Authors’ response to the comments of referee #1 on the article

"Domestic wells have high probability of pumping septic tank leachate"

by J.E. Horn and T. Harter

in Hydrology and Earth System Sciences Discussions

RC - Referee Comment; AR - Authors’ Response

We thank the referee for reviewing our manuscript and highly appreciate the constructive comments. In what follows we quote and respond to the reviewer’s questions and suggestions and describe shortly how we have implemented them in the paper.

RC: “The authors present a framework for estimating the probability of a domestic well pumping septic tank leakage as a function of aquifer properties, lot and drain field size. The research is interesting and appears to have made a significant contribution. I say “appears” because the presentation of the paper is not clear to understand well either what the authors have done, or some of the results that they claim. I would thus recommend that the paper is sent back to the authors for major revision, after which it should be sent out for re-review to assess the contribution of the paper.”

AC: We are currently performing a major revision of our manuscript with emphasis on a better understandability of the methods and clarity of the results.

RC: “1. Methods: My major comment regarding the methods is that the authors go into specifics without first giving a clear idea on what they are setting out to do which makes the paper very difficult to follow. I would suggest enhancing this section (both text and figures) prior to resubmission.”

AC: We enhanced the general description and aims of our study at the end of the introduction. Furthermore, we (hopefully) improved the explanation of the groundwater model set-up, clarified the determination of the capture zones and specified the underlying assumptions. We created a figure schematically depicting the well and the (simplified) capture zones.

RC: “a. An example is the first paragraph in Section 4. I had to go back to read the 2009 paper to understand that statement. While I am not asking that the authors go into full details on Methods and repeat the 2009 paper, it would be helpful to state a little bit more (maybe a Figure) so that this paper stands on its own.”

AC: We inserted an explanation for the procedure determining the location, shape and size of the capture zones and provide a figure in the revised manuscript.

RC: “b. The same comments hold true for the entire section 4. At times there were too much details given (for example the function name in Matlab), but overall the explanation was not adequate to get a good understanding of what the authors have done.”

AC: We revised section 4 of the methods description to be more consistent, more readable, and to provide a clearer understanding of our approach.

RC: "c. Figure 1: If the authors are not showing the capture zone here, what is the point of showing details on capture zone? Makes the figure confusing."

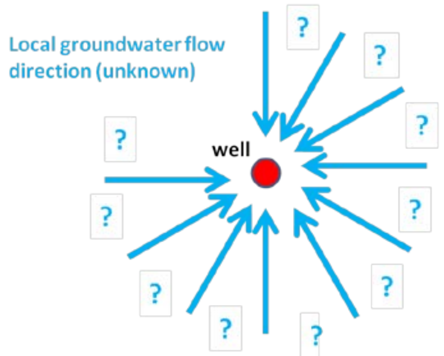
AC: The well capture zone is already shown in Figure 1. Figure 1 shows the principal, conceptual set-up of the spatial analysis: the well and its well capture zone relative to a pattern of individual property lots. The revised Figure 1 will show additional capture zone positions and its rotation as considered in the statistical analysis. The figure labels and caption will be revised to clearly identify what is shown.

RC: "d. Figures 1 and 2 would benefit if the main capture zone and the elongated capture zones can be shown"

AC: Figure 2 shows, in dark, a simplified representation of the well capture zone for purposes of illustrating our approach. To optimize the representation, in section 2, the revised manuscript will provide additional details on the method used to determine the well capture zone. We will also revise labeling and the caption of Figure 2.

RC: "e. Description of the well capture zone is based on a numerical groundwater flow model. I am struggling to see then how the flow direction alpha is a probabilistic value? If we are focusing on the capture zone of a well, the flow direction is towards the well, no? What am I missing here? Can the authors please clarify? "

AC: As explained in the introduction (p.5707 , l.2ff; p.5708, l.22ff) and in section 3, the actual groundwater flow direction at the local scale in rural areas is highly variable. Even if the regional scale groundwater flow direction is known, local hydrogeologic conditions or, for example, nearby large production well pumping, introduce significant uncertainty about the direction of local groundwater flow. Hence, the location of the well capture zone is uncertain. Similarly, the location of septic leach fields within property lots is considered to be unknown, giving further rise to uncertainty. Our approach is therefore cast as a probability analysis, considering all possible groundwater flow directions and all possible leach field locations, assuming a uniform statistical distribution. The manuscript has been revised to clarify this point.



RC: "f. The capture zone of a pumping well is circular – how do the authors make the polygon assumption?"

AC: Considering a pumping well within a superimposed groundwater flow field, the capture zone can be assumed to be elliptical with the longitudinal axis parallel to the flow field (regional groundwater flow direction). This shape and area of the capture zone can be described by analytical solutions. Taking the seal of a well, the screen depth and length, and particularly the gravel pack around a well casing into account does not allow anymore for a simple description of a capture zone. This is shown in detail in Horn and Harter (2009) and highlighted in the revised manuscript.

RC: "2. Results and Discussion: The results section should be enhanced with more figures and more quantitative analysis. Currently there are too many claims, but not enough figures or tables to substantiate them. In addition some figures are mislabeled. Following are some specific suggestions on improving this section:
a. "Figure 3 shows results for all lot-drainfield" configurations" – this is not correct. Figure 3 shows pT for different values of Kh and Kg. It is not clear what lot-drainfield configuration this is for.
b. The caption on Figure 3 also does not correspond to what is shown in the Figure. I think Fig 3 and Fig 4a have been switched."

AC: We apologize for this mistake. As noted in the previously posted "Short Comment", Figure 4a was erroneously plotted twice (just with a different scaling) and labeled as Figure 3. The correct Figure 3 is provided as Short Comment. This figure explains most of the statements which remained undocumented in the Discussion Paper.

