World Meteorological Organization

STUDY OF HISTORICAL FLOODS IN CENTRAL AND EASTERN EUROPE FROM AN INTEGRATED FLOOD MANAGEMENT VIEWPOINT

SLOVAKIA

Submitted by: Slovak Hydrometeorological Institute, Bratislava

For the WMO/GWP Associated Programme on Flood Management

1. INTRODUCTION

Slovakia is located in the Central Europe where flooding is occurred regularly every years.

Fig 1. The Slovak Republic and neighbouring states

From the hydrological point of view Slovakia is subdivided into 11 main river basins: Morava, Danube, Váh, Nitra, Hron, Ipeľ, Hornád, Bodrog, Bodva and Poprad, Fig. 2.

In the recent years, all basic types of the floods had occurred on the Slovak Republic territory, as follows:

- Regional floods from the snow melting and from rainfall,
- Ice floods,
- Local flash floods.

Historically, mainly the flash floods were documented only rarely. In fact, there were documented just two of them.
The first flash flood was on the Vydrňanka creek (Váh river basin) in June 17, 1939 (O. Dub: Regime of the large waters on small streams).
The second one was described in the Journal Meteorological News (Š. Petrovič: Flood in the Eastern Slovakia, in August 15, 1949, (MZ, *3*, 4-5, 1949). The described flash floods were occurred in the small tributaries in Torysa River basin (villages Drienov, Mirkovce, and Bogdanovce).

In the second half of the 20th Century till the half of 90th, the larger flash floods were not recorded by the hydrometeorological service, however, cloudburst (torrential rain) were occurred from time to time.
Nowadays, population living on the Central Europe is facing to the occurrence of the flash floods. In the paper A. Grešková: "Small catchment with occurrence of the flash floods in 1997-2002" was recorded 77 of them.
The overall damages caused by the all types of floods in the last years were estimated to be
2, 6 billions SKK (app. 65 mil. €).
There are approximately 2 300 small catchment areas in range 5-50 km^2 with a large potential risk for flooding especially with respect to this type of floods.

In this report, the effort was concentrated on the description of two flash floods, that had occurred in the last years and caused the great damages on properties and in one case the life losses were registered as well. Two flash floods were described and reconstructed in accordance the defined objectives of the Associated Programme on Flood Management in Pilot Project "Study of the Historical Floods from Integrated Flood management Viewpoint. The first flash flood occurred on the Malá Svinka and Dubovický Creek.

The second flash flood was recorded in the Štrbský Creek in July 24, 2001. Both localities where flash floods had occurred are presented in Fig. 2.

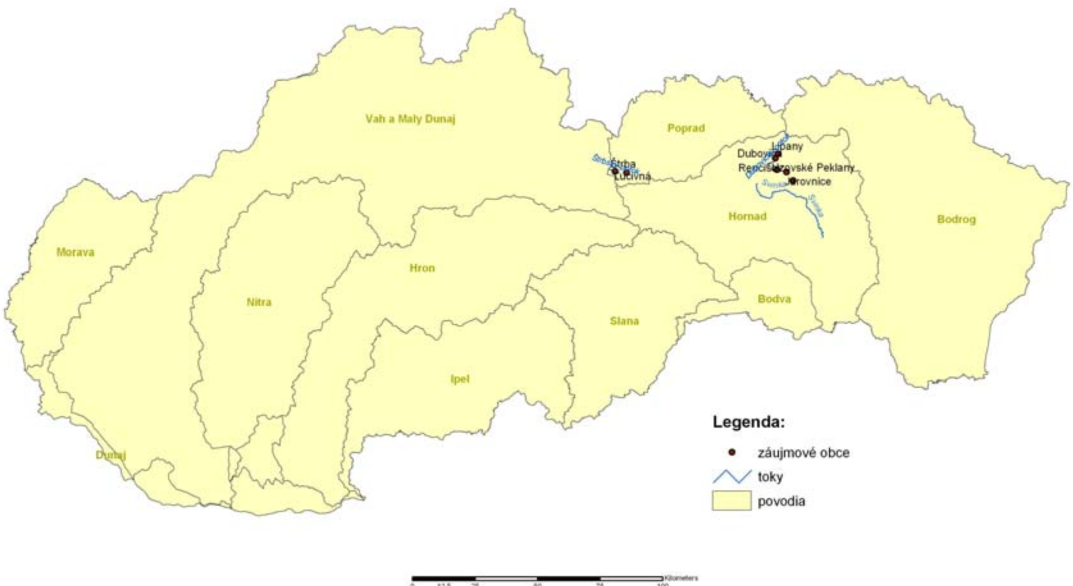

Fig 2. 11 main river basins of Slovakia and localities with described floods

2. FLASH FLOOD on MALÁ SVINKA and DUBOVICKÝ CREEK

2.1 CHARACTERISTICS OF THE CATCHMENT AREAS

2.1.1 Natural characteristics of the catchment area

Both Malá Svinka and Dubovický Creek are water- courses of the 6^{th} order. Their springs are located in the Eastern part of the Western Carpathian under the Bachureň massif (1081,5 m a. s. l.).
Malá Svinka flows in southeast direction and later turns to the south. It is a tributary of Svinka River, which is a tributary of Hornád River. Dubovický Creek flows in north direction and is a small tributary of Torysa as a tributary of Hornád River.
Hydro- geologically, this locality belongs to the flysh belt created by the sand and clay layers. Soils have a character of the cambisol. The gradient of slopes in the Malá Svinka area ranges 20-28%; maximum slopes in the upper part of catchment are more than 100%. The slope of creek itself is 2,7% in average.
In the case of Dubovický Creek, there the gradient of slopes is in the range 23-24% and maximum slopes are smaller than in Malá Svinka. The slope of creek itself is approximately 6%.

2.1.2 Climatic characteristics

Climate of the both selected catchment areas is characterised as moderately warm and humid with monthly temperature means from –5ºC (January) to +18ºC (July), with annual temperature mean 7,8ºC and with annual mean precipitation total in the range 600-650 mm. In the higher elevation the catchment belongs to moderately cool and humid sub-region. The basic climatic characteristics for both catchment areas are presented in Table 1.

Table 1. Climatic characteristics from Sabinov station

Month	1.	2	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	Year
Air temperature (^{0}C)	-4,5	-2,6	2,0	8,2	13,6	16,8	18,4	17,6	13,8	8,1	3,1	-1,1	7,8
Precipitation (mm)	28	25	26	36	66	97	93	85	47	43	44	28	618
Air relative humidity (%)	84	82	76	70	69	72	73	75	76	80	85	87	77

2.1.3 Hydrological characteristics

In this chapter basic hydrological and physical-geographical conditions in both catchment areas are described.

a) Hydrographical characteristics

In Table 2 following characteristics are presented to give more insight on the catchment areas regarding the runoff processes:

- A - catchment area in km^2
- L - length of the valley in km
- H_{avg} - mean altitude in m above s. l.
- α - shape of the catchment (A/L^2)
- β - index of the slope (h/A), where $h = 2(H_{avg.} – H_{min})$
- H_{min} - altitude of the cross seeking profile in m above s. l.

Table 2. Physical - geographical characteristics of the catchment Malá Svinka

Course/Profile	A (km^2)	L (km)	H_{avg} (m a. s. l.)	α (A/L^2)	β (h/A)	Forest (%)
Malá Svinka / above Renčišovský Creek	6,45	4,7	827	0,29	84,36	70
Renčišovský Creek/ confluence	7,06	4,6	814	0,33	65,18	20
Malá Svinka / below Renčišovský Creek	13,52	4,7	827	0,61	38,00	45
Malá Svinka / Uzovské Peklany	24,26	8,2	763	0,36	20,95	60
Malá Svinka / Jarovnice	35,39	13,6	686	0,19	16,39	50
Malá Svinka / confluence	62,21	23,7	570	0,11	8,12	40

Table 3. Physical - geographical characteristics of the catchment Dubovický Creek

Course/Profile	A (km^2)	L (km)	H_{avg} (m a. s. l.)	α (A/L^2)	β (h/A)	Forest (%)
Dubovický Creek / above Dubovica	10,9	4,4	760	0,56	35,27	70
Dubovický Creek / confluence	15,24	7,7	589	0,26	27,51	30

b) Runoff characteristics

In Table 3 following characteristics are presented to describe the runoff:

- A – catchment area in km^2
- P – average precipitation in the catchment (mm)
- R – runoff from the catchment area (mm)
- φ – runoff coefficient (R/P)
- q – specific runoff in ($l.s^{-1}.km^{-2}$)
- Q – mean discharge ($m^3.s^{-1}$)
- Q_T – T-year maximum discharge ($m^{-3}.s^{-1}$)

Table 4.

