

Flash flood on July 21, 2014 in the Vratna Valley

P. Pekarova, V. Bacova Mitkova, P. Miklanek

Abstract— A catastrophic flood on July 21, 2014 in the Vratna Valley in the Mala Fatra National Park on the stream of Varinka, and in Terchova village reminded us once again the power of water flow. Since the floods on July 20, 1998 on Mala Svinka stream, there occurred several flash floods in Slovakia, and there are suggestions that their number is growing. Answer to the question, whether the current floodings in our area actually occur more frequently than in the past, has been focused for several years at our institute. By studying historical materials, we came to the conclusion that in the past there also occurred devastating floods in our territory, which had disastrous consequences for the population. For example, in August 2013, 200 years passed since the most destructive floods, which in August 1813 affected the whole Slovakia, northern Moravia, and southern Poland. Neither the 2010 flood withstood the flood of 1813. Economic development in Slovakia after 1813 was slowed for decades.

Keywords — flash flood, Vratna Valley, Slovakia

I. INTRODUCTION

FLASH floods are defined as strong flows occurring shortly after rainfall [1]. It may be caused by relatively high rain intensity and an intensive watershed response to rainfall. The factors that affect flash flood generation are very complex and mainly include characteristics of the rain (intensity, amount, and time-space distribution), physical and hydrological characteristics of the watershed (area, slopes, shapes, type of soil and land use, vegetation and others) [2]. The type, magnitude and intensity of the hydro-geomorphic response may affect hazard and risk in the downstream channel system and floodplains ([3] and [4]). The sensitivities of runoff generation to rainfall variability and initial wetness conditions were examined for a major flash flood event by Nikolopoulos [5]. Similar problems had been investigated by several authors ([6], [7], [8] and [9]). The hydrogeomorphic response to

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extreme rainfall in headwater systems was published in [10]. For example in the last years Smith [11] applied data-based mechanistic (DBM) models to forecast flash floods in a small Alpine catchment. Kjeldsen [12] tested the effect of urban land cover on catchment flood response using a lumped rainfall–runoff model, and compared flood events from selected UK catchments with mixed urban and rural land use.

The occurrence of these extreme events of natural hazards entails acute danger not only for properties but mainly for human lives. Jonkman [13] focused on 13 flood events that happened in Europe and the US in order to improve understanding the circumstances of flood deaths and contribute to prevention strategies. Other studies have also focused on defining and understanding circumstances surrounding flood fatalities for different environments such as Australia [14] and Puerto Rico [15].

The paper is aimed at the description of the catastrophic flood event which occurred on July 21, 2014 in the Vratna Valley in the Mala Fatra National Park (Slovakia) on the stream of Varinka, and in Terchova village. Due to this flood we had done some field measurements on the stream of Varinka in the Vratna Valley on July 29, 2014 and July 30, 2014. These measurements were focused on documenting of the flood development and on measuring of the flood culmination. Subsequently, the measured results were preliminary evaluated.

II. THE FLOOD AREA: MALA FATRA NATIONAL PARK

A. The Mala Fatra National Park

The Mala Fatra National Park (in Slovak: Národný park Malá Fatra) is a national park in the northwest part of the Mala Fatra mountains called Krivanska Mala Fatra. The mountain is covered mainly with mixed beech forests, at higher elevations with fir and spruce. Pine woods and meadows occur at higher altitudes. About 83% of the area is covered by forest. It has an area of 226.3 km² (87.37 mi²) and a 232.62 km² (89.81 mi²) buffer zone. The park was declared in 1988. Between 1967 and 1988 it was a protected landscape area (Fig. 1). The highest peak is the Velky Krivan with altitude of 1709 m. An significant hill is the Velky Rozsutec, which is also the logo of the National Park. Gorges, rocky peaks and an attractive ridge tour are among its attractions too.



Fig. 1 The location of the Mala Fatra National Park in Slovakia

B. Some flash flood recorded in the Mala Fatra

The records about historical floods in many towns and villages in Slovakia we can find in some scientific literatures and chronicles. When we go more into the past, the information about floods are rarer and less precise. Let us remember, some of them which occurred in the National Park Mala Fatra.

