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Assessment of Flood Course and Consequences

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Abstract

Despite causing serious or even irredeemable losses, floods should be viewed as natural phenomena of landscape evolution. In the past, floods formed part of relief development and the scope of flood plains and sediments characteristics prove that floods used to be locally even more severe. Cases of recent floods inundating broader areas than in the past could be attributed to locally retained water due to unsuitably situated facilities or to extreme precipitations (in a particular local river basin). It can't be confirmed that activities of men were generally the main cause of floods – this statement applies only locally. To prevent damage, it is vital to study flood causes and consequences on the regional level and to tackle the problems of local enormous erosion or overflow. In areas marked by significant property damage, it is necessary to find out whether it is caused by improperly situated facilities or relatively objective causes, like extreme discharge values.

Key words: relief development, geomorphological flood manifestations, flood damage

1. Introduction

With respect to the broad range of papers published in this AUC issue, the assessment of flood course and consequences was organised stressing geomorphological aspects, anthropogenic manifestations, and general conclusions. The assessment has also certain methodological characteristics as we list typical examples of affected river basins. We opted for a methodological approach because to assess floods in terms of relief geomorphological changes it was first necessary to set assessment criteria, define "catastrophic situations" as natural phenomena, and only then to analyse such situations in individual river basins and propose remedies.

As views of floods differ among general public and scientific branches and even natural processes are explained in contradictory ways (as in conference Floods and Landcape, Brno, 1997), we enclose a brief discussion of main approaches. Many papers presented at the conference lacked a broader view and were constrained by individual scientific branches.

We draw on the following standpoints:

A/ The assessment of geomorphological processes after extreme precipitations in August 2002 should be built on general relief development principles. It is also vital to take into account specific river basin characteristics (e.g. prevailing slopes, type of rock material or hydrological watercourse features). Related countermeasures should be also discussed in the same perspective.

B/ Views on floods are based on historical and genetic approaches to such natural phenomena. We believe that floods form part of a natural relief development, they existed in the past and there is no reason to believe they wouldn't occur any more. Due to complexity of the environment, it is just a matter of natural selection where and when floods hit next. (It is impossible to make a long-term forecast.) The only exception would by a cyclic progress of floods.

C/ As natural catastrophes form a natural part of landscape evolution and can't be avoided, it is vital to know their progress, consequences and delimit areas of their occurrence. Generally, they can't be avoided, but we can limit their consequences. With respect to a natural relief development, floods could be even viewed as a "driving motor of development" bringing about sudden and intensive landscape modifications after long periods of minimal changes (e.g. erosion or accumulation).

2. Methodology

With respect to methodology, it is important to differentiate between flood consequences caused by natural factors and consequences brought about by anthropogenic interventions. However, many cases are subject to influence of both factors. For the purposes of flood assessment and consequence analysis, it is recommended as follows:

1) To document typical cases of relief development related to extreme rainfall and subsequent floods.
   - Deepward erosion occurs mostly on upstream watercourses or tributaries (to characterise erosion rate, rock type, slope, and consequences).
   - Lateral erosion is usually active on midstream or downstream watercourses (to specify impact on flood plains, links to landslides, and occurrence patterns), (Photo 1).
   - Landslides may be related to the type of bedrock (to define type of slopes and landslide causes – precipitations or watercourse erosion).
   - Enormous accumulations occur on midstream and downstream tracks (to identify typical areas of occurrence, sedimentation characteristics, and texture).
   - Modifications of channels are related to intensive lateral erosion or accumulation (to identify direct causes and relations to long-term valley evolution).
2) To make a synthesis of results and define general patterns.
   To specify processes prevailing in upstream, midstream and downstream areas (and in relation to the longitudinal profile).
3) To compare relief development in Quaternary period with current relief-forming processes caused by floods (historical-genetic analysis).
   To study schematic evolution of valley and erosion network and relations to relief-forming processes accompanying floods. To find out up to what extent relief development (or landscape evolution) reflects flood consequences and up to what extent it is determined by low discharge (low erosion rate with long-term effects).
4) To formulate relief development patterns to take into account in designing flood control measures.