Course	A (km^2)	P (mm)	R (mm)	P-R (mm)	φ (R/P)	q ($l.s^{-1}.km^{-2}$)	Q ($m^3.s^{-1}$)	Q_{10} ($m^3.s^{-1}$)	Q_{20} ($m^3.s^{-1}$)	Q_{50} ($m^3.s^{-1}$)	Q_{100} ($m^3.s^{-1}$)
Malá Svinka	62,2	648	152	496	0,23	4,82	0,3	41	51	65	76
Dubovický Creek	15,24	642	186	456	0,29	5,91	0,09	30	36	47	54

2.1.4 Social-economic characteristics

As it already mentioned at the beginning of this report the flash floods affected several municipalities, among them mainly Renčišov, Uzovské Peklany, Jarovnice in the Malá Svinka territory; and Dubovica and Lipany in the Dubovický Creek catchment (Fig. 2).

Both watersheds are settled in following downstream villages. Numbers of citizens are according to the statistics from 1970:

Table 5.

Municipality	Citizens
Renčišov	272
Uzovské Peklany	483
Jarovnice	2 234
Dubovica	1 278
Lipany	3 030

These villages are relatively small with a rural community. Industry almost absents, one textile factory is situated in Lipany town. In all villages were done regulations on streams including two bridges (which were dimensioned on Q_{20} to Q_{50}). Villages are mainly created by one and two floors brick houses with cellarage and farm barrages. Exception is a Roma part of the Jarovnice village, located directly in the inundation area, where houses are constructed from different materials (cottages). This part was completely destroyed during the flash flood including life losses. During the flash floods no water management objects were situated on the streams. There were no dikes in the catchment area and the upper parts of the catch med area are without inundation. Inundation area starts to be developed closely on the boundary of the village Jarovnice. In the case of Dubovický Creek, the inundation area is created even downstream the village Dubovica.
The percentage of farmed soils (arable soils) is approximately 20-25% in the watershed Malá Svinka to village Jarovnice and approximately 25-30 % in watershed Dubovický Creek to the confluence (to village Lipany). The percentage of forest is mentioned in Table 2 and 3. The rest belongs to meadows and pastures; in the watershed Malá Svinka to Jarovnice it means 20-25%, in watershed Dubovický Creek to village Lipany 30-35%, respectively. Comparing the present land use pattern with the past no significant changes, as deforestation or style of farming, were found.
Citizens staying in the both catchment areas have concentrated on the simple manufacture and farming style of life.
Based on the results from the Programme of the Flood Management till 2010 for the Slovak Republic, this region was inserted into the 4-5 degree regarding the risk on flash floods from the geographical point view (5 is the highest risk).

2.2 HYDROMETEOROLOGICAL ASPECTS OF THE FLASH FLOOD

2.2.1 Meteorological situation

On July 28, 1998 above our territory has occurred very unstable air mass; due to high air humidity, high temperature of surface layer of atmosphere and orographic conditions to came into being significant thunder activity. Two isolated areas of torrential rain occurred. The first was in watershed Topľa with precipitation total above 60 mm and caused local floods. Second was in the watersheds of Hornád and Torysa. Thunder activity had two isolated parts: in the watershed Topľa and in the watersheds Hornád and Torysa with higher precipitation totals and caused the catastrophic flash floods in more places. In the catchments Hornád and Torysa occurred flash floods on Svinka River and its inflows: Dolinský Creek, Hrišovský Creek, Margecianka, Branisko, Žehrica. The most catastrophic course of flash flood was on two tributaries of Svinka River: on Malá Svinka and Dubovický Creek.

On the territory of the analysed flash floods (the catchments of Malá Svinka and Dubovický creek) were not placed any equipments such as rain gauge recorders or water gauging stations. Because of this fact analysis of territorial and time course of rainfall should be done. The bases for precipitation reconstruction were:

- Data from neighbouring rain gauge stations
- Interview of inhabitants
- Terrain investigation

Table 6. Precipitation totals and duration from selected rain gauge stations

Municipality	Precipitation total (mm)	Duration of rainfall (time)
Lipovce	62,0 mm	16,10 – 17,45
Široké	46,7 mm	17,30 – 19,00
Krompachy	43,0 mm	18,25 – 18,45
Lipany	40,6 mm	15,05 – 16,15
Chmiňany	37,1 mm	16,20 – 18,45
Malý Šariš	34,0 mm	15,10 – 18,00
Prešov	14,0 mm	afternoon
Spišské Vlachy	18,5 mm	17,00 – 19,30
Veľký Slavkov	18,3 mm	17,00 – 18,00

From the interview were used those answers, which were confirmed by two persons at least. In questions the great emphasis was put on the start of rainfall, its duration, direction of the thunderstorm movement and accompanying phenomena, as hail, wind or gustiness. The questions were also oriented on beginning and duration of the flood.

The terrain investigation was aimed at flood marks after spilled water from creek banks and marks after heavy rain on meadows and fields. The marks were categorised, what was the basis for isohyets construction. (Fig. 3)
The core of torrential rainfall (cloudburst) did not touch any rain gauge station. The thunderstorm in this region had more cores with different trajectories and different time of beginning. On more places inhabitants watched strong wind or gustiness, special sound effects and hails.

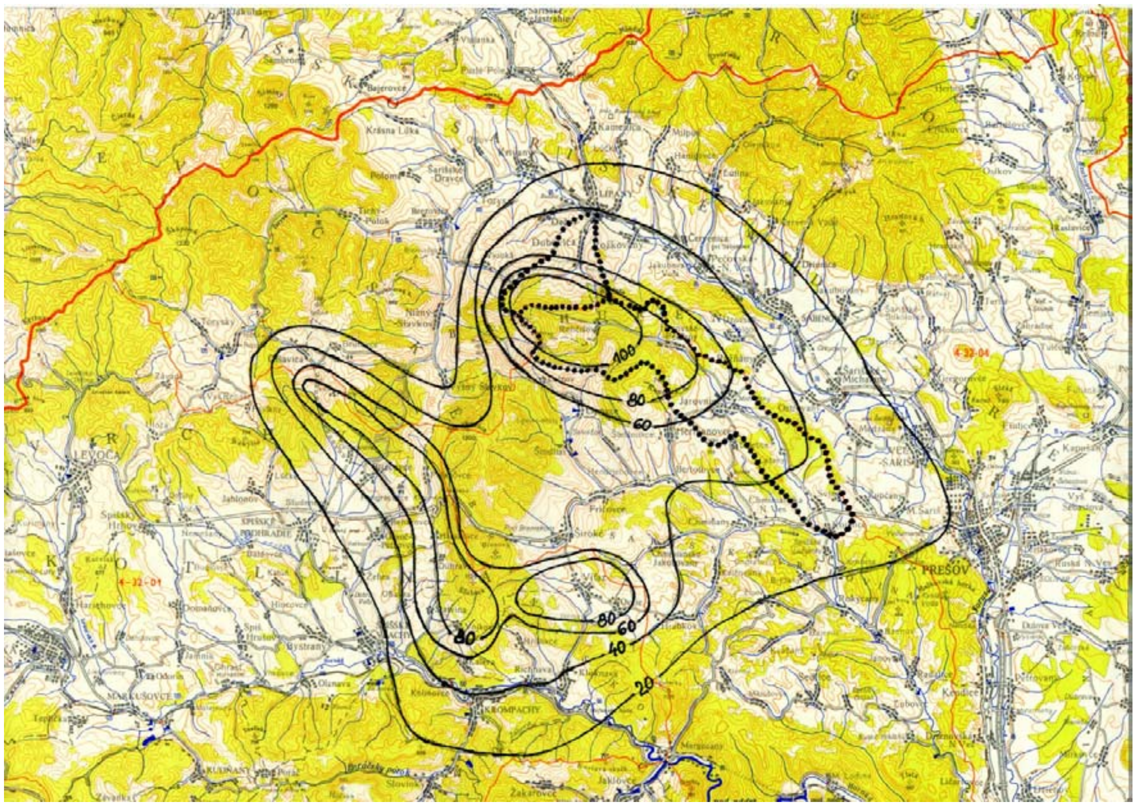

Fig. 3 Reconstructed field of torrential rain during the flash flood on July 20, 1998

In this region the 24-hour precipitation total with probability of occurrence 0, 01 (once in 100 years) is app. 80 – 90 mm. In the most vulnerable areas precipitation reached app. 100 - 130 mm during 150 min. The rainfall duration on precipitation gauging station Lipovce in the watershed Svinka was recorded from 16,10 to 17,45. The most intensive precipitation occurred in time interval 10 to 30 minutes.