The publication of Dub [16] describes a catastrophic flood on Vydrnanka (tributary of the Biela stream from flysch belt of Javorniky, the catchment area of the central Vah River), and says: “rain was so heavy that it was not seen in ten steps and valley side were all covered with water, which flowed into the river, the effect was devastating. The only longitudinal road was completely destroyed, houses was damaged, shattered and washed away. The coarse river load clogged the original stream bed up to 1-1.5 m, so that the water can create a new bed” This catastrophic flood occurred on June 17, 1939 and culmination of this flood was estimated around the value of $100 \text{ m}^3 \text{ s}^{-1}$ and specific yield around value of $10 \text{ m}^3 \text{ s}^{-1} \text{ km}^{-2}$.

It showed again, that intensive rainfall in a small catchment of flysch belt can cause catastrophic runoff from catchment. The retention capacity of the vegetation cover together with a capacity of shallow soil profile is unable to retain or effectively mitigated the runoff.

Some of significant historical flash floods which occurred in the National Park Mala Fatra were on Lubochnianka stream on May 28, 1925 or on June 25, 1893. Floods destroyed roads, railway and bridges in Lubochnianska Valley and in village Stara Bystrica. According to SHMI archive records the rainfall depth reached value of 193 mm (June 17, 1925) in village Stara Bystrica. Extreme flood occurred in 1958 in the Vratna Valley ([17] and [18]).

And finally, the most interesting and most valuable information about the catastrophic flash flood of 1848 originates from village Terchova on the Varinka / Vratnanka stream. The information was sculpted into the rock in the valley Tiesnavy in year 1948. This mark inform that on June 11, 1848 in village Stefanova died 14 people during the flood

on Varinka stream and shows water level of the flood.

III. VARINKA STREAM

Varinka stream (ID stream 4-21-05-6465) is created from several brooks in the Vratna Valley and Biely Potok (White Brook), near to the community of Terchova. The Varinka stream is the area of European importance. The basin covers an area of 167.307 km^2 and stream length is 24.46 km. The Varinka originates from Krivanska Fatra, the Mala Fatra subunit. Source of the Varinka is located on the northern slope of the mountain section of the ridge between the peaks Chleb (1647 m.a.s.l.) and Hromove (1636 m.a.s.l.). The Varinka stream flows on bottom of the Vratna Valley and flows into the Vah River in Varin village. The Stohovy stream (ID stream: 4-21-05-6748, area is 10.671 km^2 , length is 5.30 km) is one of the tributaries of the Varinka stream. The next tributaries of the Varinka are Biely Potok (ID stream: 4-21-05-6715, area is 17.162 km^2), Struharen stream and Beliansky stream (Fig. 2).

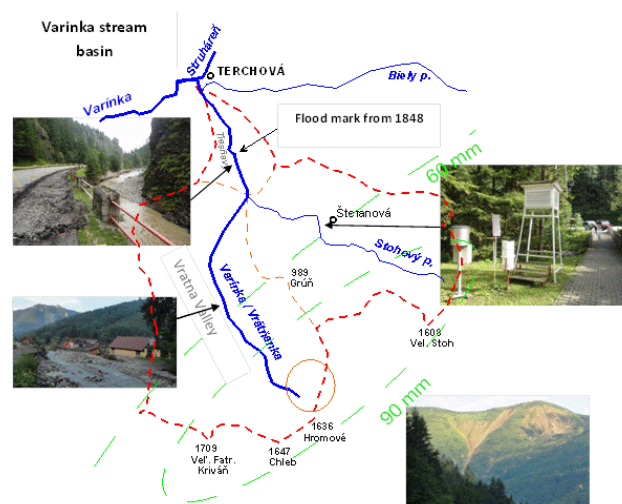


Fig. 2 The basin of Varinka and Stohovy streams in the Vratna Valley to Terchova. Rainfall depth between 4 p.m. – 5 p.m. during the flood on July 21, 2014.

