Hydrol. Earth Syst. Sci. Discuss., 10, C5301–C5306, 2013
www.hydrol-earth-syst-sci-discuss.net/10/C5301/2013/

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "Influence of aquifer heterogeneity on karst hydraulics and catchment delineation employing distributive modeling approaches" *by* S. Oehlmann et al.

S. Oehlmann et al.

soehlma@gwdg.de

Received and published: 1 October 2013

Dear Prof. West,

We thank you for your useful comments and advice that will help to improve our work. In the following, we answer your specific comments. The revised version of the manuscript is attached to this answer, including the mentioned corrections and revised figures. Page and line references refer to the attached revised manuscript.

Comments

1. The simulations are steady-state, which means that they won't reproduce effects

such as seasonal variations in catchment areas and flow pattern. The reader needs to know a little more about the extent of seasonal variations in the system to evaluate the work. To this end, authors should briefly describe the ranges of hydraulic head variation in their observation wells during the period over which averaging was undertaken as well as the typical seasonal variation in effective rainfall. They should then comment on the likely impact such of seasonal variation on the spring catchment areas identified in Fig 5 (d) and (e).

Answer: Previous research shows that the question of shifting catchment boundaries is of minor importance for the Gallusquelle spring catchment. A paragraph was added to Sect. 3 including information about hydraulic head variations (p. 8, l. 10–19):

"The average hydraulic heads in the area were derived by Sauter (1992) for the period 1965–1990. The total range of hydraulic head variations during this time differs between 6 m and 20 m depending on the observation well (Sauter, 1992). The monthly rainfall varied from less than 10 mm to more than 180 mm and the annual rainfall from about 600 mm/a to 1200 mm/a. Even though these variations are high, Villinger (1977) deduced, that the boundaries of the catchment area for the Gallusquelle spring do not change significantly throughout the year. His analysis is based on equipotential maps constructed from hydraulic head measurements for high and low water levels in the area. Furthermore, several artificial tracer tests especially in the West of the area were repeated under different flow conditions and showed little to no alteration in flow directions."

For including transient flow in the simulation more information should be added. We included a paragraph in Sect. 5.4 referring to what would be needed for the model to accurately reproduce the behaviour of the hydraulic head variations (p. 16, l. 10–15):

"Since the simulation was performed stationary, the delineated catchment areas are only valid for the average hydraulic head distribution. As known from literature (Sect. 3) they should be representative for the usually observed variations in the Gallusquelle

HESSD

10, C5301–C5306, 2013

Interactive Comment

area. For reliably simulating possible shifts in the catchment areas during extreme flow conditions, more detailed information on recession behavior of the aquifer and lateral and temporal recharge distribution should be included. This is beyond the scope of this paper."

2. Authors should report a little more detail on the (hydro)geological characteristics of their aquifer, for example, matrix porosity and permeability measurements, and the pattern of discontinuities such as joints and bedding planes (e.g. spacing, orientation data, from boreholes or outcrop). The authors suggest matrix permeability values are low compared to those obtained from calibration (Km in Table 1), so the latter reflect the smaller scale discontinuity network. It would therefore be useful to know the observed characteristics of this network, if any are available

Answer: Sauter (1992) deduced hydraulic conductivity values for the fissured system. A paragraph was added to Sect. 5.2 (p. 12, l. 29 – p. 13, l. 4) including the values and shortly describing their derivation. The hydraulic conductivity value for scenario 1 is high compared to the other scenarios and locally measured hydraulic conductivities (1E−6 m/s – 1E−5 m/s), but lies well in the range of measured values on a regional scale. We abstained from giving extensive data on orientation of joints and bedding planes. They are of relatively low relevance for our simulation, since they had to be lumped in the matrix and could not be considered individually. However, we added some more general information about the study area structure to Sect. 3 (p. 7, l. 28–29, p.8, l. 7–9)

3. The assumption of a single conduit depth corresponding to the modelled water table depth in scenario 1 seems odd, given the unrealistic nature of this homogeneous-permeability scenario (p 9036 line 6), and seems to create some problems. Why not use the actual (seasonal averaged) water table depths from Fig 5a instead?