2.2.2 Hydrological situation

Hydrological situation during the flash flood was assessed using following data and information:

- Rainfall reconstruction
- Water level gauging stations records
- In situ surveys
- Interviews of citizens

Flash flood reconstruction was based on the methods such as genetic creation of flood waves, rainfall rate intensity formulas, methods to calculate the time of concentration and lag time and water balance method.

Rainfall reconstruction was analyzed in the previous chapter

Water level records from the surrounding water gauging station.
The basic material used for reconstruction of the flash flood on Malá Svinka and Dubovický Creek was record from the water level gauging station on Torysa River in Sabinov. This station is located just below the confluence with Dubovický Creek. Because of fact that the rainfall did not affect other part of the Torysa River Basin, the water volume of the wave in Sabinov might be considered as volume strongly related to the flood in Dubovický Creek. (Fig. 4)

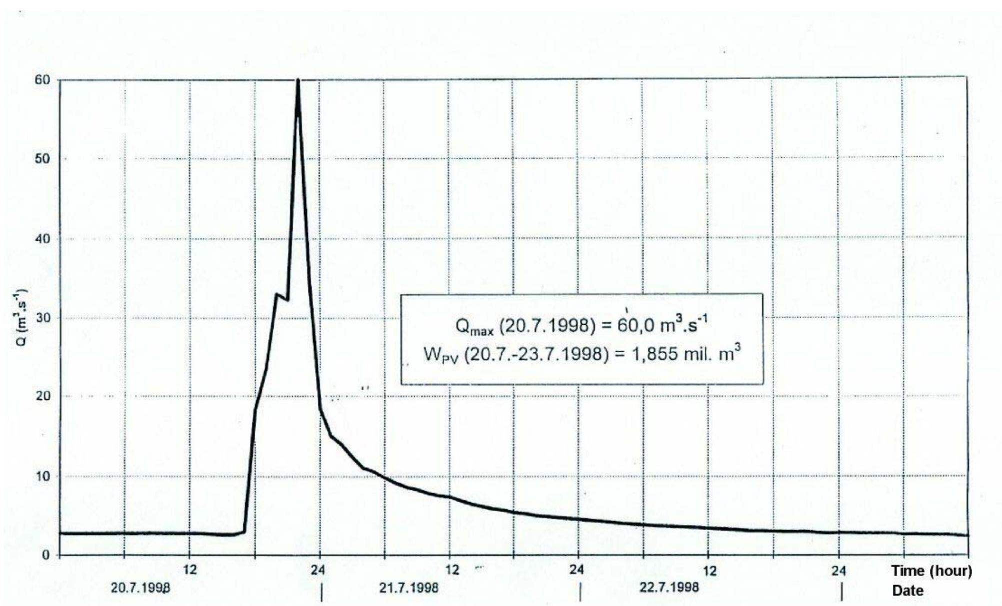

Fig. 4 Hydrogram in water gauging station Sabinov (Torysa river), July 1998

The experts have done in situ surveys from the Slovak Hydrometeorological Institute in the time period July 22-23, and August 11-12, 1998.
During the surveys signs from flooding were documented including the *interviews of the citizens* directly involved in the flash flood events. As a yardstick to correct different statements of the approached people schedule of bus traffic was used (some of the statements rejected each other).

Based on the in situ surveys and interviews following can be mentioned:

Meteorological phenomena
Extreme rainfall recording the intensity and the overall amount and relatively large extent, called as torrential rainfall (accompanied by the strong wind and hail), which caused the flash flood with

subsequent catastrophic damages on the properties and life losses in the municipalities: Renčišov, Uzovské Peklany, Jarovnice, Dubovica etc.
This thunderstorm, with which the most damaging flash flood is connected, began at 3:30 pm and lasted approximately 1,5 to 2 hours. In accordance with the visual observations done by the local citizens of Dubovica village, in the space above the spring area of Malá Svinka Creek and Dubovický Creek two individual storm clouds were merged together. It is expected that this common storm cloud later continued along the Malá Svinka catchment area and thunderstorm reached the highest intensity in the first hour of duration. We suppose the most rainfall intensity above the confluence Malá Svinka and Renčišovský creek in time from 16,15 to 16,45.

Hydrological phenomena
On both creeks the flood waves were created in the same time. Because of the lengths and areas of watersheds are approximately the same, in the confluence met the maximum discharges and created the cumulative discharge wave.

The flash flood, that is the sudden arising of the flood wave in the stream channel, has started at the upper part of the Malá Svinka catchment area approximately after half an hour from the thunderstorm. In one of the most damaged villages (Uzovské Peklany) flood wave arose after 1-1,5 hours from the thunderstorm.

The peak of the flood wave was reached in 2-2,5 hours from the beginning of the event. Providing the velocity of the flood wave was 2-2,5 $m.s^{-1}$ (7,2-9 $km.h^{-1}$), the lag time of the Malá Svinka watershed might be estimated from 80-90 minutes, and therefore, the lag time has been approximately equal to the thunderstorm duration.
From this estimate may be considered that the whole rainfall and the whole watershed created the discharge in village Uzovské Peklany. Theoretically, flood wave could have the shape of the narrow triangle with very high culmination discharge and this one might have a value of 190 $m^3.s^{-1}$, what can be expressed as the specific runoff by 7,6 $m^3.s^{-1}.km^{-2}$. The similar situation is supposed also in the Dubovica village, however with lower culmination discharge around 160 $m^3.s^{-1}$.

To make the mosaic of this flash flood more complete it is necessary to add, that during this event several negative factors occurred at the same time:

- Rainfall might have been in some places higher than 100 mm, its intensity (variable in time and space) might have been during the short time period higher than
- 3 – 5 $mm.min^{-1}$. In the Slovak Republic territory this intensity belongs to the highest one.
- High catchment saturation by previous precipitation
- The great slopes, especially in the upper parts of catchments
- Low retention capacity of the catchment area; in this case a decisive role the hydro-geological structure and slopes had played. Flyshoid structured and high slopes create this catchment. This structure does not have sufficient volume to capture significant part of the rainfall (mainly when both soil moisture and rainfall intensity are very high, similarly to July 20, 1998). Flyshoid structure after water saturation has a tendency for erosion and land sliding. Terrain destruction was visible in the Malá Svinka watershed after flash flood.
  In the upper parts of Malá Svinka catchment were evident marks of strong sheet flow, which was, in some places, concentrated in the erosive furrows. During this process quantity of material was washed away. In some places erosion touched until to bedrock and caused great landslides (together with adult tree population).

During the flash flood a series of break waves along the Malá Svinka and Dubovický Creek was occurred. Water was stored behind the artificial barriers like bridges, where detritus, flowing wooden branches and building materials were caught. By destruction of these barriers break waves were created and energy of those waves was much higher than expected from the natural flood waves. Photo 1 – 10.

Flooding line of flash flood copied the valley in a whole length of streams. In the places of the narrow valley created backwater with higher water level, here and there more than a several meters. Fig. 5,6,7.

