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FLOODS IN THE SLOVAK CARPATHIANS IN THE YEARS 1997 AND 1998. CAUSES, COURSE AND CONSEQUENCES

INTRODUCTION

Floods have always been and always will be a natural process every civilized society must learn to put up with. Development of technology on the one side has offered the human civilization many means of successful, though in many cases only temporary, control of the origin, course and consequences of floods. On the other side and quite paradoxically, precisely the means of what is called modern civilization contribute to the origin of floods or least aggravate their course and consequences. The notion flood is almost exclusively a synonym of negative phenomenon connected with human tragedies, damage and suffering. We have to realize though, that there existed a civilization in the valley of the Nile some thousand years ago existentially dependent on floods perceiving this natural phenomenon quite differently from the contemporary negativist view.

PROPERTIES OF LANDSCAPE STRUCTURE OF THE SLOVAK CARPATHIANS FROM THE POINT OF VIEW OF ORIGIN OF FLOOD HAZARD

The Slovakian Carpathians occupy a 78% of the total area of Slovakia (Mazúr et al. 1981), the rest corresponds to the lowlands of the Pannonian basin. More details with physical-geographical situation of the Slovakian Carpathians are contained in the studies (Stankoviansky and Midriak 1998; Urbánek and Lacika 1998).

Properties of landscape structure influencing the size of hazard of flood origin are generally known from literature. Principally we can classify them as natural and man-provoked properties (Hanušin 1996). Natural properties include regime and intensity of precipitations, lithological, morphometric and hydrographic properties of a catchment. While establishing the flood risk, ever increasing role is that of man-provoked (partially man-controlled) interventions into the landscape system. Here belong the way of land use and its management, scope and nature of water-managing interventions into the landscape. Water-managing interventions are drying up of the wetlands, adjustments of stream beds, construction of water reservoirs, draining of areas. The rate of flood hazard is also regulated by institutional aspects including the package of legal standards relevant for flood protection, competencies in management of a particular catchment, etc.

Let us take a close look at the single natural and man-provoked properties of the landscape structure of the Slovak Carpathians from the viewpoint of possible origin of flood hazard.

The biggest precipitation totals correspond to the tallest mountain ranges — the High and Low Tatras, Veká and Malá Fatra Mts and the mountain ranges of the north-western Slovakia (Západné and Stredné Beskydy Mts). Mean annual precipitation totals amount to from 800 mm up to 2,000 mm in the Tatras. North-western Slovakia, i.e. the basin of upper reach of the Váh and its right side tributaries Orava and Kysuce is also the region with the highest number of days with precipitations exceeding 1 mm and with the highest probability of occurrence of a long-term precipitation period (Šamaj and Valovič 1980a, 1980b).

Lithological composition, more precisely, the permeability of rocks and rock compounds is one of the decisive criteria influencing the rate of precipitation infiltration and consequently, the runoff in a catchment. The least permeable rock compounds in the Slovak Carpathians, and consequently the most vulnerable from the viewpoint of origin of flood runoff are the rocks of what is called the outer Flysch belt (mountain ranges in the north-west and north-east of Slovakia) and the Neogene claystones and sandstones (above all the fillings of some basins, as well as some hilly lands). The medium value of permeability is typical for neovolcanic rocks (mountain ranges in the southern and south-western part of Central Slovakia and in Eastern Slovakia), and the rocks of crystalline (the Tatras, core mountain ranges prevailingly situated in Central and Eastern Slovakia). The best permeability characterizes the Mesozoic limestone and dolomite (nappe mantles of the core mountain ranges prevailingly situated in Central Slovakia) along with well-classified fluvial sediments of the alluvial plains of big streams (Základná hydrogeologická mapa SSR).

Hydrographic conditions — shape of catchment, density and form of the river network are regulated by relative youth of the relief in the Slovakian Carpathians. The river network is mostly poorly developed (for instance, as compared to the rivers in older Bohemian massif), with typical elongated catchments and short, underdeveloped tributaries ending in the streams of higher orders. Such form of catchment and river network contributes to flood hazard.

