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Parameterization of small water courses conductance in hydrogeological models based on field scale virtual experiments

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Modelling water exchanges between groundwater and surface water is of great importance for water management and solute transport studies. In regional hydrogeological models, this is often accomplished with a Cauchy boundary condition (head-dependent flux) governed by a conductance parameter. The most commonly used parameterization of the conductance is the expression implemented in the MODFLOW model. It relies on the assumption that all head losses occur in the surface water bed. However, some field study has shown the absence of a distinct interface between the surface and subsurface. Therefore this conductance is often used as a lumped fitting parameter. Moreover a significant grid-size dependency of this parameter was shown by Mehl and Hill [2010]. On the other hand, some analytical solutions exist (e.g. Hooghoudt and Ernst equations, De Lange [1999]) which consider the conductance of the surrounding aquifer. They rely on different assumptions about the flow field, the boundary conditions and the domain geometry. However, field conditions often deviate significantly from these assumptions. The objective of this study is to investigate the parameterization of conductance for small surface water courses (i.e. drainage ditches and small rivers) in large groundwater model cells ($\approx$ 500 by 500 m) and the associated uncertainties. The targeted system to be modeled is the Kleine Nete catchment ($\approx$ 800 km^2, Belgium), which is an example of a lowland catchment drained by a complex network of ditches and rivers. This contribution presents a new conductance expression derived from field scale virtual experiments (i.e. numerical simulations carried out to test a scientific hypothesis). To derive this expression, transient simulations of 2D cross sections with different characteristics representing one ditch and the surrounding aquifer were performed using HYDRUS-2/3D. Simulation outputs show a good correlation between the conductance and both the hydraulic conductivity of the aquifer and the representative length (defined as the area of the considered domain divided by the total length of surface water courses). An empirical relationship linking the conductance with the aquifer hydraulic conductivity and the representative length was then derived from these observations. This new conductance expression, the approach implemented in MODFLOW and the analytical solutions of Hooghoudt, Ernst and De Lange [1999] were then evaluated against more complex 2D virtual settings (including soil layering and multiple ditches). Finally, our proposed conductance parameter and the classical MODFLOW approach were tested in a 3D groundwater model. Results from this modelling exercise show that the proposed equation outperforms the analytical solutions and the classical MODFLOW approach on the 2D evaluations, especially when the conditions deviate from their underlying assumptions.

De Lange, W. (1999), A Cauchy boundary condition for the lumped interaction between an arbitrary number of surface waters and a regional aquifer, Journal of Hydrology, 226(3), 250-261.
Mehl, S., and M. C. Hill (2010), Grid-size dependence of Cauchy boundary conditions used to simulate stream–aquifer interactions, Advances in Water Resources, 33(4), 430-442, doi:https://doi.org/10.1016/j.advwatres.2010.01.008.