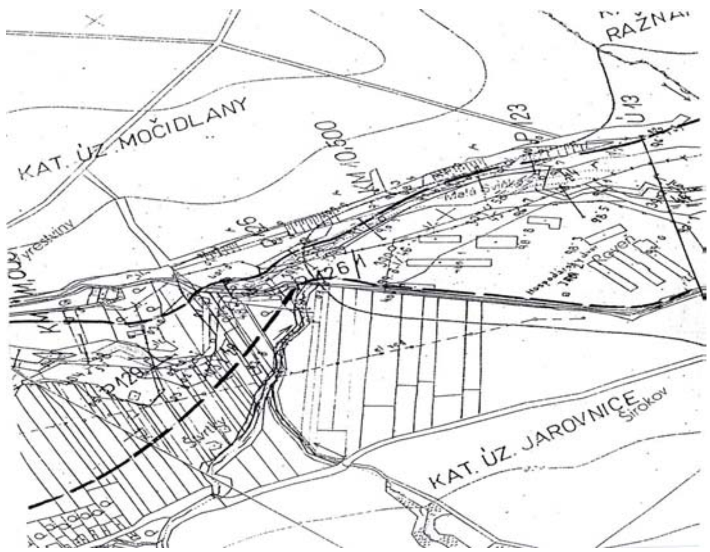

Fig.5. Flooding line in village territory Jarovnice

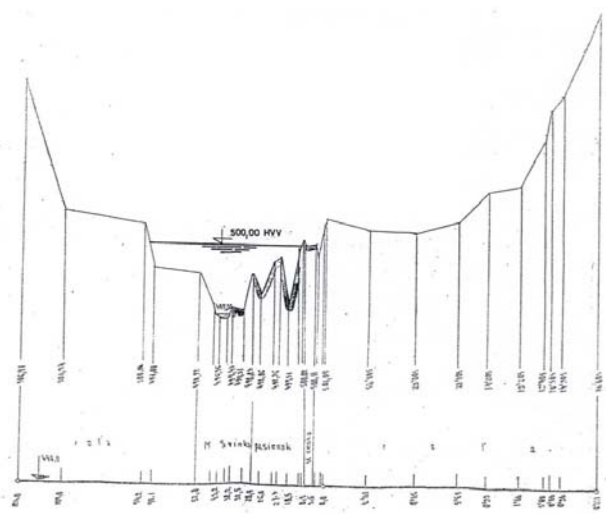

Fig 6. Example of flooding of narrow valley

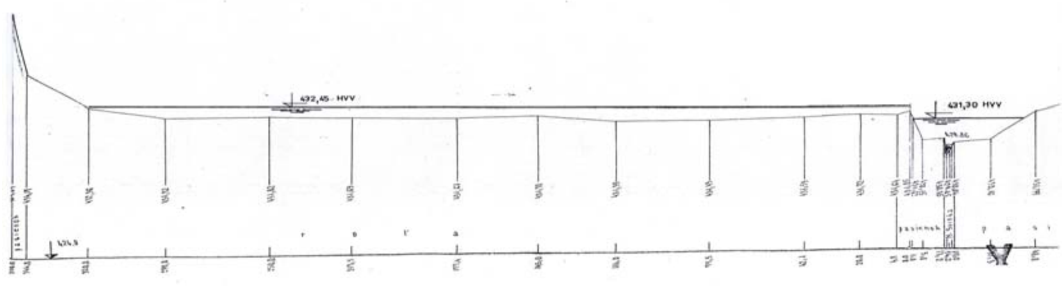

Fig 7. Example of flooding of wide valley

Based on the theoretical assumptions and reconstructed flood waves, it was found that in the villages Renčišov, Uzovské Peklany, Jarovnice and Dubovica in the local streams 1000- years discharges were occurred. Destroying energy from the flowing water rather significantly decreased by the wave transformation in the inundation area downstream Jarovnice village. This energy decrease of the flowing water caused the sedimentation of the suspended matter and flowing materials. As a result of the flood wave reconstruction, the following series of the culmination of discharges and volume for 7 most damaged localities can be presented (Fig. 8):

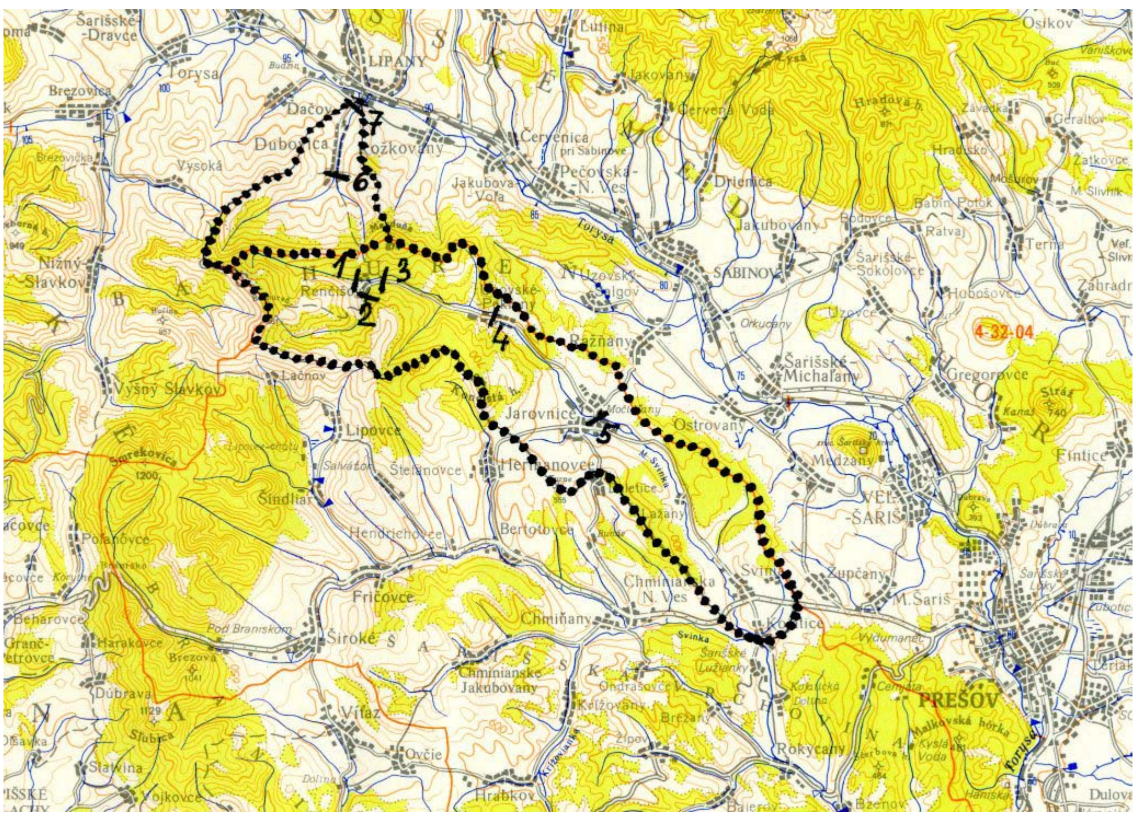

Fig. 8 The cross-sections with evaluated flash flood

1. **Malá Svinka in cross section above Renčišovský Creek**
   - Estimated maximum culmination discharge 90 $m^3.s^{-1}$
   - Estimated volume of the flood wave 400 000 m^3
   - T-year culmination discharge higher than 1 000 years

2. **Renčišovský Creek in confluence with Malá Svinka Creek**
   - Estimated maximum culmination discharge 95 $m^3.s^{-1}$
   - Estimated volume of the flood wave 425 000 m^3
   - T-year culmination discharge higher than 1 000 years
3. **Malá Svinka in cross section profile Renčišov downstream Renčišovský Creek**
   - Estimated maximum culmination discharge 140 $m^3.s^{-1}$
   - Estimated volume of the flood wave 825 000m^3
   - T-year culmination discharge higher than 1 000 years
4. **Malá Svinka in cross section profile Uzovské Peklany downstream Strem Creek**
   - Estimated maximum culmination discharge 190 $m^3.s^{-1}$
   - Estimated volume of the flood wave 1,33 mil. m^3
   - T-year culmination discharge higher than 1 000 years
5. **Malá Svinka in cross section profile Jarovnice downstream Močidlianský Creek**
   - Estimated maximum culmination discharge 230 $m^3.s^{-1}$
   - Estimated volume of the flood wave 1,9 mil. m^3
   - T-year culmination discharge higher than 1 000 years
6. **Dubovický Creek in cross section profile above Dubovica**
   - Estimated maximum culmination discharge 120 $m^3.s^{-1}$
   - Estimated volume of the flood wave 650 000 m^3
   - T-year culmination discharge higher than 1 000 years
7. **Dubovický Creek in the mouth**
   - Estimated maximum culmination discharge 160 $m^3.s^{-1}$
   - Estimated volume of the flood wave 850 000 m^3
   - T-year culmination discharge higher than 1 000 years

2.3 EARLY WARNING AND RESCUE SYSTEM

In the frame of weather forecast a warning was issued on the possibility of local thunderstorms with subsequent occurrence of the flash floods in the small catchment areas. The more precise localisation of this event was not done.
Following authorities (their responsibilities during and after flood events are defined by the Slovak law) immediately reacted on the situation in the Malá Svinka Creek and Dubovický Creek:

- Operational centre of fire brigade
- Municipal flood commissions
- Regional and District Flood Commissions and
- Technical staff of the Central Flood Commission in the Slovak Republic.

This fast response of the mentioned authorities and as well army, created a good basis for rescuing and evacuation of the citizens in affected areas. After the flash flood in July 1998, the comprehensive report was prepared and submitted to the Slovak Government, which comprised such information as mitigation measures, flood prevention measures and revitalisation of the destroyed areas including social measures.

2.4 INTERACTION BETWEEN FLOOD AND NATURAL RESOURCES

In the affected areas there were no pollution sources. Nevertheless, all sources of drinking water were closed approximately for two months. The health authority tested each local source of drinking water very carefully.
During the reconstruction and revitalisation of the affected areas all dead animals were collected and buried (all together more than 5 800 animals).

2.5 FLOOD PREVENTION MEASURES

There are no flood protection objects situated in the streams of the affected areas. Very fast starting up of the flood caused, that it was not possible to make any flood protection measures.
Based on the analyses of this flash flood, it might be said, that there are possibilities to increase the effective flood protection (health risks and life losses) via the better co-operation among the affected villages situated on the streams and by increase of the citizens` education on how to behave during the flood event. Decrease of the damages after occurrence of the flash flood (extreme and intensive phenomenon) is not feasible without long-term prevention measures and existing early warning system.

