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Emergence of Preferential Flow Networks at the Hillslope Scale

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Several experimental investigations and simulations have shown that the hydrological behavior, in particular in steep, forested watersheds, is controlled by macroscale hillslope structure. Weiler and McDonnell (2007, WRR) recently developed and applied a model to the Maimai hillslope, NZ, that describes such macroscale structure as often inherent in a lateral preferential flow (pipe) network. The work clearly demonstrated that even disconnected preferential pathways can connect to develop a network-like flow pattern. Describing this network structure, its physical meaning, and how it is generated is important for the advancement of hillslope hydrology. In this study, hill-vi, the model developed to simulate the network-like behavior at the hillslope scale, was used to investigate emergence functional properties of these networks. A virtual experiment to investigate different relations between soil matrix and pipe conductivity was set-up using soil, topographical and meteorological data from the Maimai hillslope. The simulation results demonstrate that, while for different combinations of matrix and pipe flow conductivities the subsurface flow response can be very similar, the internal development of a flow network and the importance of pipe flow will differ. The distributions of lateral flow velocity in the hillslope during peak flow and during drainage of the hillslope are distinctly different for the different combinations. This will have interesting implications to the modeling of transport processes in network dominated hillslopes as a strongly skewed distribution develops for certain combinations. Similar observations were made for pore water pressure, which may have important implications for slope stability assessment. The results raise the question if a deterministic framework like Bejan's constructal law, hypothesizing that the config-

uration of the pipe flow networks must evolve such that flow pathways maximize the amount of flow through a hillslope or other network theories, can be supported in light of our simulations.