Man-provoked interventions in catchments started practically immediately after the beginning of the settlement of territory, i.e. 4,500–5,000 B.P. (Ložek 1973). Development of human society has, naturally, brought about also increased rate of human impact. Settling or colonising waves in remote and aforested parts of the Carpathians were important from the viewpoint of flood hazard. The most important ones were the Wallachian colonization which took place there starting in mid–16th century and the "kopanitze" colonization in the 16th–18th centuries. Both are characterized by diminishing forest areas in favour of arable land, above all in north-western Slovakia which is naturally prone to creation of flood runoff anyway. Another important milestone from the viewpoint of landscape management was the beginning of the 50ies of the current century, when while applying the communist ideology, agricultural activities were collectivised. In practical life it meant the onset of a series of extensive interventions in landscape, and many of them had affected and still do the magnitude of flood hazard. The primary and most conspicuous intervention was the merging of tiny fields of private farmers into extensive blocks of fields of the cooperative farms. E.g. the mean area of identified unit of higher category arable land increased from 2.7 to 7.1 ha in watershed of the Jablonka in Myjava hilly land (162 km^2) in the years 1955–1990 (Solín and Cebecauer 1998).

After merging the arable land additional interventions came: adjustments of water streams, drying up of the wetlands, draining of the areas. In 1994 over the whole territory of Slovakia there were 7.300 km of adjusted streams equaling almost 15% of the total length of all streams. We should also add that a major part of adjusted streams is in the lowland, i.e. out of the Carpathians. Draining systems are installed on more than 4,700 km^2 of the territory, also mostly in lowlands, but a considerable portion of them is located on sloping positions of the Carpathians. Retention water reservoirs are considered, above all by the engineers, the most efficient tool of anti-flood protection. There are at the moment 46 water reservoires for different purposes in Slovakia, with the total volume exceeding 1 million m^3 each.

The aim of all quoted interventions in catchments was the effort to regulate the runoff regime, what eventually means the quickest possible draining of an area. This strategy, financially extremely demanding, became recently a subject of scrutiny and criticism by environmentally oriented hydrologists and what is more important, also by some engineers. All quoted interventions along with unsuitable forest management and removal of scattered greenery from landscape led to reduction of its natural retention ability, quick runoff in untreated or other sections of streams.

We can not ignore though the anti-flood effect of numerous water reservoirs which obviously contribute to the reduction of flood waves protecting the territory against flood. Negative is the response of the society which relies too much on the protective function of such constructions and the result is certain degree of carelessness even indifference of the competent authorities when choosing location of constructions on alluvial plains of the streams. The same as in other countries we notice in Slovakia an important reduction of permeability of the alluvial plains for flood runoff precisely because of an extensive construction activity on alluvial plains, often within Q_{100}.

FLOODS IN THE YEARS 1997 AND 1998

A large part of Central Europe was stricken by extensive and extremely intensive, long-lasting rainfalls which provoked in many places the most disastrous floods of the current century. The most affected regions were the basins of upper and lower Odra in Czech Republic and Poland. Numerous preliminary and final studies tried to analyse the situation. The flood in July 1997 did not avoid Slovakia, even though we must admit that the scope and rate of the event was far less damaging than the ones in Poland and the Czech Republic. In spite of it, its nature was that of an emergency and disaster in some places. The flood of July 20, 1998 in Eastern Slovakia, I shall refer to later, was negligible in terms of area and duration compared to the events of July 1997, but as far as the intensity of the processes and incredibly high number of victims (54) are concerned and compared to the size of inflicted area and duration, it is one of the most tragic floods in Slovakia in general.