2.6 POPULATION BEHAVIOR

Sudden occurrence of the flash flood in such a magnitude has found the people unprepared, just returning home from the work.
The citizens behaved very individually, from the organised self-protection to the panic. Confusion and panic have occurred mainly by the young Roma population, where majority of the causalities were registered. The older family members of Roma community were not in their houses that were located in the inundation area. The children had to cope with the situation alone with no experience and knowledge how to behave. It is necessary to be mentioned that neither older generation was trained by authorise to cope with such a situation nor children. However, the older generation was better prepared and organised having certain knowledge and experience with extreme flood events from the part.
In spite of occurrence of the flash flood in the afternoon hours, its consequences continued till the late night causing great difficulties to rescue teams. Communication and co-operation between rescue teams and population in the affected area was very good and smooth.

2.7 FLOOD DAMAGES

All together during this flash flood more than 3 600 people were evacuated. As a great success 56 people were rescued, whose lives were under great danger. Unfortunately, despite the enormous effort of the rescue teams 47 people died, majority of them in Jarovnice village. Published costs on rescue activities exceeded 116 millions SKK (19,6 million SKK were used to reconstruct banks, to clean the main channels and inundation areas from detritus and sediments, etc.).
The overall damages were estimated to the value 850 million SKK. Structure of the damages was as follows:

- State properties – 273,4 million SKK
- Municipal properties – 110,4 million SKK
- Legal entities – 336 million SKK
- Individual citizens – 130,2 million SKK

Appendix 1

1. Photo documentation (Photo 1 – 10: Marks after flash flood in the catchment Malá Svinka; Photo 11-12 Documentation of flood flash in villages Uzovské Peklany a Jarovnice

2. Reaction in daily press

Photo 1: Dubovický creek - The end of stream regulation destroyed by back erosion

Photo 2: The right slope of valley of Malá Svinka disturbed by slides (above the village Malá Svinka)

Photo 3: Eroded channel of Malá Svinka down to palaeogenic substratum

Photo 4: Eroded channel of Malá Svinka down to bed rock (cracked desks of sandstones)

Photo 5: Eroded channel of Malá Svinka (landslide of slope from 5 to 8 m), the creek channel silt up with branches and stones and rocks)

Photo 6: Landslides on the right side of Malá Svinka valley above the village Renčišov

Photo 7: Outfall of the erosive gouge from forest to woods pathway above the village Renčišov

Photo 8: The erosive gouge on the left slope of Malá Svinka valley (the depth 1,5 m) in the village Uzovské Peklany

Photo 9: "Walking tress" in the forest touched by erosion

Photo 10: Eroded left bank of the creek channel (down to bedrock) of Renčišovský creek above the village Renčišov

Photo 11: View on flooded village Jarovnice

Photo 12: View on the village Uzovské Peklany touched by flood

Povodeň na východnom Slovensku

Pomoc z Bratislavy

Vláda Slovenskej republiky sa v utorok na rokovaní zaoberala situáciou, ktorá vznikla v súvislosti so živelnou pohromou v Prešovskom a Košickom kraji. Vyslovila súcit a úprimnú účasť rodinám všetkých postihnutých, ako aj zatiaľ nezvestných obyvateľov. Na preskúmanie škôd a poskytnutie nevyhnutnej pomoci vláda vytvorila osobitnú komisiu. Kabinet zatiaľ zo svojej rezervy nevyčlenil finančné prostriedky. Podľa informácie hovorcu premiéra to urobí až po vyčíslení škôd. Sústrasť pozostalým po obetiach záplav v utorok vyjadrili viaceré politické strany. HZDS založila účet, na ktorý vložila základnú sumu 100-tisíc korún. Poslanci SDK venovali na odstránenie následkov prírodnej pohromy finančnú pomoc vo výške 30-tisíc korún. Poslanci SDK vyzbierali sumu 23-tisíc korún,

Supercela otvorila nebo a dolu sa liali potoky vod

DEŇ D - 20. júla, hodina H - 18. 00 hod. v Dubovici

človek a povodeň

NÁČELNÍK GENERÁLNEHO štábu Armády SR genpor. Jozef Tuchyňa (uprostred) v rozhovore so zástupcom veliteľa pre logistiku 2. armádneho zboru plk. Pavlom Mihalovi (vľavo) a ženijným náčelníkom zboru pplk. Karolom Navrátilom.

S LOPATOU A TECHNIKOU PROTI BAHNU

Meteorológ Jozef Iľko o pondelkovej búrke

Ničiaci príval

BOHUŠ LENICKÝ

● Ako a prečo k podobným javom v po-*[…]*así dochádza? Súvisia so súčasnými *[…]*horúčavami?

– Súvisia s tým, že východné Sloven-*[…]*ko bolo v poslednom období dosť boha-*[…]* na zrážky. Pre búrku je podstatný do-*[…]*tatok vlhkosti, z ktorej sa búrkový mrak *[…]*vytvorí. Zásoba vlhkosti bola v pôde *[…]* porastoch na východe dostatočná. *[…]*ruhá podmienka je prehriatie prízem-*[…]*ej vrstvy vzduchu. Také, aké bolo *[…]* pondelok. Teplo, prehrievanie vzduchu *[…]*d slnka, prehrievanie povrchu a vznik *[…]*opovitých oblakov, ktoré prerástli až *[…]*o spomínanej osudnej búrky.

● Búrkový oblak vraj dosahoval výšku *[…]*ž 12 kilometrov. Je to údaj, ktorý *[…]*ejako ovplyvňuje intenzitu búrky?

– To je horná hranica búrkového obla-*[…]*. Intenzita búrky do istej miery závisí od *[…]*ho, do akej výšky ten búrkový oblak na-*[…]*stie. Niekedy narastie do výšky 8 km, *[…]*ekedy 9 alebo aj 10 km. Pre laika je toto *[…]*lo nezaujímavé, pretože jemu je jedno, *[…]*ľko je to kilometrov, dôležité je to, aké sú *[…]*ejavy búrky, aká je jej intenzita, koľko *[…]*dy je v oblaku sústredené.

● Poznáme už množstvo zrážok, ktoré v pondelok na postihnutú oblasť spadlo?

– Ak nemáme merací prístroj priamo v lokalite búrky, nevieme, koľko zrážok spadlo. Na okolitých staniciach, konkrétne v Stropkove, sme namerali 39 mm. Určite tam však bolo väčšie množstvo vody. Búrky zasahujú vždy len veľmi úzky pás územia. Je to lokálny jav. Počas búrky sa v oblaku môže vytvoriť akýsi komín, cez ktorý sa leje voda. Môže byť úzky len desiatky metrov. Zasahuje potom len veľmi malú časť územia, čo sa pravdepodobne stalo aj v pondelok.

● Možno podobnú búrku predpovedať?

– Predpovedať sa dá. Ťažko však predpovedať, či spôsobí aj škody. Buď sa vybúri kdesi na kopci, kde nanajvýš zlomí niekoľko stromov, alebo padne do takého priestoru, kde voda stihne bez problémov odtiecť. V pondelok bolo nešťastím, že sa to vylialo do úzkeho povodia, ktoré fungovalo ako zberač, ako lievik. Povodie prijalo obrovské množstvo vody, ktorá stiekla dole. Podľa mňa to bol mohutný príval vody, ktorý všetko pred sebou rúcal...

Plávajúci transportér pluku CO z Humenného počas obhliadky ťažko prístupných častí obce Uzovské Pekľany v okrese Sabinov.

Voda brala všetko

*[…]*ok. – s. 1

*[…]*bec patrí medzi najviac postihnuté *[…]* okrese Gelnica. Koryto potoka je zni-*[…]*

s požiarnikmi, policajtmi i dobrovoľníkmi okrem záchranných prác a odstraňovania následkov zabezpečo-*[…]*

Photo 13: Titles in daily press: "The flood in eastern Slovakia", "The aid from Bratislava", "Supercell open the sky and the streams of water gushed down", "Man and flood", "Destructive torrential rain", "Water took everything" …

3. FLASH FLOOD on ŠTRBSKÝ CREEK

3.1 CHARACTERISTICS OF THE CATCHMENT AREA

3.1.1 Natural characteristics of the catchment area

Štrbský Creek is the water- course of 5th order. Its watershed occurs on the northern side of main watershed divide of Black and Baltic Sea. Its spring is 910 m a. s. l. Štrbský creek flows in eastern direction through the village Štrba. Under the village discharges to Mlynica Creek the tributary of Poprad River in its upper part.

