SOIL WATER MOVEMENT DURING THE EXTREME PRECIPITATION IN THE ŠUMAVA MTS. AND IN THE KRKONOŠE MTS. IN AUGUST 2002

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Introduction

Heavy rains in August 2002 were caused by two cyclones (6–7 August, 11–12 August) of Mediterranean origin, which moved from Hungary to Poland over the eastern part of the Czech Republic (Brázdil *et al.* 2006; Řezáčová *et al.* 2005; Řezníčková *et al.* 2007). Orographic reinforcement accompanying the crossing of the cyclones over the south bohemian mountains (the Vltava River sub-catchment) caused the rain depth to exceed the typical water retention capacity 60 to 90 mm in the mountainous catchments in Bohemia (Table 1). An extreme level of runoff was consequently generated in mountainous areas, causing catastrophic floods in the greater part of Bohemia.

Our study analyses the soil water movement in the Kout and Doupě catchments (Southern Bohemia, Šumava Mts.) and Modrý Důl catchment (Northern Bohemia, Krkonoše Mts.) as a response to these rainfall events.

Table 1. Rain amount and rain depth in the Labe River catchment and Vltava River sub-catchment (CHMI, 2003a)

Period	Vltava River sub-catchment area 28090 km^2		Labe River catchment area 144055 km^2	
	rain amount (km^3)	rain depth (mm)	rain amount (km^3)	rain depth (mm)
6–7 August	1.886	66	2.020	14
11–12 August	2.774	99	3.913	27
6–15 August	4.978	177	6.950	48

Experimental catchments and methods

The experimental catchments Kout (drainage area of 0.17 km^2, 1180–1330 m a.s.l.) and Doupě (drainage area of 0.1 km^2, 1210–1275 m a.s.l.) lie in the cold climatic zone in the National Park of the Šumava Mts. This region is part of the metamorphic complex – Moldanubicum. It is formed mainly by the metamorphosed rocks, paragneiss with smaller anomalies. Both catchments have very similar natural conditions, but they differ significantly in a vegetation cover only. The catchments are covered with Eutric Cambisol (WRB, 1998).

The Kout catchment is covered by dead forest and herb undergrowth – originally *Calamagrostis villosa* – a typically rich spruce forest. The height of herbs is about 40 cm. Dead trees are 5 to 10 m high, with a density of 200 to 300 trees per ha. The Doupě catchment is a clearing covered by herbs – originally *Calamagrostis villosa* – a typically rich spruce forest. The trees were practically missing in 2002, and the height of herbs was about 30 cm.

The Modrý Důl catchment (drainage area of 2.62 km^2, 1010–1554 m a.s.l.) is situated in the eastern part of the Krkonoše Mts. (crystalline complex of the Krkonoše Mts.). There are deposits of fluvial or fluviodeluvial sediments along the Modrý potok brook. The soil types are Humic Podzols and Lithic Leptosols (WRB, 1998) with a very thin humic layer while deeper soil of about 60 cm can be found in the bottom part of the valley. This basin represents the original spruce forest in the lower part, and artic-alpine tundra with dwarf pine covers the upper part above the timberline. The climatic conditions correspond to the characteristics of the cold humid climatic zone.

The basic quantities (precipitation total and intensity, air and soil temperatures, and tensiometric pressures were recorded in the experimental catchment. Air temperatures were measured at two levels (5 and 200 cm above the soil surface), soil temperatures at three depths (15, 30, 60 cm), and the tensiometric pressure in the soil cover at three depths (15, 45, 60 cm). Tensiometric pressure was measured with the help of water tensiometers. The discharge at the closing profiles of catchments was continuously recorded using a pressure head transducer.

Results

In the Figure 1, the rain intensity in the Kout and Modrý Důl catchments are shown. P1 to P4 denotes particular rain events. The delay S2 of the P2 rain event and the S4 delay of the P4 rain event in the Modrý Důl catchment compared to the Kout catchment are depicted in this figure. This delay corresponds to the fact that both cyclones bringing rain moved from the south (Kout) to the north (Modrý Důl). Cumulative rain in the Kout and Modrý Důl catchments are demonstrated in the Figure 2. Lower value of cumulative rain in the Modrý Důl catchment compared to the Kout catchment is caused by the movements of both cyclones from south to north. The major part of rain-water fallen down by the crossing of the cyclones over the south bohemian mountains.

The reaction of the tensiometric pressure on the rain is demonstrated in Figures 3 and 4 in the Kout and Doupě catchments. In the event P1, the heavy rain (77 mm in the Kout catchment and 74 mm in the Doupě catchment) caused the soil oversaturation (marked by the T1 arrow) lasting for 33 hours in the Kout catchment and 31 hours in the Doupě catchment (marked by the F1 arrow). In the event P2, the small rain 9 mm in the Kout catchment caused the 17 hours of the soil oversaturation (marked by the T2 arrow). In the events P3+P4, the heavy rain (123 mm in the Kout catchment and 81 mm in the Doupě catchment) caused the soil oversaturation (marked by the T4 arrow) lasting for 6 days in the Kout catchment and 28 hours in the Doupě catchment (marked by the F4 arrow).

