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Hydrology and Earth System Sciences Discussions

Interactive comment on "Characterization of groundwater dynamics in landslides in varved clays" *by* J. E. van der Spek et al.

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Overview / General comments

We thank the reviewer for his constructive review and the compliments. Here we will address the specific points mentioned by the reviewer.

The authors investigate groundwater dynamics in multi-layered fractured soils in the context of landslides. They idealize and conceptualize different parts of the subsurface system. Only few data are available. After a model calibration they obtain a reasonable agreement between simulated and measured hydraulic heads and a correlation between peaks in hydraulic heads and the occurrence of landslides. The paper is well

written and organized and only needs few extensions for publication. I have read the discussion with the other 2 reviewers.

I have the following points to be discussed: Conceptual model: Instead of using 3 different models for the colluvium layer, the varved clay and the fissures and couple them, one could use one model for all. A double-continuum Richards or two-phase flow model for porous media: colluvium layer: fracture continuum enabled, recharge directly included; varved clay: double continuum, bottom boundary: closed for clay, open for fracture / fissure domain; advantages: distance between fissures not necessary, no reservoir constant necessary; however in the calibration: fracture permeability, porosity, possibly more parameters; the authors should comment on that and should include this in section 7 if the feel it to be worth.

The reviewer brings up an interesting point. In principle it is possible to use one continuum model approach for colluvium, varved clays and fissures. We did even try that as well using the FE code Hydrus 2D software. However, the parameterisation is cumbersome and the entire model becomes numerical very unstable. The main problem is the interface between the three domains (fissure, colluvium and varved clays). The permeability contrasts oblige the modeller to increase the network density and work consequently with very short time steps. This, however, is even then not a guarantee for a stable solution. This results from the unsaturated zone calculations which are very non-linear. Moreover, how to get the soil hydraulic parameters for, e.g. the van Genuchten-Mualem equation for high porosity and high permeable fissures? Then still, one should make an assumption about the lower boundary condition to simulate drainage from the fissure outside the model domain (or include a drain function which also needs to be parameterised). Concluding, we think that making conceptualisations as we did increases the model performance as well as the transparancy of the model results.

Model calibration: You have taken 4 parameters for the calibration and you have taken other parameters from the literature which I have not read. Do these parameters (e.g.

saturated hydraulic conductivity and specific storage of silt) come from measurements or from another calibration? What would you expect if you would include these parameters in your calibration? Do you have a feeling for the sensitivity of these parameters?

Although most parameters were determined in laboratory and field experiments, it is not of all parameters indicated how the values of the parameters were determined. The influence of the hydraulic conductivity of saturated silt can be seen in eq. 8 and fig. 4 in the article. Also the influence of the specific storage of silt can be seen in eq. 8. Both parameters have a large influence on the pore water pressures in the varved clays. However their influence on the head in the colluvium is very small. Therefore, where measurements of the head in the colluvium are available, the hydraulic conductivity and specific yield of the colluvium may be calibrated partly independently of the values of the hydraulic conductivity and specific storage of silt. The influence of the porosity and the Van Genuchten parameters is small as these parameters only influence the unsaturated part of the varved clays. We will add some information on these points in the revised version of the manuscript. A detailed sensitivity analysis can be found in Van der Spek (2011).

Entrapped air: Comparing a two-phase instead of a Richards model for such a case would give an indication whether this aspect is important here; it might be the case; I refer the authors to the following publication where this aspect has been investigated for a similar case STADLER,L., HINKELMANN,R. & HELMIG,R. (2012): Modeling Macroporous Soils with a Two-Phase Dual-Permeability Model. Transport in Porous Media: Volume 95, Issue 3, Page 585-601, Springer Verlag, DOI: 10.1007/s11242-012-0064-3

We thank the reviewer for bringing us the article under attention. It is, however, outside the scope of the manuscript to study or even quantify the effect of entrapped air. This would need additional laboratory investigation. We do bring up this discussion point as we think it could be of importance in some circumstance, especially when rapidly changing water levels in the fissure and then water infiltration into the varved clays. And no detailed study has been done to this effect in the varved clays-fissure interaction.

My other minor and technical comments have already been addressed by the other reviewers.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 295, 2013.