From the hydro-geological point of view, the whole catchment creates the quarter sediments on the foot of High Tatras. Vegetation cover is composed of meadows, pastures and forest. The gradient of slopes in Štrbský Creek area ranges 20-30%; the slope of creek itself is 2,1% in average; index of the slope β=10,66. (Fig. 7)

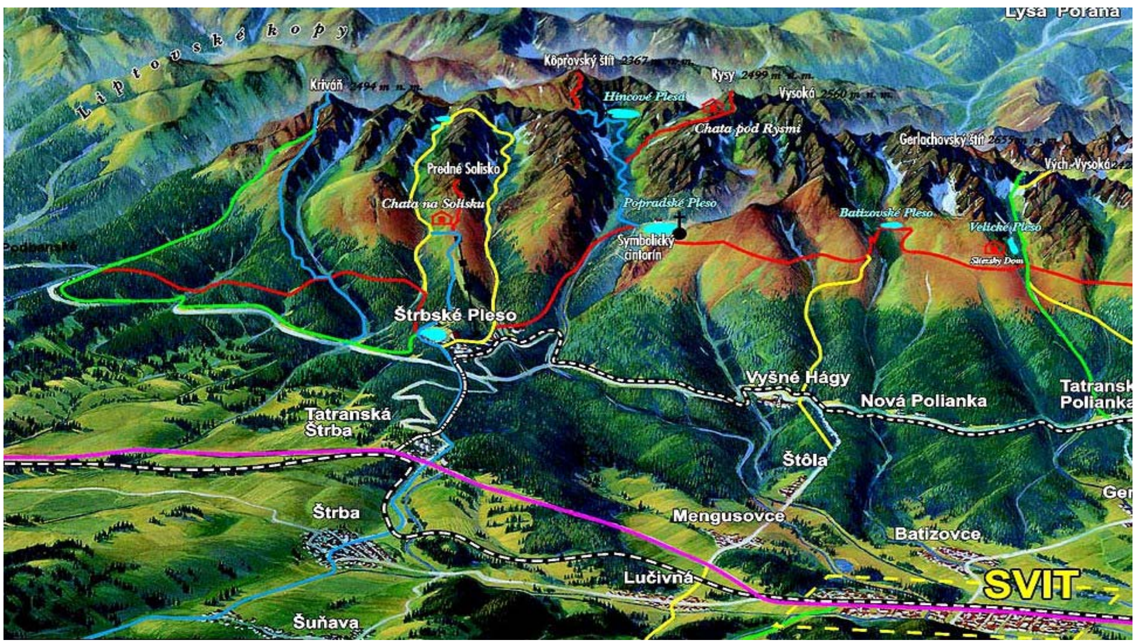

Fig 7. Plastic map of village Štrba and of surrounding

3.1.2 Climatic characteristics

The catchment of Štrbský Creek belongs to the moderately cool and humid sub region with monthly temperature means from –5,6ºC (January) to +15,8ºC (July), with annual temperature mean 5,8ºC and with annual mean precipitation total about 750 mm. The basic climatic characteristics for catchment area are presented in Table 5 (temperature and relative air humidity according to climatic station Poprad and precipitation according to neighbouring catchment station Važec).

Table 5. Climatic characteristics

Month	1.	2	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	Year
Air temperature (^{0}C)	-5,6	-3,5	0,3	5,8	10,9	14,3	15,8	15,1	11,5	6,5	1,5	-3,1	5,8
Precipitation (mm)	43	42	40	50	76	95	104	81	58	56	62	47	754
Air relative humidity (%)	81	78	74	70	70	72	72	73	74	77	83	83	75

3.1.3 Hydrological characteristics

In this chapter basic hydrological and physical-geographical conditions in catchment area are described.

a) Hydrographical characteristics

In Table 6 following characteristics are presented to give more insight on the catchment area regarding the runoff processes:

- A - catchment area in km^2
- L - length of the valley in km
- H_{avg} - mean altitude in m above s. l.
- α - shape of the catchment (A/L^2)
- β - index of the slope (h/A), where $h = 2(H_{avg.} - H_{min})$
- H_{min} - altitude of the cross seeking profile in m above s. l.

Table 6. Physical - geographical characteristics of the catchment Štrbský Creek

Course/Profile	A (km^2)	L (km)	H_{avg} (m a. s. l.)	H_{min} (m a. s. l.)	α (A/L^2)	β (h/A)	Forest (%)
Štrbský Creek - confluence	12,23	5,2	861	800	0,45	10,66	10

b) Runoff characteristics

In Table 7 following characteristics are presented to describe the runoff:

- A – catchment area in km^2
- P – average precipitation in the catchment (mm)
- R – runoff from the catchment area (mm)
- φ – runoff coefficient (R/P)
- q – specific runoff in ($l.s^{-1}.km^{-2}$)
- Q – mean discharge ($m^3.s^{-1}$)
- Q_T – T-year maximum discharge ($m^{-3}.s^{-1}$)

Table 7.

Course	A (km^2)	P (mm)	R (mm)	P-R (mm)	φ (R/P)	q ($l.s^{-1}.km^{-2}$)	Q ($m^3.s^{-1}$)	Q_{10} ($m^3.s^{-1}$)	Q_{20} ($m^3.s^{-1}$)	Q_{50} ($m^3.s^{-1}$)	Q_{100} ($m^3.s^{-1}$)
Štrbský Creek	12,23	750	340	410	0,45	10,63	0,130	14	17	21	24

c) Social-economic characteristics

The village Štrba is medium size; number of inhabitants is approximately 2800 (according to the statistics from 1970).

From presented number of inhabitants 19% are employed in agricultural sector and 26% are employed in industry.

The catchment is for the most part deforested; forest covers only 10% of catchment area.
In the watershed Štrbský Creek the percentage of farmed soils (arable soils) is app. 15%. The rest of area forms by meadows and pastures, it means 75%.
Citizens staying in the village Štrba have concentrated on the manufacture, tourism and farming style of life.

In this region the character of the land use is stabile for long term.

In down part of the village there the cannel of the creek is regulated. In the village are two bridges; the third one is outside of the village in front of the confluence of Štrbský Creek and Mlynica Creek.

3.2 HYDROMETEOROLOGICAL ASPECTS OF THE FLASH FLOOD

July in 2004 had interesting precipitation regime. The intensive continuous precipitation was combined torrential rains, connected with thunderstorm activity. High precipitation totals were the reason of some flood situation in Poprad and Dunajec river catchments. In next we pay attention to analyse of the flash flood on Štrbský Creek, which significantly hit Štrba village. The time of flood was July 24, 2001 in the afternoon. The flood reconstruction was made after terrain investigation on August 14, 2001 (21 days after the flood).

3.2.1 Meteorological situation

The High Tatras Mountain was hit by abundant precipitation in July 24, 2001. The upper cyclone with centre above East-Slovakian lowland caused the northern-eastern movement of wet unstable air mass across the High Tatras ridge. (Fig. 7) In the mountain ridge area there continuous precipitation was. In the unstable air created the cloud of Cumulonimbus type from 11 to 12 GTM. Later, after 13,30 GTM on the leeward side of mean Tatras mountain ridge one isolated Cumulonimbus occurred suddenly, which was growing and moved in southwestern direction. This cloud hit the Štrba village region with its precipitation activity.
The four resources were use to made time and spatial analyse of precipitation field, especially the core of torrential rain:

- Observation and measurement of meteorological, precipitation and hydrological stations
- Satellite and radar measurements
- Terrain investigation activities in the Štrbský Creek catchment and neighbouring catchments, too (the flood marks, terrain indicators – vegetation, grassland, soil)
- Interviews of citizen

Rain gauge station lying close to the expected rain core were (in the brakes is direction from core): Štrba 1,7 km (E), Štrbské Pleso 7,0 km (N), Važec 6,0 km (W), Čierny Váh 11,0 km (SW), and Liptovská Teplička 11,0 km (SE). The station Štrbské Pleso had pluviogram.

After station observation the occurrence of heavy rain in the Štrba village was from 15,20 till 16,10 (precipitation sum was 73,6 mm). In Važec was measured 32,2 mm (time of rain was missing). In Liptovská Teplička was measured 21,1 mm and in Čiery Váh was recorded the duration of heavy rain from 14,00 to 18,30. In the station Štrbské Pleso was daily sum of precipitation 52,2 mm, but in the time of thunderstorm over the Štrbshý Creek catchment was measured 3,5 mm only. The next heavy rain in Štrbské Pleso station was recorded from 18,00 to 19,30 (precipitation sum was 11 mm). From these records follows, that the rain core over Štrbský Creek catchment was created southward from Štrbské Pleso.