THE COURSE OF THE FLOOD IN JULY 1997

THE CHARACTER OF METEOROLOGICAL SITUATION

An important role in the process of creation of the meteorological situation at the beginning of July 1997 is attributed to a distinct temperature divide between the south-eastern and western Europe (Beránek and Sokol 1997). A low pressure trough over the western Europe started to move eastward. By 4th of July an undulated cold front proceeding from the west reached Slovakia. On July 5 an independent depression originated over Czech republic while also in the surface layers of atmosphere in the region of the Alps a front originated which set on heading to north-east. On July 6 the centre of the anticyclone in higher atmospheric levels moved to Moravia and southern Poland and the front wave started to occlude. This occluded front moved to the western and north-western Slovakia. Following the front post-frontal precipitation fell on the territory of Slovakia. The following day, July 7, the depression in higher atmospheric levels slowly moved to the Eastern Carpathians where it stayed almost motionless. On July 8 the occluded front started to diffuse, depression moved over the western Ukraine where it was filled up and consequently the precipitation activity in Slovakia stopped (Hajtášová and Pastirčák 1998).

The described meteorological situation provoked intensive and long lasting precipitation. Practically all over the territory of Slovakia the July precipitation

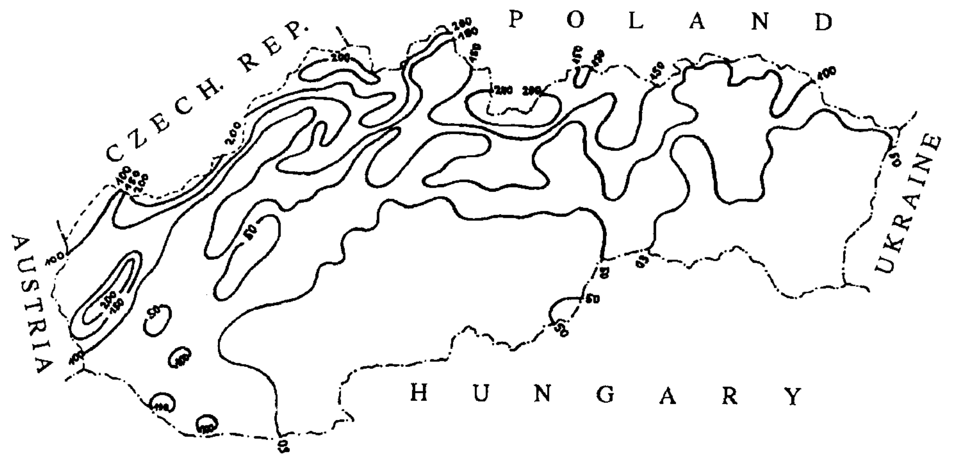

Fig. 1. Isolines of precipitation sum for period 5th–9th of July 1997 (in mm). According to P. Faško (1997)

were above average exceeding the normal gauging by 100% in all weather stations. (Fig. 1). July 1997 was the month richest in precipitation since 1881 while the all-Slovakian mean precipitation total reached the value of 179 mm (SHMÚ 1998). The highest precipitation totals were taken in the catchments of the Morava, Váh, Poprad, and Hornád where more than 200–300% of a long-term mean fell i.e. 200 to 400 mm depending of the situation and the altitude above sea level of a particular weather station. Relatively lower precipitation totals were recorded in the catchments of the Nitra, Hron Ipeľ, Slaná, Topľa, and Ondava where the total in the most exposed sites exceeded 200 mm (Faško 1997). In the period between the 17th and 22th of July another precipitation wave stroke Slovakia and a part of Central Europe which was far less intensive than the preceding one. The highest precipitation totals in critical period, i.e. between the 5th and 9th of July were taken in the territory stretching along the borders with the Czech Republic and Poland from the Malé Karpaty Mts over Biele Karpaty Mts, Javorníky Mts, Beskydy Mts, the Tatras up to Levočské vrchy Mts in the north-east. It was probably the fringe of the pressure body which has caused several days lasting rainfall in the Czech Republic and Poland while loosing intensity during its very slow progress towards the east of Slovakia. In spite of it, the precipitation totals during the mentioned five days amounted to more than 200 mm in some places. For comparison, the maximum 5 day totals in the north-east of the Czech Republic in basin of the upper Morava and Odra reached in some places more than 500 mm (Lysá Hora in Moravsko-sliezske Beskydy Mts, at 1,323 m above sea level it was even 586 mm (Buček et al. 1998). Comparison of precipitation totals in north-eastern Moravia and north-western Slovakia (effect of windward and leeward situations) points to approximately doubled totals in windward situations in Moravia compared to