IV. FLOOD ON JULY 21, 2014 ON THE VARINKA STREAM

In contrast to the regional floods from year 2010, which were caused by a several days of heavy rain on the large area, floods of July 21, 2014 had the character of flash floods. These flash floods were created as result of heavy rainfall on July 20, 2014 and July 21, 2014. For example, meteorological station in Vratna village recorded 130 mm of precipitation during two days (Fig. 3a). The rainfalls on July 21, 2014 were characterized by extreme intensity and extreme rainfall totals depth for a very short time (Fig. 3b). Assessment of the meteorological situation in this northwest area of Slovakia was described in [19]. According to data from the Slovak Hydrometeorological Institute (SHMI) from July 21, 2014 the maximum hourly total rainfall depth in the afternoon reached value of 37 mm at the station Vratna Valley (near the mountain rescue cottage), value of 46 mm in village Lubochna and value of 48 mm in town Zilina. Extreme precipitation reached value

of 50 mm per 45 minutes and was recorded near village Stefanova. These rainfall depths are above the average even if dropped during 24 hours. In calculating the average rainfall for the basin Varinka to Terchova, we additionally take into account the high altitudes in the catchment area and the fact that due to rising-altitudes the rainfall totals generally grow (an average of 5 to 10% of the 100 meters with above-sea level). SHMI rain gauge station is located in the valley below Stefanova at altitude below 632 m. On the windward side of the mountain Hromove in altitude of 1450 m rainfall might reach 100 mm during one hour (Fig. 3).

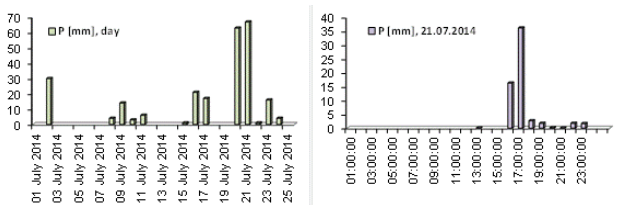


Fig. 3 a - left) Daily rainfall depths in the Vratna Valley station on July 2014.
 b - right) Hourly rain-fall depths in the Vratna Valley station on July 21, 2014 (Central European Summer Time).

Such rainfall total depth added the flood in 2014 on Varinka stream to the floods which occurred on July 7, 2011 in the Male Karpaty mountains in village Pila on the Gidra stream and on the Parna stream above the water reservoir Horne Oresany. There we estimated rainfall depth around 95 mm for 3.5 hours. Higher daily rainfall total depths were recorded in the past in Slovakia, e.g.: on June 7, 1873 in Trencin - 267 mm, on July 12, 1957 in Salka - 231 mm, on July 16, 1934 in Zuberec, Zverovka - 220 mm, on June 17, 1929 in Stara Bystrica - 193 mm, on August 14, 1944 in Mutne - 190 mm, on June 29, 1958 on Skalnaté Pleso - 170 mm.

A. Measuring of the culmination flow of the flood on 21.07.2014

All small mountain basins where occur extreme floods cannot be provided with measuring technique. Therefore staff of the Slovak Hydrometeorological Institute (SHMI) performed the hydrological exploration in the basin and measured river profiles after each major flood to estimate the culmination. One of the hydrological problems solved at Institute of Hydrology Slovak Academy of Sciences (IH SAS), are flash floods that occur on basins with the area of 25-35 km². For example we present here some extreme flash floods in Pila on Gidra stream (southwest Slovakia) and Mala Svinka stream in Jarovnice (east Slovakia). These floods were analyzed and evaluated by IH SAS. A flood event on June 7, 2011 on Gidra stream was caused by 3.5-hours rainfall (95 mm) and the specific yield reached value of 1.36 m³s⁻¹km⁻² and maximum discharge reached value of 44 m³s⁻¹. A flood event on July 20, 1998 on Gidra stream was caused by 1.5-hours rainfall (80 mm) and the specific flow reached value of 5.19 m³ s⁻¹ km⁻² and maximum discharge reached value of 178 m³ s⁻¹ (SHMI measured 230 m³ s⁻¹). Results show that the most

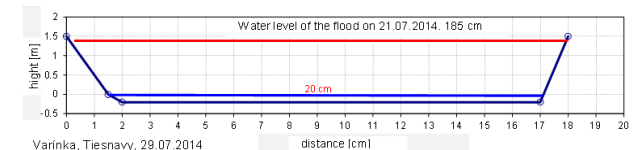
extreme flood was on Mala Svinka ([20] and [21]).

During the experimental measurements on July 29 and July 30, 2014 we were measuring characteristics of stream needed to the calculate culmination discharges at three profiles:

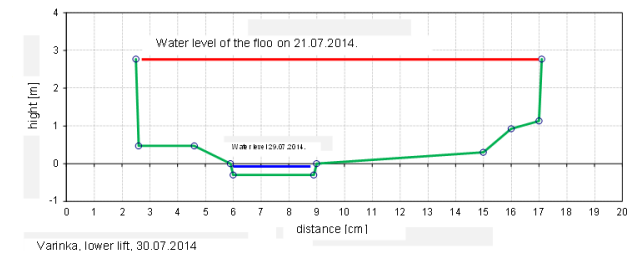
- a) on the Varinka stream in valley Tiesnavy (Fig. 4a);
- b) on the Vrinka stream at lower lift station (Fig. 4b);
- c) on the Stohovy stream near the mountain rescue cottage in Stefanova (Fig. 4c).