Radar and satellite observations suggested the isolated Cumulonimbus in the leeward side of the High Tatras massif. The impulse of lee turbulence eddy is possible reason of its occurrence. The movement of this Cumulonimbus was from NE – NNE direction in Štrba village area. The radar records from Kojšovská hoľa did not show the extreme phenomenon, neither reflectivity, nor the upper boundary high of cloud. At 13,15 GTM in the Štrba region was small cloud with upper boundary high about 9 – 10 km, later, at 14,15 GTM the extension of supper boundary was growing and the cloud moved over the Low Tatras massif.

The radar reflexivity from this object was at 13,15 GTM 18 – 24 dB, at 13,45 GTM 30 – 36 dB, at 14,15 GTM 18 – 24 dB. The satellite pictures showed occurrence of isolated Cumulonimbus in Štrba region at 13.30 GTM and its movement southward. The interview with citizen found the position of the rain core near the village boundary north-western or western direction. The witnesses of this phenomena suggested the occurrence of the dark cloud with the intensity of the rain markedly exceeded the surrounding.

3.2.2 Hydrological situation

The reconstruction of hydrological situation in the locality of Štrba village was based on facts as follows:

- Identification of area of intensive torrential rainfall – Fig. 8
- Disposable measurement from rain gauge station in Štrba village
- Information (by interview) about rainfall duration as well as about its time and space distribution
- Information from terrain investigation (marks after heavy rain and flood)
- Video record from flood course (which was made by citizen app. 5 – 10 minutes after culmination)
- Measurement of two cross sections with flood remarks

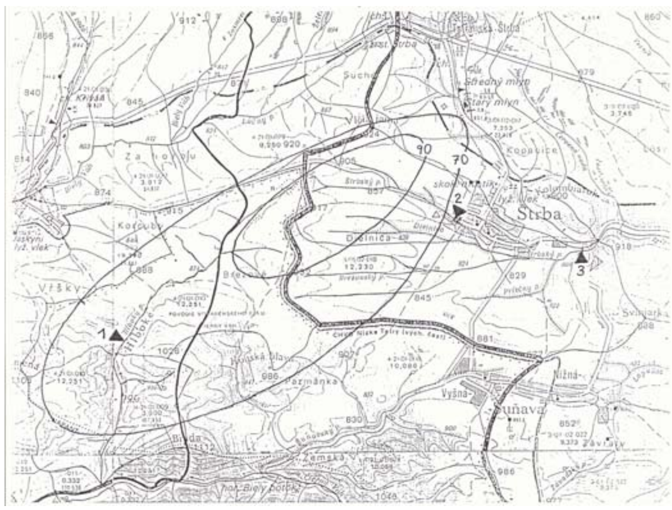

Fig 8. Isohyets of torrential rain in the catchment of Štrbský Creek

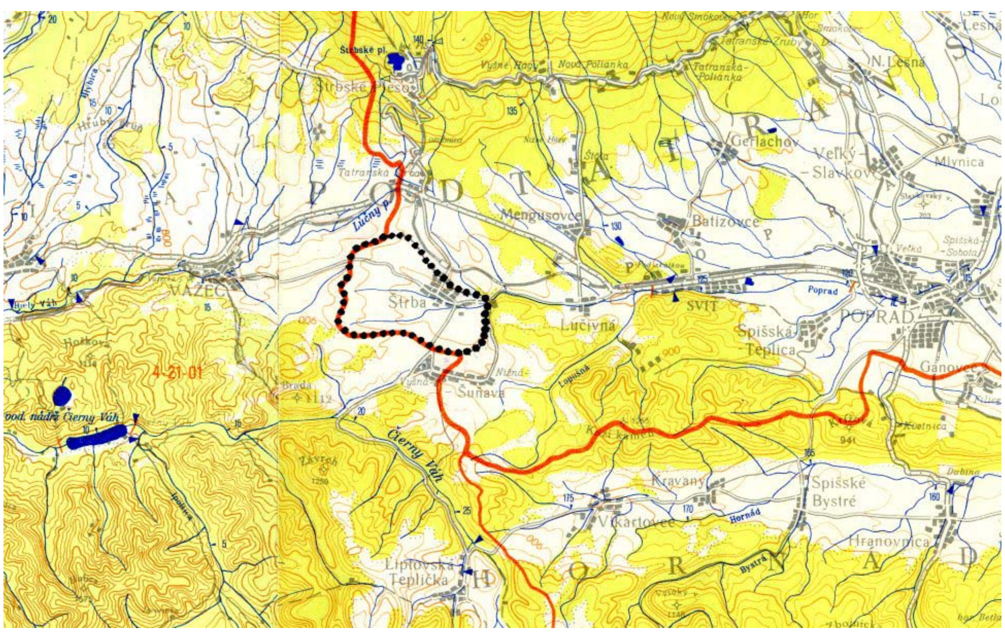

Fig9. Situation of Štrbský Creek catchment

Measured rainfall total was 73,6 mm near the location of the first cross section on Štrbský Creek. According to information, the whole rain continued circa 55 minutes, however 95% of precipitation fell out during 30 minutes. This fact was confirmed also by video record, which started at 15,50.

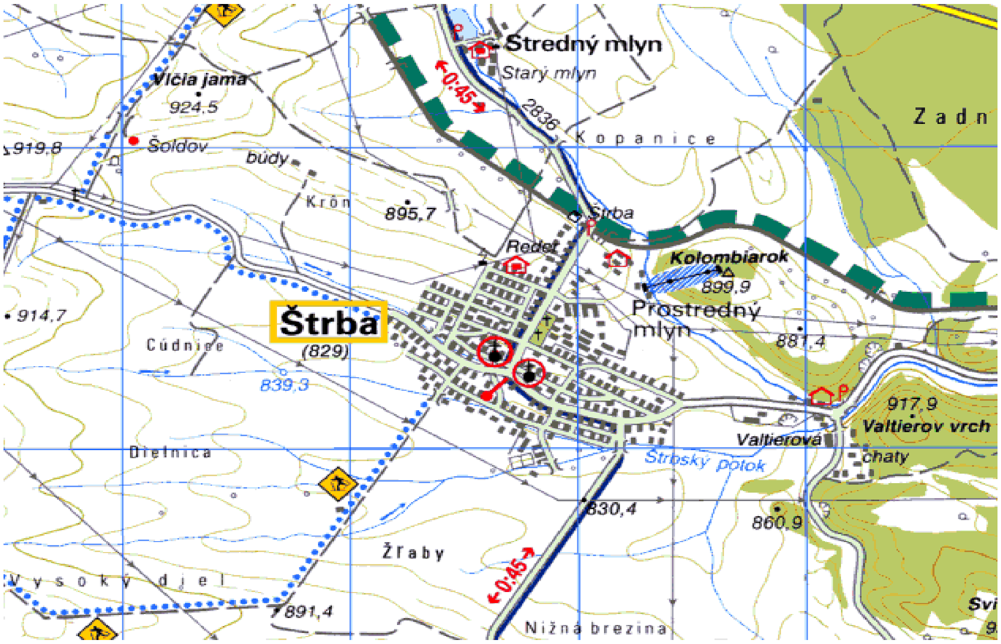

Fig 10. Situation of Štrba village with measured cross sections on Štrbský Creek

The evaluated cross sections:

- Profile on Štrbský Creek above the first bridge in the Štrba village
- Profile on Štrbský Creek above the main rod before the confluence of Štrbský Creek and Mlynica Creek

Table 8. Basic information about two measured cross-sections

	1. Štrbský Creek	2. Štrbský Creek
Area of catchment (km^2)	2,5	11,2
Length of valley (km)	2,3	4,8
Mean length of slopes (m)	540	500
The slope of valley (%)	1,5	1,4
Index of shape of catchment	0,47	0,49
Mean precipitation total from torrential rain (mm)	80	65
Runoff coefficient	0,6	0,6
Effective rainfall (mm)	48	39
Area of cross section (m^2)	15,0	54,1

Table 9. Estimation of flash flood parameters

	1. Štrbský Creek	2. Štrbský Creek
Peak flow ($m^3.s^{-1}$)	65	120
Peak specific runoff ($m^3.s^{-1}km^{-2}$)	26,0	10,7
Mean discharge during the flood ($m^3.s^{-1}$)	35	70
Mean specific runoff during the flood ($m^3.s^{-1}km^{-2}$)	14,0	6,25
Discharge wave velocity ($m.s^{-1}$)	4,3	2,2
Duration of culmination (min)	5-6	15

The basis for reconstruction of flood situation was the genetic method of calculation of maximum discharges and comparison of volumes of flood wave volume and effective rainfall.
The estimated value of peak discharge was 120 $m^3.s^{-1}$. It means, that T-year culmination discharge was higher than 1 000 years.

