocated a point value converted to a ratio of observed phenomenon. For example, if the value of phenomenon A with 85% has 5 points, and the value of phenomenon B with 15% has 1 point, after conversion the resulting phenomenon value is 4.4 points.

To clarify the points according to the kilometres of the river flow, see Figure 7. The lowest score was 20.48 points for the section within the boundaries of the city of Ústí nad Labem, where the riverbed is largely artificially altered. Almost the entire length is straightened and

Tab. 3 The resulting number of points of individual map sections.

Section code	River km	Total points	Section code	River km	Total points	Section code	River km	Total points
BIL001	0.00	21.00	**BIL013**	10.22	36.50	**BIL026**	20.56	32.80
BIL002	0.45	20.48	**BIL014**	11.15	29.75	**BIL027**	21.46	31.30
BIL003	0.87	24.40	**BIL015**	12.50	28.50	**BIL028**	23.26	33.16
BIL004	2.27	29.75	**BIL016**	12.80	33.83	**BIL029**	24.66	28.30
BIL005	3.37	27.40	**BIL017**	13.63	29.16	**BIL030**	26.31	21.23
BIL006	4.02	21.40	**BIL018**	14.28	37.00	**BIL031**	26.91	26.83
BIL007	4.90	34.65	**BIL019**	14.73	24.99	**BIL032**	28.56	32.88
BIL008	5.60	32.85	**BIL020**	15.53	38.50	**BIL033**	29.72	27.60
BIL009	6.48	27.80	**BIL021**	16.36	36.50	**BIL034**	30.07	28.20
BIL010	7.10	30.67	**BIL022**	17.31	37.50	**BIL035**	31.37	22.50
BIL011	8.70	28.86	**BIL023**	18.01	27.50	**BIL036**	32.51	20.96
BIL012	9.70	30.00	**BIL024**	19.36	31.00			

Note: River kilometer unit corresponds to the start point of the section.

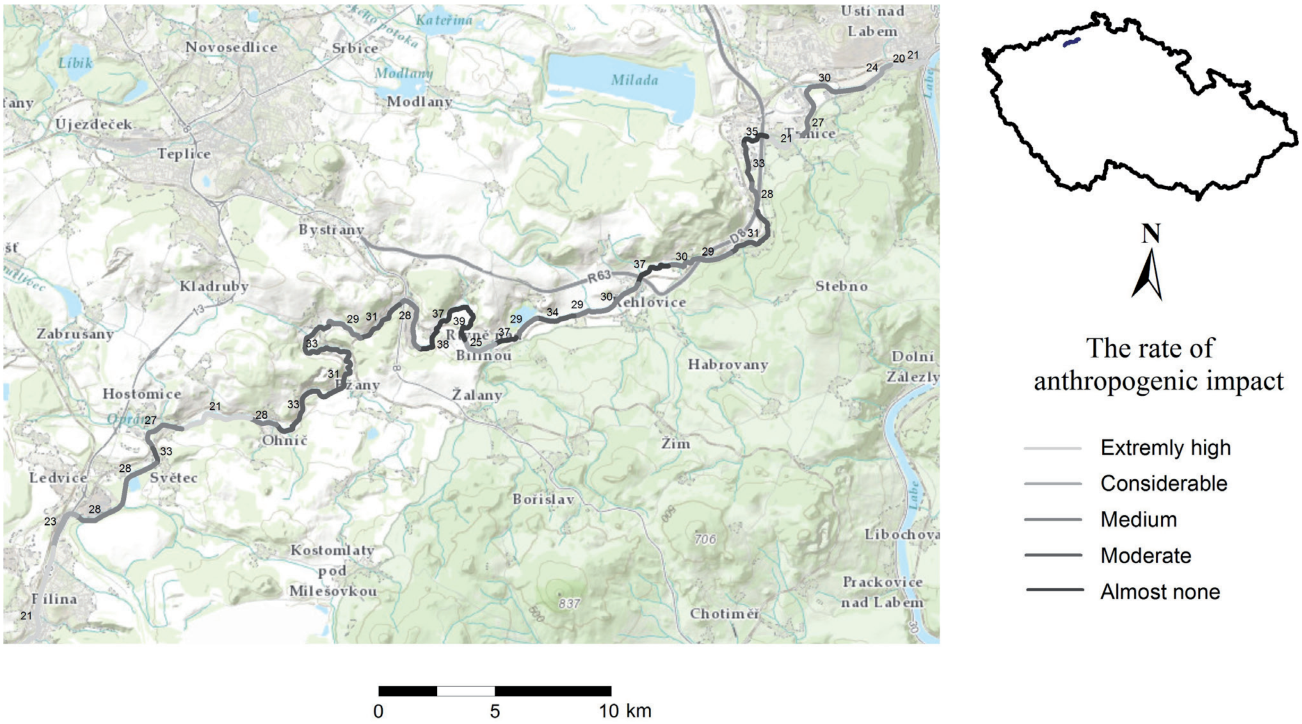

Fig. 7 Analyzed parts of the river with their rates of anthropogenic impacts.