According to our measurements after the flash flood on Varinka in the Vratna Valley the peak discharge reached at least value of 56 m³s⁻¹ and specific flow reached value of 2 m³ s⁻¹ km⁻² (on the Varinka stream in valley Tiesnavy, catchment area is 28.05 km²).

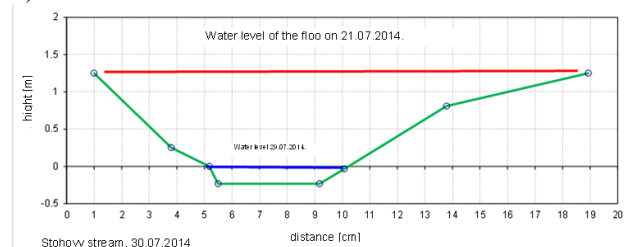
Peak discharge reached value of 57 m³ s⁻¹ and specific yield reached value of 4.4 m³ s⁻¹ km⁻² (with respect to smaller basin area) on the Varinka stream at lower lift station. Peak discharge reached value of 6.7 m³ s⁻¹ on the Stohovy stream.



a)



b)





c)
Fig. 4. a-c. Fixation of the cross sections on Varinka and Stohov streams according to flood tracks of the flood on July 21, 2014.

V. DISCUSSION AND CONCLUSIONS

The lower photo (Photo 1b) shows water level in 2014. Comparison of the photo 1b with photo 1a (flood in 2012) shows 60 cm brighter layer of rock. Flow of the Varinka stream in this narrow profile took away almost all of the bottom sediments and revealed the bedrock.



a)



b)

Photo 1. a) Flood mark situation in 2012, b) Detail of flood mark with indicated water level in 1848 and flood water level in 2014 fixed after the flood with the stream bed nicked by 60 cm approximately (white rock above the water). (Photos by Pekarova, 13.07. 2012 and 30.07. 2014).

Similarly, Photo 2 a)-b) shows riverbed of the Varinka stream in Tiesnavy with two years delay. Photo 3 shows catastrophic mud flows in the Malá Fatra Mountains due to extreme rainfalls on July 21, 2014.



a) valley Tiesnavy 13.07.2012



b) valley Tiesnavy 29.07.2014

Photo 2. a) - b) Original status of the stream channel in 2012 and the stream channel raked out by the flood on July 21, 2014. (Photos by Pekarova 2012 and 2014).



Photo 3. Catastrophic mud flows in the Malá Fatra Mountains due to extreme rainfalls on on July 21, 2014 (Photo by Miklanek, 2014).

Whether the next flood occurs in the future, the history does not tell us, however, suggests that its occurrence in the country is real. Therefore, it would be desirable to build the flood marks after each flood on buildings, bridges, water gauge. Old flood marks, up to 1000 years, we can also to find in Italy or Austria. Human life is short and unfortunately, human memory

is even shorter. After 100 years this great flood will probably fall into oblivion.

