Reply to comment on “Computing residence times for flow towards a pumping well: nomograph solution and validity of the small draw-down approximation”, Technical Note published in Hydrogeology Journal (2005) 13:889–894

Matthew J. Simpson

The comment in this journal on “Computing residence times for flow towards a pumping well: nomograph solution and validity of the small draw-down approximation”, discusses an analytical solution derived to calculate the travel time to a pumping well in an ideal horizontal unconfined aquifer under steady-state conditions. Chapuis and Chesnaux (2006) developed a simplified expression for the travel time. In this reply, it will be shown that the original (in Simpson et al. 2003; Simpson 2005) and simplified models give comparable results without ambiguity.

For the development of the original model (Simpson et al. 2003; Simpson 2005), the problem was posed so that the travel time was expressed as a function of the hydraulic head h, the radial coordinate r, the hydraulic conductivity K and the porosity θ. For the simplified model, Chapuis and Chesnaux developed the governing equation as a function of the steady-state pumping rate Q_w, hydraulic head h, the radial coordinate r and porosity θ. Either approach is valid; and, neither approach is more correct than the other.

In the hypothetical test case, the following parameters were chosen: r_w=0.1 m, r_r=10.0 m, h_w=3.5 m, h_r=4.0 m, K=50.0 m/day and θ=0.3 (Simpson et al. 2003). The corresponding steady-state pumping rate (see Eq. 1 in Simpson et al. 2003) is Q_w=128 m^3/day (to the nearest whole unit). The travel time according to the original model (Simpson et al. 2003) and the simplified model (Eq. 4 in the Chapuis and Chesnaux comment) is evaluated for these parameters and the results are given in Table 1, showing that both approaches give compatible results.

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M. J. Simpson (✉)
Department of Mathematics and Statistics,
University of Melbourne,
Melbourne, Victoria 3010, Australia
e-mail: m.simpson@ms.unimelb.edu.au
Tel.: +61-3-83446517
Fax: +61-3-83444599

Table 1 Evaluation of the travel time in an unconfined aquifer for conditions described in Simpson et al. (2003)

Radial coordinate r (m)	Hydraulic head h (m)	Travel time (days)	Simplified travel time (days)
2	3.833	0.111	0.112
5	3.929	0.713	0.720
10	4.000	2.909	2.929
15	4.041	6.615	6.654
20	4.070	11.845	11.911

The fluid flows from the radial coordinate r (column 1) to the well casing r_w=0.1 m. The hydraulic head at position r is h (column 2) for Q_w=127.91 m^3 /day. The travel time according to the original model (Simpson et al. 2003; Simpson 2005) is given in column 3 and results for the simplified expression (Eq. 4 in the Chapuis and Chesnaux comment) are given in column 4

Both the graphical method of evaluation (Simpson 2005) and the simplified model presented by Chapuis and Chesnaux are attractive to evaluate the travel time. Both of these alternative methods are simple to implement as they obviate the need to evaluate the imaginary error function.

Chapuis and Chesnaux make several minor comments of lesser significance. The concept diagrams in Simpson (2005) show that the datum is taken to be the horizontal plane at the base of the aquifer; therefore, the hydraulic head coincides with the saturated thickness of the aquifer. In this case, there is no difficulty in referring to the saturated thickness as the hydraulic head. Chapuis and Chesnaux also make a comment about using the symbol θ to represent the porosity of the porous medium and claim that this could be confused with the water content. This symbol causes no confusion in this context, since the analytical modelling does not involve variably saturated conditions. It was stated from the outset that the modelling is based on Dupuit-Forchheimer flow (Simpson et al. 2003; Simpson 2005) and as such is only relevant for fully saturated conditions. Finally, Chapuis and Chesnaux suggest it is counterintuitive to express the travel time t without direct reference to the steady-state pumping rate Q_w. This is simply a matter of personal choice since, as Chapuis and Chesnaux acknowledge, the expressions given in Simpson et al. (2003) and Simpson (2005) are implicit functions of Q_w. A similar but opposing

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argument could easily be made that it is preferable to express t as a function of K rather than Q_w. After all, the time taken for fluid to travel to the pumping well is related to the fluid velocity, which in turn is directly proportional to K. The argument over whether it is preferable to represent t as a function of Q_w or K is circular and it is probably more important to be aware that both are possible rather than to take the opinion that one option is better than the other.

References

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