Photo 1 Lateral erosin in middle part of the Rožnovská Bečva river (Photo V. Vilímek)

To use specific examples to show where it is unnecessary to curb floods and where it is more effective (and cheaper) to allow a natural progress.

5) To compare current overflows with flood plains scope to explain differences.
   The recommendations mentioned above shall be implemented on two levels. First, in the course of a detailed research that can provide specific causes and explanations, and second in generalising and defining universal patterns.
6) To compare partial river basins in terms of their acreage, precipitation volume, slope inclinations, vegetation land cover, rock type, and runoff. To assess the rate of geomorphological manifestations in given river basins.

3. Geomorphological Flood Manifestations

River basins can be used as basic units to measure the volume of water and sediments produced by runoff and erosion and therefore it is important to study relations between river basin morphometry and the volume of water runoff and sediments. Such an example is mentioned by Hadley – Schumm (1961). The hydrographic network density and characteristics in the river basin depend on geological and paleogeographical evolution (e.g. steepnes of slopes, rock type and bedding, resistance to erosion, precipitations, and area extensiveness). Flood effects on the relief result from many processes (mainly in upstream areas). The following chapters focus on geomorphological and geological effects. The most significant quantitative characteristics of surface runoff were defined by Horton (1932) in the 30s as follows: 1) hydrographic network morphometry; 2) soil characteristics mainly in relation to infiltration; 3) structural – geological conditions with respect to rock erosion; 4) vegetation land cover rate and its influence on erosion, infiltration, and evaporation; 5) meteorological and climatic conditions characterising rainfall. We could also include slope characteristics affecting runoff velocity. Horton's model was further developed and completed by other morphometric aspects of hydrographic network by Strahler (1952).

Relief changes caused by enormous precipitations and subsequent flooding can be attributed to the following processes: erosion, sedimentation, flooding, and landslides. The processes are interrelated. It is our intention not to limit the focus only to floods, but also pay attention to flood-preceding precipitations because they alone can cause landslides. Geomorphologically oriented research was performed e.g. by Hrádek (2000).

Runoff is modified by vegetation land cover, slope inclination, and characteristics of soil and rock affected by rainfall. Permeable sediments with impermeable bed may carry water in parallel with the surface at a speed comparable to surface runoff. This process occurs also in coarse sediments, e.g. in rock slides or block fields and in areas formed by carbonate rocks (limestone, dolomite). Underground runoff running in parallel with surface runoff can lead to an increase in water level. Factors affecting infiltration capacity of rocks are: 1) saturation rate, 2) permeability, 3) thickness, and 4) rate of perforation by organisms (e.g. worms, insects, mammals, or plant roots). Soil saturation is the most significant factor (Bolt et al., 1975). Assessment of hydrological soil and vegetation cover characteristics and their impact on flood runoff was studied by Janeček (1997).

Abnormal erosion and sedimentation usually occurs in arid and semiarid regions, but areas with high amounts of sediments may also have serious problems. Landslides, debris flows, or other types of slope movements may lead to transfer of a huge amount of material into channels.

Rock resistance to erosion differs. In case of sedimentary rocks it is only a question of penetration between individual particles while compact rocks have a significantly higher resistance. Nevertheless, resistance depends on many factors. Baker et al., (1988) describes variations in rock resistance to erosion in relation to bedding. Relatively resistant solid granite shows a stronger resistance in channel sides where it is affected only upon higher water levels by transported particles while on channel bottoms where buried under sediments it is often "scraped" by siliceous grains even under lower discharge conditions. Rocks resistance is indicated by the shape of valleys (in cross section). Widely open and shallow valleys are usually based on low-resistance rocks while narrow and deep (closed) valleys are formed by high-resistance rocks. However, we have to take into account also other factors affecting valley evolution – the age or systems of faults because fault debris is an easy target of erosion. The amount of flowing water also plays a significant role. Depending on paleogeographic evolution, this factor is quite variable. In southern slopes of Pyrenees (northwards from the town of Huesca), different types of rocks define the character and shape of valleys. The narrowest parts are found in limestone formations, wider spaces in sandstones, and shallow and open valleys mostly appear in clay sediments.