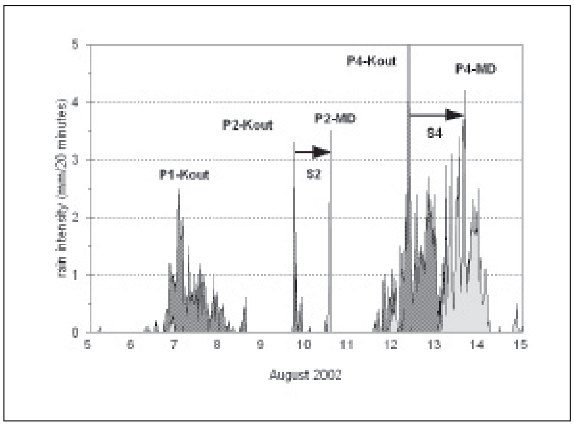

Figure 1. Rain intensity in the Kout and Modrý Důl (MD) catchments. P1 to P4 – rain events. S2 – delay of the P2 rain event in the Modrý Důl catchment compared to the Kout catchment, S4 – delay of the P4 rain event in the Modrý Důl catchment compared to the Kout catchment.

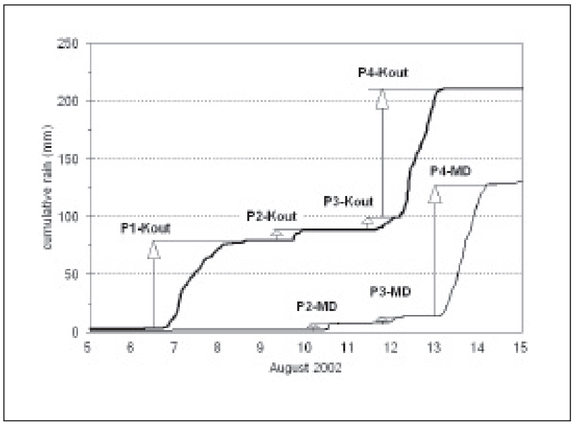

Figure 2. Cumulative rain in the Kout and Modrý Důl (MD) catchments. P1 to P4 – rain events.

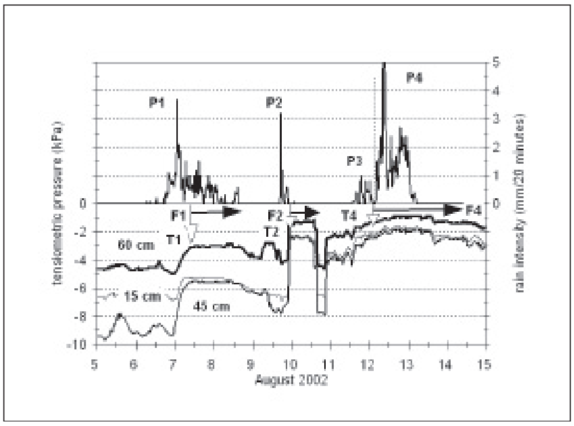

Figure 3. Rain intensity and tensiometric pressures in the depth of 15 cm (thick line), 30 cm (thin line), and 60 cm (very thick line) in the Kout catchment. P1 to P4 – rain events, T1 to T4 – tensiometric pressure in the depth of 60 cm corresponding to the appropriate rain events, F1 to F4 – arrows indicate flood generation.

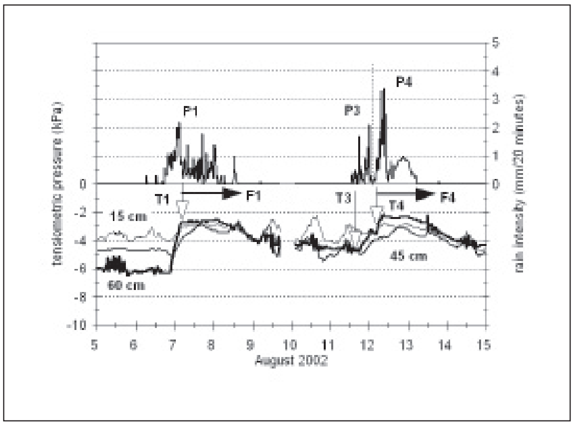

Figure 4. Rain intensity and tensiometric pressures in the depth of 15 cm (thick line), 30 cm (thin line), and 60 cm (very thick line) in the Doupě catchment. P1 to P4 – rain events, T1 to T4 – tensiometric pressure in the depth of 60 cm corresponding to the appropriate rain events, F1 to F4 – arrows indicate flood generation.

