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Comment on “Basin-scale geohydrologic drought flow features of riparian aquifers in the southern Great Plains”

by Wilfried Brutsaert and James P. Lopez

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1. Introduction

Low-streamflow hydrographs can reveal the hidden structure of a catchment groundwater system. Researching for such a knowledge, *Brutsaert and Lopez* [1998] performed recession slope analyses on drought hydrographs from 22 subbasins in central Oklahoma. They confronted their results with three well-known approximate solutions of the Boussinesq equation when these solutions can be expressed in the form of the following differential equation (their equation (3)):

$$\frac{dQ}{dt} = -aQ^b$$

The three solutions correspond to three particular values of the b exponent, namely, $b_1 = 1$, $b_2 = 3/2$, and $b_3 = 3$. However, experimental data show a large range of actual values of the b exponent from <1 to >4 . It is therefore interesting to try and find an expression that could encompass the three solutions and, in addition, offer a possibility to accommodate intermediate solutions as well as extrapolated ones.

2. Generalizing the Three Boussinesq Approximate Solutions

An attempt has been made to derive a general expression by just resorting to dimensional considerations. Notations are the same as those employed by *Brutsaert and Lopez* [1998]. The aquifer is sketched using the “open book” image. L is the length of the stream bisecting the subhorizontal aquifer whose semiwidth is B , depth is D , and hydraulic conductivity is k .

Referring to the downward vertical movement of the top of the groundwater body, a nondimensional discharge (q) could be expressed as

$$q = Q/2kBL$$

Along a similar line, a nondimensional time (T) could be expressed as

$$T = kt/fD$$

The energy slope (s), which stands for the driving force, is

$$s = D/B$$

Then the simplest relationship (i.e., without introducing an additional shape parameter such as L/B), similar to their equation (3), can be formulated as

$$dq/dT = \phi s^a q^b$$

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where ϕ , a , b are parameters. At this point, it is interesting to check whether the three approximate solutions of the Boussinesq equation could be written using the same formulation. Actually, this is possible as evidenced by the three following relationships that translate, using the new variables, their equations (3)–(6):

First approximation $dq/dT = -0.855s^2q$

Second approximation $dq/dT = -2.40sq^{3/2}$

Third approximation $dq/dT = -4.53s^{-2}q^3$

When one looks at the relationship between values taken by a and those taken by b , it can be seen that

$$a = 2(2 - b)$$

Therefore the relationship that can bring together the three approximate solutions is given as

$$dq/dT = -\phi(b)s^{2(2-b)}q^b$$

Reverting to the original variables yields

$$\frac{dQ}{dt} = -\phi(b) \frac{k}{fD} \left(\frac{D}{B} \right)^{2(2-b)} (2kBL)^{1-b} Q^b$$

A possible curve fitting for $\phi(b)$ could be

$$\phi(b) = \frac{b^4}{1.2 + 4.2(1 - b)^2}$$

but this last expression is too flimsy to retain attention. It is not sure that the approximate constants a_1 , a_2 , a_3 are to be considered as derived in a homogeneous manner and, consequently, to be reproduced accurately. It is likely more reasonable to assume a simple relationship such as

$$\phi(b) = 2.5^{(b-1)}$$

which will be used thereafter.

3. Comments on the Experimental Data

A schematic of Figure 2 (top) of *Brutsaert and Lopez* could be drawn as on Figure 1. According to the interpretation of b decreasing with time, points on the graph can be joined to form trajectories starting from the right side, with a slope equal to 3 and progressively lowering the slope toward a value close to 1. However, this limiting slope is not evident on most graphs and seems to be in contradiction with the lower boundary which corresponds to a value of b close to 0.63, clearly smaller than 1.

In the upper part of the graph, the cluster of points could be viewed as generated by straight lines with varying slopes, originating from the top right vertex. If so, and using notations

Figure 1. Schematic corresponding to Figure 2 (top) of *Brutsaert and Lopez* [1998] Points of which are circumscribed by the above three lines with approximate slopes.

explained on the schematic, it could be stated that the following relationship would hold:

$$\frac{dQ}{dt} = -\frac{Q_*}{t_*} \left(\frac{Q}{Q_*} \right)^b$$

When comparing that relationship with the generalized Boussinesq approximation, it could be deduced, by identifying

terms that are under the b exponent and those that are not, that

$$Q_* = 0.8kDL \frac{D}{B}$$

and

$$t_* = \frac{fB}{k} \frac{B}{D}$$

These two parameters, Q_* and t_* , could be used to derive k and f , the hydraulic conductivity and the drainable porosity, respectively. This could be used to bear out scale dependencies studied by *Brutsaert and Lopez* [1998].

Reference

Brutsaert, W., and J. P. Lopez, Basin-scale geohydrologic drought flow features of riparian aquifers in the southern Great Plains, *Water Resour. Res.*, 34(2), 233–240, 1998.

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