Areas where river beds are formed in sediments are alternatively affected by erosion and accumulation of new sediments. At the beginning of the process, accumulation prevails, but under high discharge conditions watercourses erode and with water level decline sedimentation takes the lead again (Leopold and Maddock, 1953). The alternating course of erosive and accumulative processes may also depend on the amount of transported material. At certain discharge values, watercourses are capable of absorbing a certain amount of floating matter, but after exceeding the limit excessive material accumulates in the form of natural bank reinforcements along channels. In opposite cases, watercourses tend to erode their banks broadening river beds, cutting down velocity and ability to transport material (Baker et al., 1988). The same experts also indicate that the erosive process is the most problematic issue of fluvial geomorphology. From what has been stated above it is clear that we are dealing with a very complex system of interlinked processes and relations. Anthropogenic modifications of channels should be implemented very cautiously because they can lead to adverse responses in so-far problem-free areas.

There are many types of flood sediments, e.g. channel fillings, flood plain sediments, and alluvial cones of various thickness, texture, transport time, and source area. Sand sediments form ripples, horizontally accumulated layers, or cross bedding. Such sedimentary formations reflect typical features of watercourses during flood (e.g. watercourse depth or flow velocity) and on their basis it is possible to a certain level to derive hydrological conditions during floods (Baker et al., 1988). Flood effects on gravel sediments haven't been thoroughly studied yet (Church and Jones, 1982). So-called ribs of fluvial accumulations are oriented perpendicularly to the watercourse direction. They are formed by pebbles, cobbles, and boulders and typically are of a smaller size (e.g. Koster, 1978). Vaster accumulations (e.g. mounds) in channels of various bed textures are described by Baker (1984). This type of sediments can be formed by back currents or appears in areas of a sudden watercourse outflow into a broader channel. Fluvial sediment mounds formed upon such an expansion reflect a decline in watercourse energy and a sudden reduction of transported particles size. Sediments also accumulate in areas where watercourses by-pass large barriers reducing locally their transportation capacity. Large ripples on the bottom are symmetric and made of coarse fractions. Their height on large watercourses may vary from 50 cm to 10 m and the length of "waves" may vary from 10 m to 150 m.

In downstream areas with large flood plains or alluvial plains, sediments are also affected by geological factors. In river basins formed by less consolidated or fine-grained sediments, accumulations are mostly made of dust particles or mud. Conversely, in river basins formed by erosion resistant rocks, sediments are mostly made of coarse grains. The scope of coarse or fine grains depends on weathering under various climatic conditions, rainfall intensity, slope values, and rock physical characteristics. The amount and characteristics of transported material affect soil and underground rock properties.

Meandering watercourses form alluvial plains by combination of the following processes: a) lateral watercourse migration accompanied by sedimentation; b) sedimentation at slow discharge, but at the same time at a water level higher than a normal discharge (Baker et al., 1988). Both processes are independent, but may work in parallel. Once water spills over from channels, the velocity slows down leading to sedimentation with the exception of lateral erosion broadening channels to such an extent that waters stay within.

Gradual growth of sedimentary mounds along channels increases the discharge capacity. However, bursting of such mounds leads to critical situations because watercourses can suddenly and freely overflow to a broad area. Abandoned meanders are often clogged by other types of sediments, mainly proluvial deposits from lateral valleys. This creates a complex stratigraphic system that when subject to an analysis in large plains in downstream areas allows for reconstruction of phases of watercourse stability and activity in the late Quaternary period. One of the prerequisites of a correct reconstruction of sedimentary development of alluvial plains is discontinuity of accumulation processes facilitating a stratigraphic separation of individual layers. In relatively stable evolution periods, the discharge capacity and bank height are adapted to the prevailing flow regime, and sedimentation is very slow. To the contrary, when watercourse intensity is high, erosive and accumulative processes, often precipitant, lead to bank erosion and changes of channels. Comparing episodic sedimentation with climatic records on the late Quaternary period and other environmental changes, we can study paleogeographic valley evolution in the last 10^4–10^5 years of history. Field works in alluvial plains prove that episodic valley evolution in Holocene was quite a frequent phenomenon (e.g. Brakenridge, 1980; Kozarski and Rotnicki, 1977).