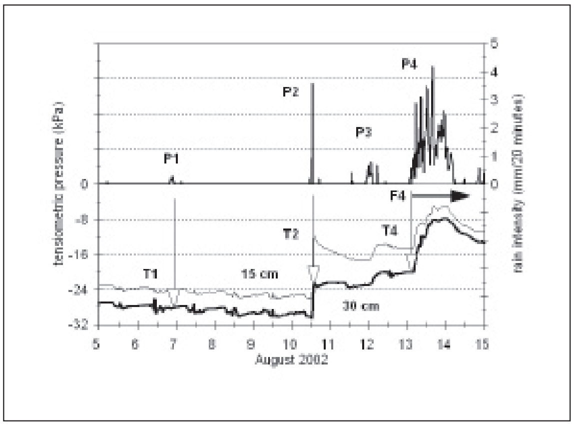

Figure 5. Rain intensity and tensiometric pressures in the depth of 15 cm (thick line) and 60 cm (very thick line) in the Modrý Důl catchment. P1 to P4 – rain events, T1 to T4 – tensiometric pressure in the depth of 60 cm corresponding to the appropriate rain events, F4 – arrow indicates flood generation.

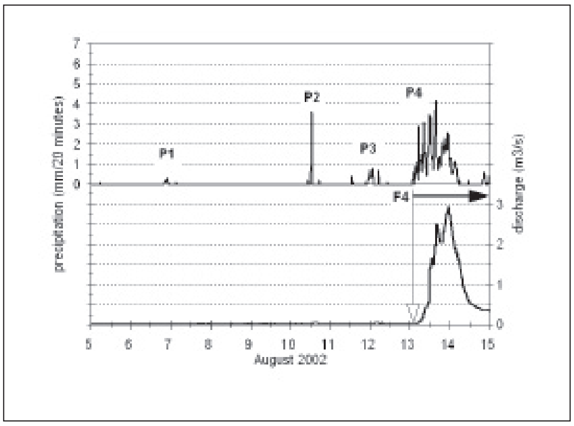

Figure 6. Rain intensity and discharge in the Modrý Důl catchment. P1 to P4 – rain events, F4 – arrow indicates flood generation.

In the Doupě catchment, the measurement of all variables was interrupted for some hours between 9 and 10 August. In consequence of this malfunction the precipitation situation P2 was not recorded in the Doupě catchment (Figure 4). The discharge measurement was interrupted by the malfunction of measuring devices in the Kout and Doupě catchment during the flood caused by extreme rain in the period of 6–7 August.

The reaction of the tensiometric pressure on the rain in the Modrý Důl catchment is demonstrated in Figure 5. The tensiometric pressure in the depth of 15 and 30 cm reacts markedly (T2, T4) on precipitation P2 and P4. In Figure 6, the discharge measured in the closing profile of the Modrý Důl catchment is related to the rain. P4 denotes rain event (131 mm) which caused perceptible discharge peak F4. The soil layer fully absorbed the precipitation P1, P2 (6 mm), P3 (14 mm). The role of the soil saturation excess is shown in Figures 5 and 6. The event P4 shows the dependence of the discharge on the duration of soil saturation excess and the rain amount. These figures show that the discharge peak formation is markedly influenced by the water retention in the soil profile.

Discussion and conclusions

A significant role of the soil water in the hydrologic cycle was pointed out in the textbook of Kutílek (1978). The author called attention to the fact that the soil cover forms a huge water reservoir. Its retention capacity is one order greater than the capacity of all artificial and natural water reservoirs in the Czech Republic. The typical water retention capacity is 60 to 90 mm in the mountainous and submontane catchments in Bohemia (Doležal *et al.*, 2004; Tesař *et al.*, 2004).

As shown in Table 1, the first rain event in the period of 6–7 August (denoted P1 in Figures 1 to 4) fully saturated the soil profile in the Vltava River sub-catchment including Kout (Figure 3) and Doupě (Figure 4) catchments. While the Labe River catchment was not saturated by the P1 rain event which testifies the Modrý Důl catchment (Figure 5). In this period the first flood (F1 in Figs. 3 and 4) was generated in the southern Bohemia (CHMI, 2003b). In the period of 11–12 August (P3+P4 in Figures 1 to 6) a catastrophic flood was generated in the southern Bohemia and heavy flood in the northern Bohemia because the rain caused a saturation excess leading to the hortonian runoff in southern and northern mountainous areas.

This analysis shows that the huge rain amount in both periods exceeded the retention capacity of the catchments covered by mature spruce forest and dwarf pine forest (Modrý Důl), dead forest and herb undergrowth (Kout), clearing covered by herbs (Doupě). It means that the plant cover played a negligible role in the runoff generation. The soil cover in mountains (e.g. Eutric Cambisol in Kout and Doupě, Humic Podzols and Lithic Leptosols in Modrý Důl) was not able to prevent the country from catastrophic runoff because its retention capacity is rather low.

Acknowledgements

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