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How geophysical methods can contribute to subsurface storm flow investigations

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Fast subsurface storm flow (SSF) can contribute significantly to stream flow and lead to unexpected fast drainage of the soil. SSF occurs mainly in preferential flow paths, which develop particularly above shallow layers of reduced hydraulic permeability. Besides the flow path geometry, the intensity of SSF depends on a complex interaction of preferential flow and flow in the soil matrix which is influenced by soil properties as well as by initial soil water content and precipitation characteristics.

To understand this interdependency of temporally and spatially variable factors, detailed observations of SSF mechanisms were made on different plots with a combined hydrometric and tracer approach. The structural factors and soil properties influencing SSF were identified and scaled up by analysing soil profiles in combination with geophysical methods.

On one test slope, SSF occurred due to a reduction of the hydraulic permeability between the soil and the underlying ground moraine material. The topography of the moraine material could be mapped on a larger scale with GPR and with resistivity measurements. During rainfall events with high intensities, the runoff generation mechanism changed. Overland flow occurred due to saturation of the uppermost thin soil layer. This layer could not be detected with geophysical methods.

On another test slope, SSF occurred extremely quickly, although the deep soil had a low hydraulic conductivity. High subsurface flow velocities of over 1 cm/s were measured over a large distance using instantaneous tracer injections. Such fast SSF requires preferential flow in long and well-connected lateral flow paths. These flow paths could be located with ground penetrating radar, when highly concentrated NaCl-solution was injected into the soil at the top of the hillslope to enhance the radar reflections. Simultaneous resistivity measurements had no success due to the limited

spatial resolution.

Together with a detailed analysis of the site-specific SSF mechanisms, the geophysical methods helped to locate structures influencing SSF and to identify its spatial variability. However, the restrictions of penetration depth and spatial resolution have to be considered.