4. Flood Manifestations in Landscape

Major floods provide a unique opportunity for monitoring direct effects on relief development. The long term impacts of floods was studied e.g. by Vaishar et al. (2000). The task of geomorphology is to identify significant paleogeographic relief modifications after shorter or longer periods of time. The success rate is determined by a sufficient amount of documented sites and data. Good conditions and informative value of sites and their sufficiency are the major challenges of such attempts.

In terms of geomorphology, major floods and other natural catastrophes represent a unique opportunity for studying relief development of given areas. It is vital to study not only these processes and identify resulting formations (this is known from the past), but also to gain valuable experience witnessing a) the energy of watercourses affecting valleys under certain discharge conditions in terms of erosion; b) the size of boulders transported by water; c) the types of relief allowing water flow without any adverse responses etc. Acquiring such experience, it is easier to solve problems related to relief development.

From this perspective, field research conducted directly after flood events is very valuable because it is easy to read flood water level marks and get a good picture of ongoing processes. Flood marks in the landscape disappear after a certain period of time and many anthropogenic activities tend to rub off such marks although in terms of landscape revitalisation such works may be unnecessary and even damaging.

4.1 Speed of Flood Marks Disappearance in Landscape

After floods, the first marks to disappear are destructive (or erosive) manifestations, e.g. damaged bridges, or undermined roads because of practical efforts to re-establish the transport system. Sediments remain visible for a longer time, but major accumulations are mostly removed and transported away. Overall, they disappear after several months. To localise such sediments and study their texture is very useful for reconstruction of water flow after overspill. We can learn about the water carrying capacity in particular areas (in relation to the longitudinal profile) and localise tracks prone to accumulation or erosion. It is also useful to compare new and old flood sediments with respect to location and texture. (Results may be used in paleogeographic reconstruction of valley evolution.) Among other types of flood marks, waterlogged houses and damp walls also remain visible for several months. We should bear in mind that water creeps up in brickwork and leaves stains higher than the actual flood water level. This was easily documented comparing exact indicators of water level and marks on adjacent buildings. Grass caught in tree branches during floods remains approximately for 1 year (or longer), but it can't serve as a precise indicator because the water level could have been even higher or trees and bushes may have bent and later rectify again. Major lateral erosion of banks outside developed areas remains visible for a relatively very long time, unless such banks are reinforced. But even then, we can distinguish recent reconstructions from original structures. Landslides also serve as good and relatively permanent indicators (although they aren't always triggered by water flow).

5. Flood Situation in 1997 in Moravia and in 2002 in Bohemia

Reconnaissance works and field mapping performed in the Opava, Bečva and partially Morava river basins after the 1997 floods and in the Otava river basin after the August 2002 floods show that river basins respond in different ways. Differences in relief changes depend on variations in spatial and time distribution of rainfall and different geological and geomorphological conditions. To design specific flood control measures, it is important to study such aspects in all river basins on both regional and local levels.

The comparison of overflow during the 2002 flood and spatial scope of flood plains around the Volyňka, Blanice, and Otava rivers proves dependence on rainfall. The upstream Blanice river was affected by rainfall to a higher extent than the Volyňka and Otava rivers and in parts of the Blanice valley, overflow significantly exceeded flood plains limits. The Otava (down to Sušice) and Volyňka rivers were in completely different conditions. Major overflow (almost copying the scope of flood plains) was found on the Otava only on its track below the Volyňka confluence. In this area, villages are built on adjacent hills of the valley leaving the flood plains undeveloped and floodwaters therefore didn't cause any significant damage.

With respect to lateral erosion and accumulation, i.e. symptoms of valley modulation, intensive processes were detected on the Losenice river (the area of intensive rainfall) and on downstream Volyňka in places affected by major anthropogenic modifications around influx to the town of Strakonice.

