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Numerical studies of the influence of soil heterogeneities on water flow in the unsaturated zone of the Erstein polder site

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To analyse the influence of water ponding on the water balance of an artificial flooding area, the so-called Erstein polder site, numerical studies were conducted using the finite element model FEFLOW. The study focuses on the quantification of both the flux of infiltrated water during flooding event and its impact on the groundwater flow, and the determination of the velocity of the moving waterfront, from the soil surface through the unsaturated zone towards the groundwater. One major question was if the implementation in the numerical model of all available information on soil heterogeneity may lead to a better representation of the observations compared to a homogeneous modelling approach. We thus firstly quantified the uncertainty of the hydraulic properties of the vadose zone in terms of spatially distributed Van Genuchten parameters and then analyzed the influence of soil heterogeneities on the water flow within the unsaturated zone.

The Erstein polder is a research site of about 600 ha, that is located 30 km south of Strasbourg town center. The recorded hydraulic heads and water suctions collected from the measuring probes, will be used for the analysis of our numerical results obtained for the flooding event in January 2004.

At the laboratory scale, the distribution of heterogeneities within a soil sample may be taken into account in numerical models; however for a modelling at the regional scale, a representative consideration of soil heterogeneities within the unsaturated zone is more difficult since the unknown exact distribution of the different zones. To define hydraulic parameters of the soil, many numerical studies have only considered their horizontal variability while neglecting textural layering at different locations. In our numerical model, the unsaturated zone was discretised by 8 layers of 0.25 m height with estimated Van Genuchten parameters, representing the inhomogeneous soil profiles at different locations at the Erstein polder site.

The finite element code FEFLOW was used to run simulations with different scenarios. In the first scenario, we simulated a three-dimensional transient unsaturated water flow through an homogeneous domain. The estimated discharge of infiltrating water was of about 1,21 m3/s that corresponds to 27,1% of the annual outflow rate. However, comparing the measured water heads on the site during the flooding event with those calculated, the numerical results do not reproduce satisfactorily the observations. Therefore we decided to take into account the available information on soil heterogeneities at the site. The inhomogeneous domain was treated via two scenarios. The first one consisted of simulating three-dimensional transient unsaturated flow with spatially limited heterogeneities, those of the terrace zone and channel zone. The estimation of the Van Genuchten parameters were done from (i) grain-size distributions and (ii) laboratory hydraulic measurements (capillary pressure-saturation curves,) conducted on undisturbed soil samples at four locations and different depths. Two methods were used for quantification of the Van Genuchten parameters: (a) the Hydrus 1D tool based on a large textural database, and (b) an inverse modelling approach using the Levenberg-Marquardt algorithm. The second scenario, an alternative modelling approach, was also based on a spatial distributed field of heterogeneities but with a larger variability: the estimated hydraulic parameters of the unsaturated zone were based on soil samples taken with an auger at 100 points covering the whole area of the polder. The proposed approach is based on an estimate of percentages of sand, silt and clay from the information available on these soil samples which is only a qualitative description of soil classes. Up to now, this type of description has not been often used in other studies because of the difficulty of handling this qualitative information and transferring it into a quantitative one.