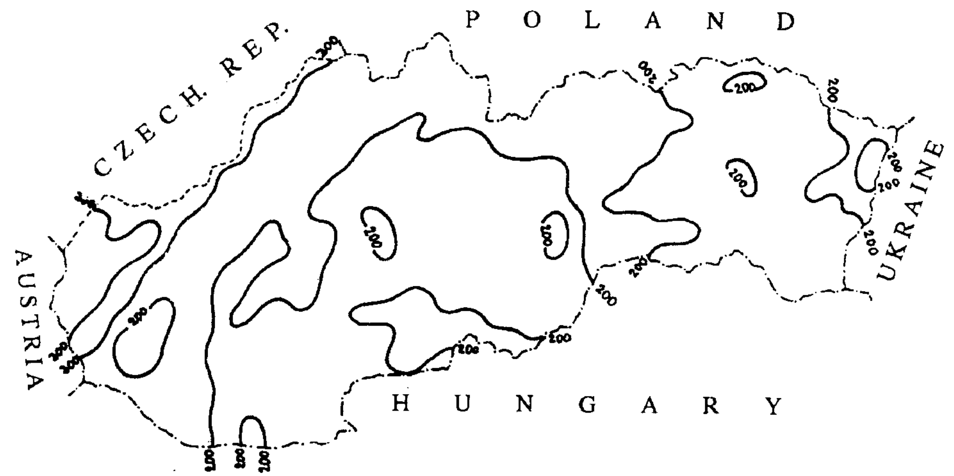

Fig. 2. Isolines of precipitation sum for July 1997 (in % of longterm mean). According to P. Faško (1997)

the leeward Slovakian side. We have to admit though, that the pronounced gauged differences were not caused exclusively by the situation effect in this case (Fig. 2)

HYDROLOGICAL EVALUATION OF THE FLOOD

Relative advantage was, by the beginning of July 1997 and from the point of view of creation of flood runoff, the low saturation of the catchments, result of a long dry spell. From October 1996 to April 1997 the precipitation total equaled less than 50% of a long term mean while in the following months May and June they increased only slightly to 60–70% of the long-term mean (Faško 1997).

If we compare the values of n-year return period culmination discharges reached during the flood we find out that only in isolated cases in small streams in the western Slovakia in catchment of the Morava (Teplica, Chvojnica) the culmination discharges acquired the character of hundred year return period (Škoda et al. 1997). We do not include here some profiles in a border section of the Moravia, where the nature of the discharge was that of 100–1.000 year return period (Faško et al. 1998), which originated out of the Slovak territory. The culmination discharges in other streams of the Slovak Carpathians reached the 20–50 year return period discharge, namely in catchments of the Kysuce and Rajčianka in the north-western Slovakia and in the Little Carpathians. Culmination values in other catchments stricken by the flood were even lower (5–10 year return period) (Faško et al. 1998). If we compare these values with the situation in the Czech Republic and in Poland where the 100–1.000 year return period discharges were reached in big streams (Morava, Odra) we can see that the overall