Generally speaking, different watercourse tracks trigger different geomorphological processes depending on the stream gradient, amount of flowing water, inclination of adjacent slopes etc. Enormous precipitations affected river basins formed by different types of rocks. With a certain level of simplification, it is useful to stress the processes of relief modulation ongoing on tracks of a steeper gradient (mostly in upstream areas) where unabsorbed water flows fast from hills to channels. Due to steep-sided valleys, the overflow scope is limited, bed erosion prevails over lateral erosion, and loose sediments are washed away from the valley network. During the floods, bed erosion affected mostly the most upstream parts of main watercourses and their tributaries (Photo 2). Besides sediments transportation within the valley network, in some places we also detected stream incision into the rocky bed, particularly where there were rocky steps in the way. In 2002, sediments clearing was performed among others on the upstream Úhlava and its tributaries and in 1997 on tributaries of the Nedvědička river affected in the period 5. 7.–7. 7.1997 by relatively less intensive precipitations (the Sejřek station – 113 mm). Incision into the loose bedrock of the Nedvědička right-hand tributary close to Spálený mlýn could be also caused by tectonic predispositions. Bed erosion also steepens valley slopes making them less stable than prior to floods, which due to gravitation and changes of saturation conditions leads to small landslides. Such slope processes are less frequent than under lateral erosion.

Photo 2 Bed erosion at the tributary of Vsetínská Bečva river. The incision was realised in the soil cover and weathered rocks (Photo V. Vilímek)

On short and steep slopes, we detected also sheet erosion. Due to surface wash (once rocks and soil are saturated by water), great amounts of soil and weathering residues may be carried away from river basins and transported to channels. Watercourses cutting through deep ravines could thus be even blocked. To estimate the extent of transported material accumulation in downstream or midstream areas, it is important to determine the volume of relatively loose weathering residues in upstream areas, possibilities of their supply from valley slopes, and the watercourse capacity to erode banks during floods.

Flat flood plains usually appear in areas of a milder watercourse gradient in broadened valleys. In bends, lateral erosion affects banks and the property could be damaged. On the Opava river, such situation could be documented in the town of Karlovice on the Rožnovská Bečva river around the town of Rožnov pod Radhoštěm. Below the town of Prostřední Bečva, lateral erosion pulled down a bridge pillar and thus a whole bridge. Lateral erosion of concave banks also damaged a railway embankment by the town of Kalovice. In the Otava river basin, no significant flood plains damage was detected in the area delimited by Strakonice and Písek because villages were built outside the inundation area and the bridge connected to the embankment close to Písek had a sufficient flow capacity and wasn't blocked. There was also another bridge vault in the road embankment allowing for a free flow of water running through flood plain (outside the channel).

Baker – Costa (1987) state that geomorphological flood manifestations aren't related to water flow conditions or to frequency of flood events, but to shear stress (intensity of shearing stress) expressed in terms of surface units. For example on the downstream Opava river, banks are significantly less affected by erosion than some parts up the stream, e.g. around the towns of Zátor and Pocheň. Costa – O'Connor (1995) suggest that geomorphological manifestations of major floods shouldn't be derived only from hydraulic characteristics, but also from flood duration.

Bed, lateral and backward erosion represent an integral aspect of natural valley development. Erosive processes are more active under higher discharge conditions and velocity (e.g. due to narrowed channels). Flow acceleration and subsequent bank erosion left their marks (in 1997) close to the town of Horní Bečva where the river cuts through a rocky gorge. The Bečva river was studied in detail e.g. by Kirchner et al. (2000). Dury (1973) and other authors argue that there is no significant interrelation between floods size and sedimentation intensity along channels. Extreme floods aren't always accompanied by extensive sedimentation although it can be the case. Less intensive erosive processes on downstream tracks could be a result of a lower watercourse velocity, e.g. due to a milder gradient or overflow or higher soil compactness (Magilligan et al., 1998) significantly limiting erosion.

6. Discussion

After the 1997 flooding on the Morava river, experts from many fields and laymen presented very different opinions in public debates as well as in a specialised conference organised under the name "Floods and Landcape (Povodně a krajina)" in Brno (November 1997) and suggested very different approaches to a wide range of aspects and problems related to such natural catastrophes. Same contradictory opinions were voiced after the 2002 flood. We would like to comment briefly only on selected aspects of discussions held after the Morava floods in 1997 with respect to regional geomorphology and general conclusion of a technical committee focused on physiogeographic factors ("Natural Hazards Studies" – International Geographical Union).

