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Interactive comment on “Transient flow between aquifers and surface water: analytically derived field-scale hydraulic heads and fluxes” by G. H. de Rooij

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Initial reply to Dr. S. Hergarten

Dr. Hergarten appreciates the science of the paper but expresses concerns that it may meet with limited demand. Referee 2 made a few suggestions that will hopefully help me to clarify some issues to which the material presented here could be beneficially applied.

In addition to that, it may be worthwhile to point out that this transient study is a follow-up to a review comment made to an earlier paper in this series, where the analysis

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was initially largely restricted to stationary water (de Rooij, 2010). One of the reviewers correctly viewed this as a limitation of the study, and I developed theoretical results for steady state flows as a response (de Rooij, 2011). The further development for transient flows presented here is a logical extension of that earlier work.

Dr. Hergarten's analogy of providing a tool box is quite accurate. However, the drive to develop the tools in the box was not provided by the groundwater community, since these researchers would normally focus on a particular aquifer. I fully agree with Dr. Hergarten that it would often be just as convenient to turn to a numerical model. But a new category of potential users with a new set of questions and a new modelling framework is emerging: I met with global scale climate researchers and regional/national scale hydrological modellers that are well-versed in large scale atmospheric modelling, but experience more difficulty with modelling soil hydrology at their preferred scales, and are starting to venture into groundwater modelling at that scale. The kind of research interests of that community are best illustrated by the request I received for a global (!) groundwater model.

Running MODFLOW at these scales has its limitations, even though an attempt was recently made for the Rhine-Meuse basin (Sutanudjaja, 2011). And the climate research and regional hydrology communities are not so much interested in detailed maps groundwater levels and velocity fields, but more in the conversion of rainfall to runoff, hydrological teleconnections between high and low areas, etc. Furthermore, detailed groundwater levels will often not be available, but novel techniques (e.g., gravimetry) may well be able to provide average groundwater levels. I therefore examined whether predictable relationships exist between large-scale features of saturated flow (average heads, aquifer-scale discharge, etc.). I started out at the field scale because there we can rely on experience gained from areas where the groundwater is controlled by artificial drainage and we know the analytical expressions work quite well, the inevitable heterogeneity in the rainfall and the hydraulic properties notwithstanding.

This makes the nature of the study exploratory – analytical results as such are widely

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available (although not for the range of forcings presented here), but to my knowledge the direct link with aquifer-scale flow characteristics is novel. One of the motivations for reverting to an analytical treatment was the opportunity it provided to make the scale-transition from the Darcian to the aquifer-scale fully transparent. A numerical analysis would require an elaborate discussion about the required averaging technique, particularly with non-equidistant nodes, the results would be blurred to some degree by round-off errors, and the clear advantage of having explicit averaging expressions that lend themselves for detailed analysis would be lost – the analysis would have to be inductive: carry out many simulations and see what relationships emerge, if any. The analytical approach is more direct in that the relationships sought emerge directly from the equations. The other side of the medal of this exploratory approach is the scarcity of readily usable results observed by Dr. Hergarten. The findings make me optimistic that such results can be obtained, however. A few of those will be clarified as I incorporate the suggestions by R2, others will require substantial further work. For instance, to make this approach applicable to an entire region, that region must be characterized by its distribution of spacing in its surface water network, superimposed upon the variation of the aquifer property KD. The storage coefficient may be spatially distributed as well (and would be related to the soil map). A joint pdf of these three characteristics (with measured and/or calibrated parameters) would allow an estimation of the regional response to rainfall and evapotranspiration, either through the analytical approach presented here or via a numerical models based on the results reported here. But to do so, we need theoretical building blocks to work with, and this paper proves some of those.

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