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Hydraulics of flows over and through multi-layered soils on mild slopes

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In early researches overland flow was only considered for the case of a single soil layer. However, there are multiple layers of soils in reality, so this work considers not only the surface flow but also the subsurface flow passing the parallel multi-layered soils with a mild slope. The flow field is divided into a homogenous water layer and permeable parallel multi-layered soils with infinite thickness. The water flow in the top layer is described by the Navier-Stokes equations, and the pore water flow inside each soil layer is governed by the Biot's theory of poroelasticity. Both water flows are considered as laminar flows. After the boundary-value problem is formulated, the solution can be theoretically derived by the method of separation of variables. Then, the velocity profiles and shear stress profiles are investigated. The variation among each interface is especially important and thus is also discussed.

As a result, the bottom slope of each layer and the soil type influence the profiles of flow velocity and shear stress significantly. Because the soil layers are considered permeable, the flow velocity profiles are nonzero at the interfaces among the layers. For a constant slope, the subsurface flow velocity is mainly affected by the soil porosity, i.e. the soil type, and it is continuous at the interface of each layer. Moreover, the distribution of shear stress in the water layer appears to be linear and the maximum value occurs at the interface of the water-soil matrix. The shear stress distribution for a certain soil or inside each soil layer approaches to zero except near the interfaces of soil layers since the flow velocity is nearly constant. To sum up, this study successfully presents the solution of water flows over and through multi-layered soils on mild slopes by an analytical approach. While the multiple layers degenerate into a single one, the solution is exactly the same as the previous research. This validates the present results.