Environmental associations repeatedly argue that the 1997 floods on the Morava river had such devastating effects due to anthropogenic modifications of landscape. Láznička (1997) also believes that activities of men played a very significant role. It is true that in some areas the scope of damage wouldn't have been so extensive. However, it is evident that floods couldn't be avoided due to extreme rainfall conditions. The scope of damage on property is mainly determined by the scope of development in inundation areas and not by deforestation of upstream areas or similar interventions. Further we provide illustrations from technical literature to clarify the standpoint.

According to Hrádek (1997), improper human interventions into landscape can't have a significant effect on so-called "catastrophic" floods. "Controlled logging and forest reproduction don't lead to any dramatic rise in peak discharge values. When forest evapotranspiration is decreased, it is substituted fast by functions of a compact herb layer" (Runštuk et al., 1997). "Globally, effects of deforestation on flood runoff have been proved only to a limited extent and in extreme cases " (Blažková and Beven, 1997). On the other hand, Graham et al. (1983) use an example from the USA and demonstrate an increase in floods after deforestation. According to Novák et al. (1997), the 1997 flooding originated paradoxically in forest areas – the lowest precipitation totals were detected in zones formed by shallow and skeleton soils of relatively low retention capacities. Agricultural areas showed lesser damage by erosion than forests. Kasprzak – Hejduk (1997) argue that effects of agricultural activities on large regional floods are low. Šlezingr (1997) attributes only 5% to the impact of anthropogenic modifications on floods out of all causes. We agree with Hrádek (1997) that improper anthropogenic interventions into landscape have only a small impact on major floods and their scope and consequences. This is proved by the 2002 catastrophic floods triggered mainly by high soil and rock saturation after the first precipitation episode (August 6–7, 2002), which is a purely natural factor.

We believe that it is beneficial to build storage sedimentation reservoirs in upstream areas. They would reduce the scope of overflow and blockage of narrowed profiles (e.g. under bridges). Such reservoirs should be built to meet regional specific needs considering mainly the following three negative factors: 1) valley beds in upstream areas are mostly difficult to access and making them accessible by employing heavy machines would be damaging to the environment; 2) construction of reservoirs requires high costs which may not be adequate to obtained results; 3) it is possible to catch only part of transported sediments and weathering residues. Due to lateral erosion, a high amount of sediments would get to channels below such reservoirs.

Except specific situations, it is very useful to enable rivers to overflow freely in undeveloped flood plains and not to impede such overflow even when agricultural crops are at risk. For example, above Vsetín the Vsetínská Bečva river is limited by a mound impeding its outflow to flood plains. During floods, water flew away very fast causing severe damage down the stream. One of the watercourses subject to significant shortening and regulation is the Blanice river that inflicted considerable damage in the town of Putim. It is interesting that shared flood plains at the Blanice and Otava confluence are protected from flooding by the Blanice. During the 2002 flood, the total precipitation amount was higher on the Blanice than on the upstream Otava, but this particular barrier had been built in the past implying that floods were causing problems on the Blanice river even before the year 2002.

When channels are significantly shifted during floods, it is better not to return them to their original (abandoned) river beds. Opposite opinions are promoted by Bláha (1997). Balanced approaches to the environment were advocated by Fousek – Slavík (1997), Zuna (1997), and Novák et al. (1997).

The ideal would be to adopt a sensitive approach to extreme or even catastrophic situations in nature, although we are aware that it is a very relative term. Therefore it is important to proceed case by case and with respect to methodology, drawing on the following principles:

- to respect the course of natural processes and leave space for a long-term natural relief and landscape evolution;
- where protection of existing residential zones, infrastructure, historical and archaeological monuments etc. by technical means is indispensable, it is important to proceed cautiously to minimise negative effects on nature;
- designers of new buildings should consider the suitability of particular sites taking into account possible hazards and risks, e.g. risks of flooding, landslides, earthquakes etc.

It is also important to file records on landslides and other sudden or slow recent geodynamic processes in river basins (or to use current records) and specify their relations to geomorphological processes ongoing on watercourses during floods.

7. Conclusions

The aim of this methodological study was to explain the geomorphological aspects of flood situations (in Moravia in 1997 and in Bohemia in 2002) and to suggest priorities of relief research in river basins affected by floods. In our opinion, the analysis of modifications of surface formations and landscape should be based on geomorphological development data from the late Quaternary period.

