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Hydrogeophysical investigations of spatial flow patterns in unsaturated sandy alluvial sediments

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The quality and quantity of the groundwater resources depend highly on the flow and transport properties of the unsaturated zone. Traditionally, unsaturated hydraulic parameters have been estimated using destructive small-scale sampling of the soils investigated. These small-scale analyses are not, however, able to describe preferential flow paths or instable wetting fronts that have been observed at field scale.

At Hjelm Hede, Denmark, a 6-m-deep well was installed in a 25 m deep alluvial deposit of unsaturated sands and gravels. Seven one-meter-long Time Domain Reflectrometry probes were installed horizontally at half to one meter intervals throughout the depth of the well, and were set to continuously record estimated moisture content values over time. The moisture content time-series indicate that infiltration through the unsaturated zone is highly non-homogeneous, since duplicate probes at the same depth do not exhibit similar developments in moisture content. Furthermore, wetting fronts are observed to bypass certain probes, and observed responses to an infiltration event are in some circumstances recorded at deeper probes before it is observed closer to the surface.

To further investigate the spatial heterogeneity of moisture content and the conditions that lead to bypass phenomena, two different types of ground penetrating radar (GPR) techniques were applied. 1) Cross-borehole GPR was collected between two 10-m-

deep boreholes located 5 m apart at five different time intervals. 2) A 3D reflection GPR grid using high frequency antennae was collected for a 5 m by 5 m surface area. The high spatial sampling of the GPR method allowed for a detailed description of small-scale variations of the sediments, and these structural features were compared to dye-staining from a Brilliant Blue infiltration experiment over the same area.