RC: "c. Since this is a parametric study, it is important to state in the figure caption the magnitude of the parameters that are held constant (lot size, drainfield size and Kg). This has not been done which makes it difficult to assess the results."

AC: We performed the analysis for all possible combinations of the six lot sizes considered, the three drainfield sizes and the 76 combinations of the various conductivities of the aquifer and the gravel pack. The latter are listed in the table below (Table 1) and will be provided in the revised manuscript. Altogether, the intersection probability for 6*3*76=1368 lot-drainfield-conductivity-combinations was calculated.

Figure 3 shows the intersection probabilities, p_T, for all these combinations plotted versus the horizontal aquifer hydraulic conductivity (K_h); form and color indicate different lot sizes and drainfield sizes. Fig. 3 does not differentiate between different K_g-values (gravel pack conductivity) and anisotropy ratios of the aquifer.

Figure 4a shows the effect of K_g on p_T for an example configuration, which is specified in the figure caption. Figure 4b illustrates the effect of the anisotropy ratio on p_T for all configurations; different K_h-values are indicated by the color. We made this clearer in the figure captions in the revised manuscript.

K_h	K_v	K_g
1	0.2	50, 125, 250, 500, 750, 1000
1	0.5	50, 125, 250, 500, 750, 1000
3	0.6	50, 125, 250, 500, 750, 1000
3	1.5	50, 125, 250, 500, 750, 1000
5	1	50, 125, 250, 500, 750, 1000
5	2.5	50, 125, 250, 500, 750, 1000
10	2	50, 125, 250, 500, 750, 1000
10	5	50, 125, 250, 500, 750, 1000
30	6	50, 125, 250, 500, 750, 1000
30	15	50, 125, 250, 500, 750, 1000
100	20	125, 250, 500, 750, 1000
100	50	125, 250, 500, 750, 1000
300	60	500, 750, 1000
300	150	500, 750, 1000

Table 1: Considered model combinations of the horizontal hydraulic conductivity, K_h, the vertical hydraulic conductivity, K_v, and the gravel pack hydraulic conductivity, K_g. All values are in units of [m d^{-1}]. Each of these 76 configurations were further combined with six different lot sizes as well as three drainfield sizes, leading to 1368 combinations analyzed.

RC: “d. Pg 5714, line 10: “For the half acre lots pT is above 50%”. This does not correspond to what is shown in the figures”

AC: In the revised manuscript, this statement is supported by the correct Fig. 3, which was missing in the original Discussion Paper.

RC: “e. Pg 5714, third and fourth paragraphs: Instead of statements like “An increase of Kh causes an enlargement of the capture zone which results in an eightfold increase in pT. The smallest increase due to Kh is observed for the smallest lots, for which pT is already very high at small Kh; the largest lot and drainfield sizes are most sensitive to Kh”, the authors should consider stating that the relationships are non-linear, and if possible fit a relationship to demonstrate the non-linearity”

AC: In the revised manuscript, we will provide fits for a non-linear function describing the dependency of p_T on K_h.

RC: “f. The authors state in page 5715 “Generally, the larger the lots are, the lower the sensitivity to the gravel pack hydraulic conductivity, i.e., absolute variations of the intersection probability due to Kg decrease with increasing lot size. For the largest lots (L6) and the smallest drainfield (D1), the probability increase 5 between lowest and highest Kg is only 0.1%. Here, the variation of the size of the capture zone has only a marginal effect on the intersection probability”. : : :: : :: : :: : :: : :: : :: : :.. Is this shown in a Figure somewhere?”

AC: Yes, it is shown in the originally missing Fig. 3; for a given lot-drainfield configuration (which is marked by the different marker forms and colors), the sensitivity of p_T-values to K_g is mirrored by the range covered by the markers . For example, the absolute p_T-range within the L6-group (red) for all drainfield sizes is much smaller than that of the L1- or L2-group (black, magenta). This is made clearer in the revised manuscript.

RC: “g. The authors should consider presenting one or more additional figures that help substantiate their claims better. Instead of making statements like parameter A has a greater effect than parameter B, the authors can think of presenting contour plots of change in pT with changes in the two parameters along the two axes. Other options might be fitting the variations to equations and comparing the parameters of the equations.

AC: The revised analysis provides a stronger substantiation of our findings with the figures presented.

RC: “h. Pg 5716 first para: Is there a figure showing this?”

AC: The stated “wide range of intersection probabilities” is shown in the originally missing Fig. 3, which depicts all intersection probabilities for all configurations analyzed. These probabilities nearly cover the entire range from 0-100% probability. That the determined probabilities are controlled “primarily by lot density and aquifer hydraulic conductivity” is also shown by Fig. 3 (distinct non-linear dependence of p_T on K_h, large effect of lot size/lot density on p_T, medium effect of drainfield size). The smaller impact of the gravel pack conductivity on p_T is demonstrated in Fig. 4a. The comparatively marginal effect of the anisotropy ratio on variations in p_T is illustrated in Fig. 4.

RC: “i. Pg 5717: The authors have made statements made regarding the mass balance estimates being insufficient without adequate proof in the form of figures etc. Suggest adding a figure that states how QP/Qr ratio provides an incorrect estimate of the probability of risk.”

AC: We revised the statement to clarify our observation that the mass balance analysis holds only under specific conditions, namely when the well capture zone is of similar areal extent as the lot size.

RC: “j. Same comment holds true regarding the Qs/Qr estimation. Figures and more text are necessary to understand specifics. It is often unclear when the authors are switching between the mass balance estimations that they seem to be doing in the discussion section versus limitations of their probabilistic approach.”

AC: We clarified our discussion.

RC: “k. Pg 5717: line 20 reference missing.”

AC: The revised manuscript provides the reference.