Although many indications of past floods tend to disappear in the course of time, some relief formations caused by erosive or accumulative processes can be identified even after longer periods of time, e.g. significant erosion steps, channels shifts, or slope deformations. Drawing on alluvial plains stratigraphy, we can reconstruct the history of fluvial and other processes in river basins. To do so, the main prerequisite is to have enough suitable supporting documentation and shallow geological boreholes, dug probes and to conduct special purpose geomorphological mapping.

Global geomorphological research of flood situations proves that floods should be respected as general and usual natural phenomena forming part of a long-term landscape evolution. This aspect of fluvial modulation processes can play decisive role in costing flood damage because many changes of surface formations don't have to be necessarily classified as damage or technically remedied. Respecting natural processes and phenomena (of various spatial and time scales) we can implement an effective geoecological strategy of natural hazards prevention and clearance of consequences of sudden or catastrophic geodynamic events. In practical terms, such findings significantly enrich the awareness of principles and rhythms of natural processes and bring about financial savings because we can save considerable amount of money and prevent damage repetition during next floods in some areas. In the Czech Republic, we detected improper bank modifications (Šílený and Jirásek 1997; Vanýsek, 1997). For example in Karlovice or below Nové Heřminovy, the Opava river significantly broadened its river bed and during next floods it probably wouldn't spill over. The only remedy to implement was to reinforce banks affected by erosion. Instead, levees were built inside the channel further narrowing the flow profile (Photo 3). Now, even a smaller flood than in 1997 will be sufficient to cause problems. The same criticism applies to the Veltrusy castle park damaged during the 2002 flooding where the Vltava river banks were unnecessarily repaired instead of leaving the reservoir created during floods to play a natural revitalisation function (which would be done for free!) (T. Just, verbal communication).

The research of relief modifications during and after floods shows (Costa 1974, Magilligan et al., 1998) that major floods don't always have only negative effects on the landscape. Even within one river basin, we can find very different manifestations

Photo 3. An example of wrong localised levees by Nové Heřminovy (Photo V. Vilímek)

and consequences of erosive and accumulative processes. It is therefore vital to analyse local and regional natural conditions that are the original driving factors of catastrophic floods. A realistic interpretation of such research results could facilitate design of specific measures to prevent and reduce natural catastrophes.

Drawing and reviewing maps of areas exposed to flood risks, we should also take into account dynamic geomorphology. Applying the methods of geomorphological research, we can ensure a comprehensive approach to hydrographic network development, broaden possibilities of reconstruction of past natural catastrophes, and support forecasting efforts in monitored areas.

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HODNOCENÍ PRŮBĚHU A NÁSLEDKŮ POVODNĚ

Résumé

Zhodnocení průběhu následků povodně bylo v tomto příspěvku provedeno především z pohledu geomorfologie, antropogenních projevů a obecně platných zákonitostí vývoje krajiny. Toto vyhodnocení má rovněž zčásti metodický charakter s uvedením typických příkladů z postižených povodí, a to jak z povodně 2002, tak i ze starší z roku 1997 na Moravě. Bez ohledu na výši škod či následky je povodeň přírodním fenoménem, při kterém dochází k poměrně dynamickému vývoji reliéfu i krajiny. Ze studia rozsahu údolní nivy a z charakteru sedimentů, které byly uloženy při starších povodních v holocénu vyplývá, že starší případy povodní

byly minimálně srovnatelné či ještě větší, než dokumentované povodně na přelomu 20. a 21. století. Nelze souhlasit s názorem, že u takto rozsáhlých a velkých povodní je hlavní příčinou jejich vzniku špatné hospodaření člověka v krajině. Vliv člověka se může projevit pouze lokálně. Minimalizovat následky povodní je možné pouze na základě detailního studia bezprostředních příčin enormních projevů eroze a sedimentace, tedy s ohledem na konkrétní příčinu destrukčních projevů povodňových průtoků. V řadě úseků údolí, pokud nebyla údolní niva zastavěna či nebyl kladen odpor přirozenému proudění vody, nebyly totiž zaznamenány po povodních viditelné škody.

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