According to peak specific runoffs we can suppose with high probability, that peak specific runoff on Štrbský Creek was higher than specific runoff in upper part of Malá Svinka catchment on July 1998. Fortunately, the flash flood on Štrbský Creek had not so tragic consequences.

The peak specific runoffs on Malá Svinka were from 6,5 $m^3.s^{-1}km^{-2}$ in cross section in Jarovnice to 13,9 $m^3.s^{-1}km^{-2}$ in cross section in Renčišov. On Štrbský Creek in evaluated cross sections they were from 10,7 to 26,0 $m^3.s^{-1}km^{-2}$.

Also the relative high values of index of shape of Štrbský Creek catchment compared with values in Malá Svinka could contribute to more intensive runoff concentration. On the other side to more moderate course of flood on Štrbský Creek certainly contributed fact, that this watershed has more solid soil and hydro- geological ground. In water during the flood were not so much suspended and bed loads.

3.3 EARLY WARNING AND RESCUE SYSTEM

In the weather forecast a warning was given on the possibility of intensive precipitation in The High Tatras region, as well as on the possibility of local thunderstorms. In consequence of local heavy rain was the possibility of occurrence of the flash floods in the small catchment areas. The more precise localisation of these events was not specified.
Following bodies immediately reacted on the situation in the Štrbský Creek:

- Citizens
- Operational centre of fire brigade
- Municipal flood commissions
- Regional and District Flood Commissions and
- Technical staff of the Central Flood Commission in the Slovak Republic.

This fast response of the citizens and Operational centre of fire brigade (with help of technical assistance of local farm) created a good basis for elimination of impacts immediately after flood.

After the flash flood in Štrbský Creek, the comprehensive report was prepared and submitted to the Central Flood Commission in the Slovak Republic, which comprised such information as evaluation of flash flood, estimation of flood damages, mitigation measures and revitalisation of the destroyed areas including social measures.

3.4 INTERACTION BETWEEN FLOOD AND NATURAL RESOURCES

In the affected areas there were no pollution sources. The drinking water in water supply system was not contaminated; only some local sources of water (wells) were polluted. Fallen animals were not registered. The health authority tested each local source of drinking water very carefully.

3.5 FLOOD PREVENTION MEASURES

There are no technical flood protection objects situated in the streams of the affected areas. Very fast starting up of the flood caused, that it was not possible to make any flood protection measures. Decrease of the damages after occurrence of the flash flood (extreme and intensive phenomenon) is very problematic without long-term prevention measures and existing early warning system.

3.6 POPULATION BEHAVIOR

The flood situation in touched village occurred in afternoon. In spite of sudden occurrence of the flash flood in such a magnitude the behaviour of people was reasonable. No people died, no damage of people health was registered.

Immediately after citizens purposefully joined to eliminate issues of the flood. One of local citizen filmed the course of flood suddenly after culmination. He provided with video record the experts of Hydrometeorological service.

3.7 FLOOD DAMAGES

With respect to reasonable behaviour during the flood no evacuation of population was needed.
To the Central Flood Commission in the Slovak Republic were reported only damages on municipal properties in total high of 1,085 mill. SKK (app. 30 thous. EURO). The damages were generated on local communications, on flooded sewer system and sewage water treatment plan.

APPENDIX 2

Photo documentation (after and during the flood)

Photo 1. Štrbský Creek - the water level in cross section 1 immediately after culmination

Photo 2. Štrbský Creek - the water level in cross section 1 ca two weeks after flood

Photo 3. The flood situation on Štrbský Creek in Štrba village

Photo 4. The flood situation on Štrbský Creek in Štrba village

Photo 5. The flood situation on Štrbský Creek in Štrba village

Photo 6. The flood situation on Štrbský Creek in Štrba village

4. IN CONCLUSION

4.1 FLOOD DAMAGES REMOVAL

All responsible authorities and groups in this field removed the consequences of the flash flood and damages; in the first place local citizens, municipalities of touched towns and villages, all concerned departments and their institutions. The Central Flood Commission carried out co-ordination of this activity.

The competent River Basin Authorities did the first technical actions in the affected areas. The inherent part of the activities during this phase of the flood damages removal is the estimate of the damages expressed by the financial means (including rescue damages actions). Expenses related to the rescue and flood damages removal actions are paid from the state budget to the organisations, which have mode these activities. Damages on the state properties are covered by the state budget, as well. Legal entities and physical persons, if their properties have insurance, should apply for covering the expense regarding flood damages to insurance companies. In case the property is not insured, the expenses are borne by the individual owners. However, in some particular cases of extreme damages state administration can contribute to cover the expenses related flood damage removal and after flood reconstruction. This has happened in the case of flash flood Malá Svinka, as well as Štrbský Creek.

The last but not least, general public is deeply involved to provide with material and financial support to the affected areas. Obviously, the financial means are collected by the NG0s on the special bank account and subdivided to the people based on the real needs.

4.2 FLOOD PRETECTION MEASURES ADOPTED

After each flood event the information on damages and flood consequences are collected and assessed. Experience and knowledge which was received from the individual floods by competent flood management authorities, other involved institution and from the in situ surveys are generalized and used to be applied in the flood prevention measures development.

The flash flood event on Malá Svinka described in this report as well as the further floods in 1997 – 1999 has caused a great response of the general public and state administration. As a result, Slovak Government has accepted strategy document the Programme of Flood Protection till 2010 in year 2000. This Programme consists of the following parts:

- A complex of long-term, midterm and short-term both structural and non-structural measures
- A groups of the research and development projects related to flood protection
- Upgrade and modernisation of the Flood warning and forecasting system of Slovak Republic (POVAPSYS).

From the analysis of described flood situation we can say, that there are possibilities to increase the effective flood protection (health risks and life losses) via the better co-operation among the affected villages situated on the streams and by increase of the citizens` education on how to behave during the flood event. Decrease of the damages after occurrence of the flash floods (or others extreme and intensive phenomena) is very problematic without long-term prevention measures and existing early warning system.

The flash floods unlike the regional floods in river system have their specific character. They are the product of local conditions. Generally, in connection with them, we have no direct observation of precipitation and discharges, because the direct investigations and interviews in situ are needed. Floods of this type are not directly evaluated by hydrometeorological services. Their evaluation is more exception than rule; it is done rarely in extra (very extreme and intensive) cases.

For the retroactive reconstruction of hydrological situation during the flash floods probably do not exist universal guide; only one can be recommended – concrete reconnaissance of terrain in suitable time after. The last years brought of these possibilities more than in the past.
With respect to current development of climatic system we suppose that in the future we can expect more frequented occurrence of extreme events of this type. Because of this assumption it would be useful these phenomena to register and evaluate **systematically**.

On the base of analysis and evaluation of described flash flood as well as on the base of existing experiences we suppose, that it would be useful to assess and adopted scenario of complex view on flash flood phenomenon. This complex view could help to know not only the runoff process from flash floods but also their impacts on environment and society.
The comprehensive view should consist from fields as follows:

- **Prevention**

- The evaluation of actual state of natural and social environment and its readiness to potential occurrence of flash floods (to come within scope of municipalities and river basin authorities)
- Systematic education of inhabitants to prevention, to protection of health and lives, to protection of properties, to safety removal of flood impacts (to come within scope of Ministry of environment, Ministry of health, river basin authorities, municipalities, relevant government and non-government organisations, scientific societies and professional civil associations, electronic and printed media, etc.)
- The evaluation of potential risk of area from the point of view of possible occurrence of flash floods (to come within scope of hydrometeorological service and relevant specialized professional institutions)
- The enforcement of existing Water Act in Slovakia to be applied in all parts related to both flood prevention and protection measures

- **Warning**

- Early warning system on torrential rains (to come within scope of hydrometeorological service and municipalities (by construction of local warning systems)

- **Rescue system** (to come within scope of state, in conformity with the laws)

- **Removing of flood damages** (to come within scope of inhabitants, municipalities, river basin authorities, relevant government and non-government organisations)

- **Evaluation of impacts on environment**

- Complex hydrometeorological evaluation of flash flood on the base of accessible measurement and terrain investigation (precipitation, runoff, flood marks, accompanying phenomena, assess of probability occurrence (to come within scope of hydrometeorological service)

- **Interaction between floods, soil and vegetation (to come within scope of Ministry of environment)**

- Evaluation of erosive processes (to come within scope of Ministry of environment)
- Interaction between floods, mineral and water resources (to come within scope of Ministry of environment)
- Influence on protected regions (to come within scope of Ministry of environment)

- **Impacts on social sphere**

- Evaluation of flood damages on private, municipal and state properties (to come within scope of local and states governments, insurance companies)
- Evaluation of flood damages on remains (to come within scope of Ministry of culture)
- Evaluation of psychical and somatic health (to come within scope of Ministry of health)
- Influence on function of common life (municipalities)

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