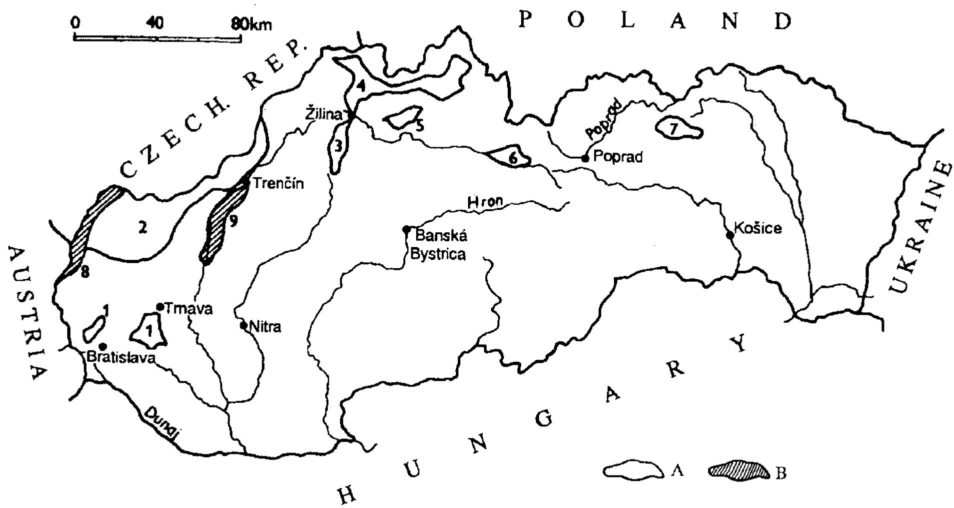

Fig. 3. The most affected and threatened areas during the July 1997 floods. Compiled by I. Hanušin. A — areas affected or threatened due to heavy local rains, 1 — small streams in the Malé Karpaty Mts, 2 — the Myjava river basin and the Biele Karpaty Mts region, 3 — the Rajčianka river basin, 4 — the Kysuca river and upper Orava river basins, 5 — the Belá river basin, 6 — the upper Váh river basin, 7 — the upper Torysa river basin, B — areas affected or threatened due to the flood waves from the upstream part of the basin, 8 — the Morava river basin, 9 — the stretch of the Váh river between Piešťany and Trenčín

course of the floods in Slovakia in spite of indisputable damage and problems was substantially milder than in the two neighbouring countries. The total damage of property caused by the flood in 1997 was estimated at approximate 2.4 thousand million Sk. Number of communities affected was 366 and an area of 23.680 ha and 8.255 houses were flooded, and population of almost 20 thousand had to be evacuated (Supek and Abaffy 1997). Most of them, 15 thousand, had to be moved in the spa Piešany where there was the risk of breaking the dike next to discharge channel of the water power plant of the Váh and consequent flooding of the city (Fig. 3).

THE 1998 FLOOD

The flood of July 20, 1998 which affected 82 communities in the area of Šarišské vrchy Mts, Levočské and Branisko Mts in the north of the Eastern Slovakia had a completely different origin, nature and scope. Duration and range of this flood was far smaller than the one of previous year. On the other side, intensity of rainfall and runoff were among the highest ever recorded in Slovakia.

The quoted event is described as a downpour flood caused by extreme storm which in this case did not proceed as usual tracing certain route but it remained "hanging" over the stricken area. Two conditions determining the origin of an extreme storm were complied with: unstable layering of the whole troposphere and a high air moisture (Škulec 1998). The preliminary analyses show that it was a phenomenon of what is called "supercell", i.e. the one accompanied by extremely intensive precipitation. Unfortunately the observing and gauging network of the Slovak meteorological institute (SHMÚ) is not that dense or well-equipped as to be able to analyze and warn early enough against similar, statistically little probable events affecting the areas sized several tens of km^2. Analysis of the gauged values before the storm nor the analysis of accessible data from wider hinterland of the event did not and could not lead to warning as no real grounds existed. During the event in places almost 50 mm of rain fell in an hour, while the total during the whole event which took 1 to 1.5 hour exceeded 100 mm in some spots. The maximum discharge in the local streams reached according to the data of SHMÚ the level of 1,000 year return period discharge, which, for instance in the profile of Malá Svinka-Jarovnice represented the culmination discharge estimated at 230 $m^3 \cdot s^{-1}$ (SMHÚ 1998). If we realize that the area of the catchment in question is about 36 km^2, specific runoff reached the maximum value of approximate 6.400 $l \cdot s^{-1} \cdot km^{-2}$! For comparison: during the flood in 1997 on river Rožnovská Bečva flowing out from the Moravsko-sliezske Beskydy Mts, one of the most rainy areas of Czech Republic, reached the value of specific runoff during culmination "only" 1935 $l \cdot s^{-1} \cdot km^{-2}$ in station Valašské Meziříčí (256 km^2). Even though the areas of the mentioned catchments are different, we can see that the intensity of flood in Eastern Slovakia in July 1998 was an extraordinary one (Fig. 4).