REFERENCES

- [1] E. Grunfest, C. J. Huber, "Toward a comprehensive national assessment of flash flooding in the United-state." *Episodes* vol. 14, no. 1, pp. 26–35, 1991.
- [2] S. Rozalis, E. Morin, Y. Yar, and C. Price, "Flash flood prediction using an uncalibrated hydrological model and radar rainfall data in a Mediterranean watershed under changing hydrological conditions", *J. Hydrol.*, vol. 394, pp. 245–255, 2010.
- [3] M. Jakob, K. Holm, O. Lange and J. W. Schwab, "Hydrometeorological thresholds for landslide initiation and forest operation shut downs on the north of British Columbia." *Landslide*, vol. 3, no. 3, pp. 228–238, 2006.
- [4] L. Marchi, M. Cavalli, M. Sangati, and M. Borga, "Hydrometeorological controls and erosive response of an extreme alpine debris flow." *Hydrol. Process.*, vol. 23, no. 19, pp. 2714–2727, 2009.
- [5] E. I. Nikolopoulos, E. N. Anagnostou, M. Borga, E. R. Vivoni and A. Papadopoulos, "Sensitivity of a mountain basin flash floods to initial wetness condition and rainfall variability." *J. Hydrol.*, vol. 402, no. 3–4, pp. 165–178, 2011.
- [6] M. Hino, Y. Odaka, K. Nadaoka and A. Sako, "Effect of initial soil moisture content on the vertical infiltration process – a guide to the problem of runoff-ratio and loss." *J. Hydrol.*, vol. 102, , pp. 267–284, 1988.
- [7] S. Yatheendradas, T. Wagener, H. Gupta, C. Unkrich, D. Goodrich, M. Schaffner and A. Stewart, "Understanding uncertainty in distributed flash flood forecasting for semiarid regions." *Water Res. Research*, vol. 44, no 5, p. 17, doi:10.1029/2007WR005940, 2008.
- [8] V. M. Castillo, A. Gomez-Plaza and M. Martinez-Mena, "The role of antecedent soil water content in the runoff response of semiarid catchments: a simulation approach." *J. Hydrol.*, vol. 284, pp. 114–130, 2003.
- [9] J. A. Moody and D. A. Martin, "Post-fire, rainfall intensity–peak discharge relations for three mountainous watersheds in the western USA." *Hydrological Processes, Special Issue: Wildfire and Surficial Processes*, vol. 15, no. 15, pp. 2981–2993, 2001.
- [10] M. Borga, M. Stoffel, L. Marchi, F. Marra and M. Jakob, "Hydrogeomorphic response to extreme rainfall in headwater systems: Flash floods and debris flows." *J. Hydrol.*, vol. 518, Part B, pp. 194–205, 2014
- [11] P. J. Smith, L. Panziera, and K. J. Beven. "Forecasting flash floods using data-based mechanistic models and NORA radar rainfall forecasts". *Hydrol. Sci. J.*, pp. 1–15, Publ. online: Jan 2014, 2014.
- [12] T. R. Kjeldsen, J. D. Miller, and J. C. Packman, "Modelling design flood hydrographs in catchments with mixed urban and rural land cover", *Hydrology Research*, vol 44, no 6, pp 1040–1057, 2013.
- [13] S. N. Jonkman and I. Kelman, "An Analysis of causes and circumstances of flood disaster deaths." *Disasters* vol.29, no. 1, pp 75–97, 2005.
- [14] L. Coates, "Flood fatalities in Australia 1788–1996. *Aust. Geogr.*, vol. 30, no. 3, pp. 391–408, 1999.
- [15] C. Staes, J. C. Orengo, J. Malilay, J. Rullan and E. Noji, "Deaths due to flash floods in Puerto Rico, January 1992: implications for prevention. *Int. J. Epidemiol.*, vol. 23, no. 5, pp. 968–975, 1994.
- [16] O. Dub, "Regime of high water in small streams." The publication of the State Hydrological and Meteorological Institute in Bratislava, (in Slovak), 1941.
- [17] J. Pacl, "Catastrophic flood in the Tatras area in June, 1958." *Proceedings of the works of the Tatra National Park*, vol. 3, pp. 17–56, 1959.
- [18] P. Pekarova, P. Miklanek, P. Skoda and A. Svoboda, "Analysis of floods on the Danube and Vah." In conference proceedings of Conference Floods 2010: Causes, course and experience, Strbske pleso, High Tatras, Slovakia, Water Research Institute (WRI), pp. 1–10, 2010.
- [19] P. Šťastný, M. Turňa, L. Méri, P. Zaujec, "Meteorological assessment of storm activity in northwestern Slovakia July 21 2014. *Water management reporter*, vol. 57, no.9–10, pp.24–25, (in Slovak), 2014.
- [20] A. Svoboda and P. Pekárová, "The catastrophic flood of July 1998 in the Mala Svinka catchment – its simulation." *Journal Hydrol. Hydromech.*, vol. 46, no. 6, pp. 356–365, 1998.
- [21] P. Pekarova, A. Svoboda, P. Miklanek, P. Škoda and D. Halmová, "Estimating flash flood peak discharge in Gidra and Parná basin: case study for the 7–8 June 2011 flood." *J. Hydrol. Hydromech.*, vol. 60, no. 3, pp. 206–216, 2012.