Answer: It was avoided to rely on the average water table depth of Fig. 5a due to the nonuniform distribution of boreholes, which can now be seen in the revised Fig.

5a. There are no values in the Southwest of the area and the contour lines after Sauter (1992) are simply based on hydrogeological assumptions. In the West, where no measurements are available, Sauter (1992) assumes rather high hydraulic heads up to 740 m and close to the Fehla even up to 760 m. The simulations do not confirm this behaviour (see Fig. 5) and the conduits in the West would have run dry during simulation, if they had been placed at that height. Furthermore, it was found, that the karst conduits themselves have a very significant influence on the hydraulic head distribution. Of course, the karst network is still evolving under current conditions and there might be karstification in several depths, but in this case it was assumed, that the homogeneous simulation approaches roughly the conditions during the onset of karstification. A sentence conveying this information was added to Sect. 4 (p. 8, l. 32 – p. 9, l. 2). We assume, that you refer to the overlapping catchment areas, when you say that the choice of conduit depth creates problems. We do not see this as a problem. In nature, there is not necessarily a sharp border between spring catchments.

4. As mentioned by the previous reviewer there is currently not sufficient information given about the goodness of the calibration, with only the overall RMSE reported. Ideally the head calibration targets (observation wells) should be shown on Fig 5, and calibration target errors specified and reported for both head and spring flow calibration targets. This will allow the reader to better evaluate the fits produced by the modelling scenarios.

Answer: In addition to the new figure that was added after the comment of the first reviewer (Fig. 6, revised manuscript) the names of the observation wells are now reported in Fig. 5a and a new table (Table 3) was added reporting the hydraulic head errors for the specific measurement stations. The spring discharge errors can be inferred from Table 2, where the measured and simulated spring discharges are documented, and from Fig. 7, which is a visualization of Table 2 for scenarios 3 and 4.

Technical corrections:

line 24 p9033 – theoretical distance of hydraulic head difference should be b' (b-prime) as in eqn (5) rather than L?

Answer: You are of course correct. The parameter name was adjusted accordingly.

Page 9037 line 2 and Table 1. Please explain how the calibration parameter recharge R = 1mm/d was derived (presumably this is a long-term seasonal average?)

Answer: Yes, that is the case. We included this information and a respective reference (p. 9, l. 25–27). Sauter (1992) describes the derivation of the value in much detail.

Page 9043 line 6. The text 'In scenario 3... strange shape of the areas is caused by early filling of the conduits with water' makes no sense as this is a steady-state simulation? Please reword.

Answer: Done.

Page 9043 line 20 Text 'Gallusquelle Spring drains nearly all water from the springs at the river Fehla' – do you mean that it drains water from the conduits feeding into these smaller springs?

Answer: Yes, it draws water from the conduit feeding the Fehla-Ursprung spring in the West of the area. Furthermore, like stated directly afterwards in the text, the Gallusquelle drawing water from the western part in general leads to influent flow conditions along parts of the Fehla. There are several springs in that area (Fig. 3) that could not be included in the model. Therefore, they do not have specific conduits in the simulation, but effluent flow conditions can be expected along their positions, especially since they are all perennial.

Fig 4 – please label the fault zones (as mentioned in the text p98035 line 15) on these cross sections. Also suggest that you show the seasonally averaged water table elevations.

Answer: The names of the graben-structures Hohenzollerngraben and Lauchertgraben are mentioned above the respective part of the cross-section. The faults are their respective boundary faults, which is now clearly indicated in the revised figure. The average water table was drawn after Sauter (1992) as indicated in the legend of the revised figure. Please see the revised figure (Fig. 4) in the attached revised manuscript.

Fig 6 – add units for the 'y' axis

Answer: Done.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/10/C5301/2013/hessd-10-C5301-2013-supplement.pdf

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 9027, 2013.