An important destructive factor in this flood were what is called breaking waves i.e. the waves which originate after breaking the barriers created in the stream bed during the flood, namely near the bridges. The most tragic consequence of this flood were the 54 victims, mostly children. In the flood plains of the streams in question there were dwellings of the Romany population, very simple and inadequate constructions. Such "buildings" unfortunately together with their inhabitants including small children were the easy prey of the element.

The flood affected 10,800 inhabitants, 756 persons became homeless, 3.618 persons were evacuated and 2.059 houses were flooded (Šastný 1998).

What were the causes of this flood, could it be prevented or at least its consequences paliated? The primary causes, an exceptional synoptic situation, saturation of the catchments by previous precipitation and unfavourable lithological composition of the catchment (Flysch base rock) are practically irreversible. There originated a comparably wide discussion of the share of the land use method applied in catchment in the flood scope. The most discussed subject was the one of the retention ability of the forests. An officially stated share of the forests in affected catchment is 78%. Opponents representing non-governmental organizations point at a cheating nature of such data. Much

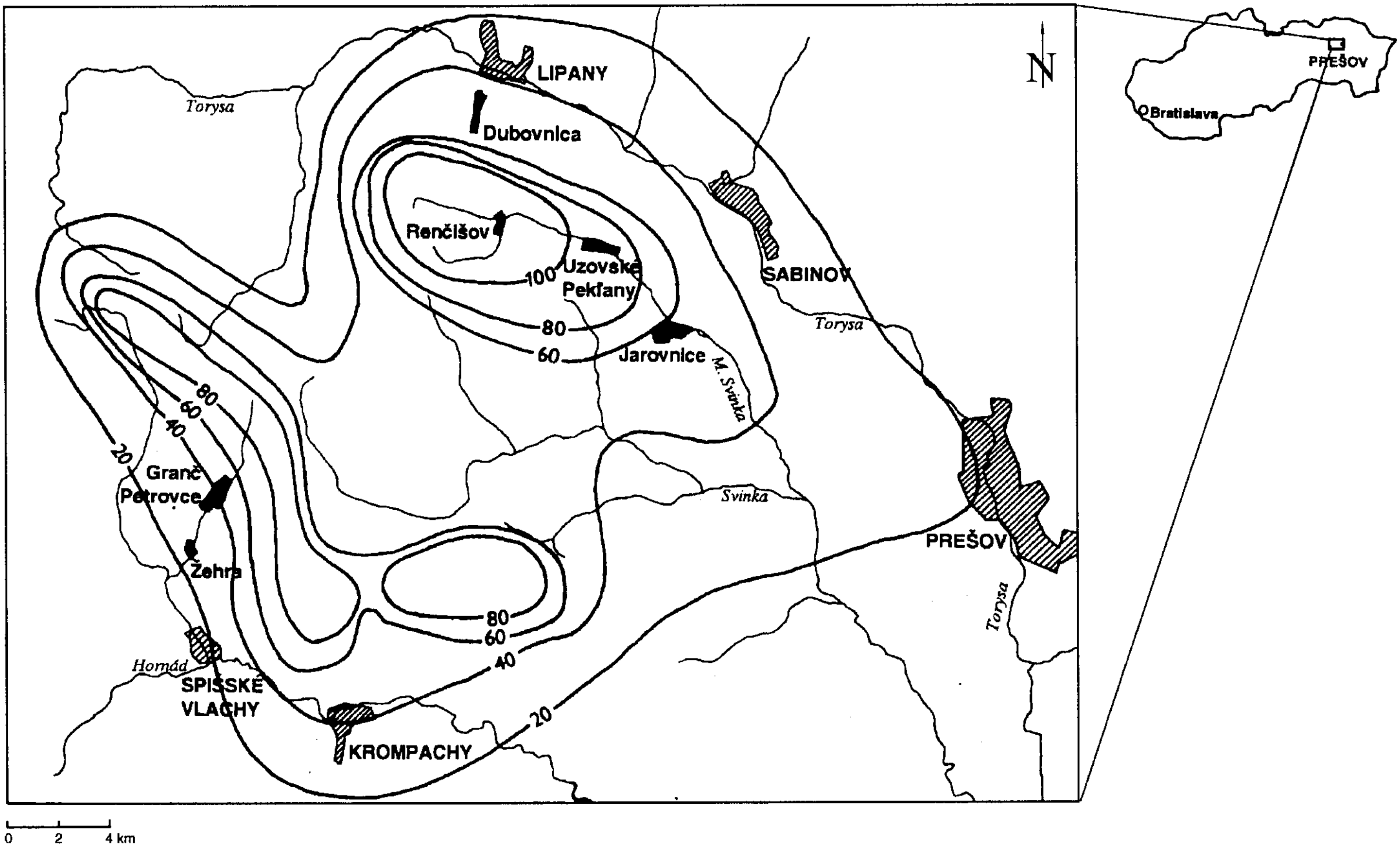

Fig. 4. Isolines of precipitation sum from the 20 July 1998 flood in Eastern Slovakia. Compiled by I. Hanušin according to P. Šastný (1998). Black shape — the most affected settlements

greater importance than the statistically recorded share of forest in the area of a catchment is the real retention ability of the forest given by the character of its composition, management, density and aspect or orientation of the forest roads. In any case, we can assert that not even a catchment totally covered by forest with a maximum retention ability would be able to neutralise the downpour rainfall of similar intensity.

SEARCH FOR POSSIBLE CAUSES AND SOLUTIONS TO THE PROBLEM

Disastrous floods in 1997 stirred up the discussions of experts and public in general of the possible causes, and above all the ways to prevent or reduce the damage. Multiple declarations, standpoints and analyses were published. The spectre of opinion on the subject is similar in almost all countries concerned. Severe technical measures on the one extreme including construction of retention water reservoirs, higher and firmer dikes, construction of dry polders, straightening of the streams and facilities for the most rapid possible runoff from the landscape are contradicted by the orthodox conservationists who oppose the dams of any kind. Increase of natural retention of catchments is presented by them as the only one and most efficient tool of anti-flood protection. As usual, neither of the parties is altogether right.