the river has a culvert that prevents the natural flow of water. Larger flow rates cause water to overflow through it and communicate this after it passes. Furthermore, the inundation area is narrowed by adjacent routes. The highest score was 38.5 for the section between the villages of Rtyně nad Bílinou and Sezmice. The river passes through undeveloped country and meanders naturally. There are no signs of anthropogenic alterations of the bottom or bank. Both banks have developed a broad floodplain. The surroundings of the river are used as meadows or pastures. The average score was 29.3 (on Figure 7 shown by a bright line). A total of 19 mapped sections (52.8%) had values below a predetermined level and 17 segments (47.2%) were above the average point value. A large number of sections oscillate around the average number of points. These are segments in which adjustments have been carried out to a lesser extent; the river passes through smaller villages where no extensive alterations have been carried out. The watercourse is largely straightened or part of a natural meander. The bottom is only partly converted, either by stone or in smaller sections by pavement. The banks are regulated by stone fortifications, gravel or vegetation. There are small dams causing backwater, but not more than 1 metre high. Neither are there sections with complete alterations, such as concrete.

Tab. 4 List of critical parts.

Section code	Title	Description	Regulation proposal
BIL001	road bridge	under the bridge on the right side are lots of silt deposits accumulation	cleaning the silt deposits by water basin authority
BIL002	system of conduit	barrier in the riverbed	removing conduites
BIL003	unfinished building	unfinished building near the riverbed	completion and protection of the object
BIL005	stone wall in the riverbed	Artificially created stone wall in the riverbed, restricts the water flow	removing object
BIL005	cottage on the riparian zone	inconveniently placed objects near the riverbed	removing object
BIL007	riparian vegetation	riparian vegetation and silt extending into the riverbed	pruning riparian vegetation
BIL013	riparian vegetation	riparian vegetation and silt extending into the riverbed	Pruning riparian vegetation
BIL015	historical bridge	historical bridge in Brozánky village, where are deposits of silts	cleaning the silts by river trustee
BIL019	urban village of Rtyně Bílinou	inappropriately placed buildings directly on the edge of the watercourse	construction elements of flood protections around the buildings
BIL029	destroyed concrete adaptation shore	destroying the concrete bank fortifications and lateral water erosion	repair fortifications by river trustee
BIL032	old bridge	old concrete bridge over the river, which is in disrepair and threatening to collapse into the riverbed	repair or remove of the bridge

Parts that overlap the final score value of 35 can be described as very slightly modified; in a near-natural state. The flow in these sections naturally meanders or could even be described as natural, depth variability and the recess channel is moderate, i.e. the natural state. The sufficiently developed floodplain is not in the area of potentially endangered objects or obstructions to the flow in the channel (weirs, dams) or in the floodplain (road embankments). The flow of the surrounding forest or grassland, the bottom and the banks are not regulated or are used close to nature and the near-natural river state (vegetation fortification). These sections do not need any further adjustments to ensure the ecological stability. The opposite are sections with a score of under 25. This category includes partial flow through an urban area where there is a great emphasis on flood control and the riverbed and its surroundings are heavily anthropogenically altered. Specifically, the city at the beginning of the mapped route (Ústí nad Labem), and its end (Bílina). These sections are artificially straightened, the channel recess is over 4 metres because of its capacity. Also, in most cases it is paved or concreted. The surrounding area is intensively used for industrial purposes.

When comparing the various categories we can generally say that the proportion of near-natural and modified reach is equivalent. Many of the parts around the average value change but the number of sections near-natural is greater than the number of those strongly anthropogenic treated. Therefore, unlike the original assumptions the mapped stretch of the Bílina River was rated as slightly modified. The exceptions are, as already mentioned, large urban cities. Furthermore, a great change in the natural and modified sections can be observed. This is due to the water flow through a plurality of small communities. This is a potential major problem during flooding. In other than urban areas the water has a great potential to spill over the riverbed. However, in urban areas, although water is transferred into a deep riverbed when it overflows it flows directly into the built-up area. This issue was discussed in the introduction, where it was stated that adjusted riverbed provide stability and protection against floods only to the point where it exceeds the limit flow.

5. Discussion (identify problematic parts)

The aim was to identify problematic parts or sections and generally highlight potentially endangered objects. The risk analysis is essential to assess the critical sections and locations. The risk is seen as probably experiencing undesirable phenomenon that has negative impacts (e.g. on the lives and health of people, their property and the environment). The essential steps of identifying hazard scenarios (presence of undesirable phenomenon), estimating the probability of the occurrence of the phenomenon and quantifying the impacts and risks include identifying and evaluating the flood risk. The risk analysis and defining potentially vulnerable sites can be divided into qualitative, quantitative and semi-quantitative (Drbal et al. 2005). The choice of the method of analyzing the critical points depends primarily on how the results will be used, as well as the availability, correctness and accuracy of the input data and finally the available resources of their own investigation. The choice then determines the level of detail of the endangered area and determines other procedures and specific methods. For this study it was critical that the points and sections identified a synthesis of several aspects. A qualitative analysis was carried out from the view point of the researcher. Critical points were identified according to several criteria of potential threats:

- The health and lives of people
- Property population
- Environment
- Cultural heritage
- Economic activities
- The effects and functionality of existing flood control measures
- The course of the watercourse and its natural properties

The principle of determining problematic parts because the object is inappropriately positioned near the edge of the flow channel and thus at the risk of increased flow rates was used. Increased attention is paid to bridge structures, both in terms of their technical condition and the capacity of their flow profile. These are bridges with a profile that is estimated to be insufficient for high water flows and the culvert could be blocked causing water to overflow the riverbed. Then silt is deposited as this it is a good place to create a temporary dike with the clogging. It also identifies a breach of a bank and the days of treating a watercourse. Despite the overall weak rate of anthropogenic effect on the mapped sections of the Bílina River locations and regions were identified during the field survey that could cause complications during any increased flows of water and also objects that could be directly affected by floods and damage.

The list of all critical parts is on Table 4. There are describe the problematic parts and situations on riverbed or its surroundings and suggest interventions which could lead to eliminate problems.

In following article are some examples of selected problematic parts. In a larger study would be proposed interventions to reduce the risk in these areas. In general, can be said, that among the measures should include periodic service of the riverbeds and riparian belt. These are mainly the removal of silt, fallen trees or bushes. Attention should be paied to periodic services and repairs river bank fortifications and bridges. In case that it's construction is already in a dangerous condition and does not serve original purpose, their demolition is suitable (Figure 11). A separate chapter is also development in the riverbeds, floodplains and riparian

Fig. 8 Riparian vegetation and silt extending into the riverbed.
Reach BIL007, vegetation extending into the riverbed that could collect silt. This narrowing of the riverbed silt, along with a conduit across the river could cause clogging of the riverbed and water overflowing outside.

Fig. 9 The urban village of Rtyně nad Bílinou.
Reach BIL019, inappropriately placed buildings directly on the edge of the watercourse. In combination with reduced throughput caused by narrowing the channel profile bridge, high water flows could threaten buildings along the river channel.

Fig. 10 Destroyed concrete adaptation shore.
Reach BIL029, because of the riparian vegetation and water destroying the concrete bank fortifications and lateral water erosion the situation before the bridge over the river could eventually disrupt the bridge structure and scour the adjacent road.

Fig. 11 Old bridge.
Reach BIL032 stretch of an old concrete bridge over the river, which is in disrepair and threatening to collapse into the riverbed. This could clog the riverbed and make the water overflow.

belt. Generally, the construction in floodplains are always risky. They are not only threatened by floods, but also can influence the direction of the flood wave into the territory. The main objective of government should be in places for the natural overflow of water at all not built buildings.

Examples

6. Conclusion

The study is focussed on evaluating the anthropogenic interference with the nature of watercourses and their manifestations in the context floods. It focused on mapping alterations of riverbed in connection with floods. The analysis was conducted on anthropogenic alterations of riverbed and evaluated their positive or negative effect on the course of a flood. This methodology was used on the 36.51 km long section of the Bílina River through different types of landscapes. The sample is long enough to be representative and nearly all these mappable characteristics could be observed on it. Some critical sections were also identified that, during increased flows of water, could cause problems during a flood wave. After analyzing the impact of anthropogenic river alteration and evaluating the potential effects on the development of floods the surveyed stretch would be labelled as moderately influenced by human activity. Based on the results of the previous survey and analysis of the resources it can be said that the examined part of the watercourse is not subject to a greater degree of the consequences of inadequate or poorly implemented flood protection or inappropriate alterations.

It must however be observed that if the field survey of only part of the water flow had included its entire length, especially sections passing through the area of the North lignite basin, the final results would be different.

Acknowledgements

This study was supported by the internal University of Jan Evangelista Purkyně project SGS 2014-15 (Landscape–man–catastrophes: landscape transformation and adaptation to difficult natural conditions in historical-geographical perspective. We also thank to Pavel Raška for his help with finalization of this article.

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RESUMÉ

Antropogenní úpravy vodních toků a jejich vliv na průběh povodní (případová studie řeky Bíliny)

Příspěvek se zabývá hodnocením jednotlivých druhů antropogenních zásahů do přirozenosti říčních koryt a jejich okolí, antropogenními změnami v krajině a jejich dopady na hydrologické poměry daného povodí a případnými dopady na vznik a průběh povodní. V práci je předložena vlastní metodika terénního mapování, vycházející z již existujících prací. Metodika je navržená k mapování klidového stavu řek, poukazuje na případná povodňová rizika a pomáhá vytipovat potenciální riziková místa, ve kterých by při případné povodňové události mohlo docházet ke škodám na majetku. Navržená metodika je testovaná na dílčím úseku vodního toku Bíliny. Tento vodní tok se nachází v silně industriální oblasti severních Čech, a proto zde byl předpoklad silného antropogenního ovlivnění koryta vodního toku. Při mapování dílčího úseku mezi městy Ústí nad Labem a Bílina se však tento předpoklad nepotvrdil, neboť vodní tok jevil známky spíše menšího stupně antropogenní upravenosti.

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