In a relatively densely populated landscape, which Slovakia certainly is, it is not quiet possible to exclude the hydrological and technical interventions, as for instance, the water reservoirs. However, while evaluating their efficiency we should also take into account the cost of adaptation of the sediments deposited at the reservoirs, or the cost of its dismantling after expiration of its lifetime.

Apparently the hydro-technical measures themselves if not combined with adequate management in entire watershed are little efficient and guarantee only a partial protection against small floods. And paradoxically some hydrological works even cause flood situation in streams. A classic example of an above mentioned situation occurred in the 1997 floods in waste channel of water power station near Piešťany where the water damaged the dikes and there was a risk of flooding the town by water flowing in an artificially made technical system which eventually did not collapse only because the intensity of rainfall in watershed of the Váh amounted only to a half of the one which fell in the neighbouring catchment of the Morava.

What chances of protection against floods do we have? Firstly, we have to realise that the extreme events contributing to the origin of extensive floods among which are also the extraordinary and long-lasting rainfalls occurring with a statistical probability in n-years, almost always provoke the floods. Even the richest society is not able to provide for a complete and economically acceptable protection against such situations. In such cases not even tens or hundreds of million square metres of retention reservoirs or high-quality dikes and extensive retention capacity, watersheds with a 100 percent forestation can save the situation. The most efficient protection is then a targeted defensive behaviour of society against the streams. In practical life it means that the rivers must get their space back, we must abstain from massive settling within the inundation space of the rivers, from building industrial compounds in such areas, namely the ones that can cause water pollution during floods (chemical production storing, hazardous waste sites, etc.).

In densely inhabited and relatively narrow valleys (the one of the Váh, for instance) a consequent application of such measures would naturally require huge investments, efficiency of which is questionable. At least the most problematic spots (potential sources of chemical pollution) should be moved out. A very efficient way of immediate anti-flood measure is an enlargement of inundation space where it is plausible. It practically means, for instance, moving the dikes farther from the stream, building of polders with discharge, similar to the ones of the river Rhine in Germany. The diking of the riverbeds with a relatively small inundation space is acceptable only in those settlements where they ensure a rapid outflow of the flood discharge and reduction of the flood risk.

Conservation of flood ecosystems and riverbank growths will also contribute to the increase of the accumulation capacity of riparian landscape. The efforts concerning the most rapid possible transfer of flood water out of landscape preferred in the past were rather short-sighted and anti-ecological though perhaps comfortable for someone as it brought a local effect in a form of a quickly "washed away" water and the problem passed to the next reach of the stream in question.

One of the principal, so far underestimated anti-flood measures is an increase of natural retention capacity of a catchment that should be one of the decisive or equivalent tools accompanied by hydro-technical measures. The nature of runoff originates within a catchment and it is the reason why its properties and management are highly important also from the viewpoint of anti-flood protection. Not in vain it is said that the rivers are landscapes products and the purposeful management in landscape with regard to its anti-flood function is more cost-effective than huge, expensive and sometimes controversial hydro-technical interventions in streams. Decisive importance is that of the forest and agricultural landscape.

In spite of the differing opinion over the function of forest, research mostly proves that the natural forest possesses a retention capacity comparable with water reservoirs, while it also provides for other irreplaceable landscape-ecological functions. Unfortunately, the practical life in forest management in spite of all stated is questionable. Inadequate activities, i.e. biased composition of forests, clearcuts, expansions of forest road network and ever-worsening condition of the forests contribute to decrease of their natural retention function. The management in a co-operative agricultural landscape is not ideal either. Fusion of small plots into large fields, removal of line and dispersed greenery, compression of subsoil also lower the natural accumulation capacity of agricultural landscape and assist to accelerated runoff (Hanušin 1998).

CONCLUSION

The 1997 and 1998 floods in Central Europe have reminded us of natures force in a tragic way. They renewed the lost memory of generations, comforted by an impression that the nature has been dominated and by long periods free from big floods. They also posed a question what should a modern anti-flood protection rely on. Even though qualified opinion on the mentioned questions should differ, one thing is certain: the human society entering a new millennium will have to learn to respect again the unalterable natures laws.

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STRESZCZENIE

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POWODZIE W SŁOWACKICH KARPATACH W LATACH 1997 I 1998. PRZYCZYNY, PRZEBIEG I SKUTKI

W latach 1997 i 1998 wystąpiły powodzie w Karpatach Słowackich. Powódź w lipcu 1997 była znacznie łagodniejsza niż w Polsce i Czechach, chociaż w skali lokalnej była wydarzeniem ekstremalnym o charakterze katastrofalnym. Katastrofalna powódź, którma miała miejsce we wschodniej Słowacji w dniu 20 lipca 1998, chociaż bardziej ograniczona przestrzennie i czasowo miała gwałtowny przebieg i była tragiczna w skutkach. Pochłonęła 54 ofiary i jest zaliczana do najtragiczniejszych powodzi w historii Słowacji. W pracy są rozważane sposoby zapobiegania powodziom. Ponieważ zdarzenia ekstremalne takie jak wyjątkowo wydajne opady oraz opady długotrwałe zawsze prowadzą do powstania powodzi, więc rozważa się środki zapobiegawcze. Za jedno z podstawowych, niedocenuianych działań przeciwpowodziowych autor uważa zwiększenie naturalnej pojemności retencyjnej zlewni, która może być równie skuteczna jak budowle hydrotechniczne.