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Hydrology and Earth System Sciences Discussions

Interactive comment on "Nonlinear estimation of aquifer parameters from surficial resistivity measurements" *by* K. P. Singh

Anonymous Referee #1

Received and published: 25 June 2005

This manuscript examines the correlation between hydraulic conductivity and electrical conductivity in a series of aquifers. The conclusions of the paper is that there is an exponential relationship between hydraulic and electrical conductivity, at least for certain sites in certain materials. This reviewer believes that the article needs significant revision to be accessible to the readership of HESS. The author needs to highlight 1) why readers should believe that there should be a relationship between electrical and hydraulic conductivity at any particular field site, 2) how these studies might be of use to other scientists working in other field locations, and 3) his/her contributions to the scientific community in this work. While it seems to this reviewer that there are some interesting results in this paper, there is little discussion of those results. The results are interesting, but they require significant discussion to produce a stand-alone manuscript. This paper additionally requires significant editing to improve its English, and contains numerous spelling errors. I cannot, at this stage, recommend this paper

for publication. My comments are divided between those general and specific in nature (below):

1) Does the paper address relevant scientific questions within the scope of HESS? While the issue of whether hydraulic and electrical conductivity are related is an interesting one, this reviewer doesn't believe that there is or should be a universal relationship between hydraulic and electrical conductivity, and isn't sure what the goal of this paper is (to show that there is an exponential relationship? If so, why?). While hydraulic conductivity and electrical conductivity are related through their common dependence on tortuosity, surface area, and porosity, they are not analogous; electrical conductivity is also a function of rock conductivity, ion mobility, temperature, pressure, charge of the surface area, and the conductivity of the double layer surrounding the grains. Additionally, how does one deal with aquifer heterogeneity and the averaging and scale of the geophysical measurements? How does the spatial variability in the measurement physics affect these results? Why would anyone expect hydraulic and electrical conductivities to be directly (or indirectly) related at any field site? The author certainly needs to address this more fully in their paper.

2) Does the paper present novel concepts, ideas, tools, or data? No. The issue of whether hydraulic and electrical conductivity are related was frequently studied in the late 70s and early 80s, and it seems to this reviewer that this paper does not make any significant contributions beyond those in the Kelly-Kosinski papers (and the ensuing written discussion) in Ground Water in 1979-1980. The author should frame this work in the context of these older works, and better highlight to the audience was his/her contribution is.

3) Are substantial conclusions reached? No. The conclusion of the paper is that there is an exponential relationship between hydraulic and electrical conductivity, but there is no discussion of why this should be or how this is applicable or interesting outside of the limited datasets the author chose to examine.

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4) Are the scientific methods and assumptions valid and clearly outlined? Yes. However, the authors should consider the fact that the mathematics between so-called "direct-current resistivity" methods and fluid flow aren't entirely analogous. The equations for fluid and electrical flow are analogous only for the steady-state case. Direct current resistivity in the field is actually low frequency alternating current, resulting in transient electrical flow. Transient electrical flow creates magnetic fields. In a steady-state circuit, the values of voltage, current, and resistance are fixed, whereas the values of current and voltage vary with time in dynamic circuits. In addition to resistive elements, dynamic circuits contain elements of capacitance and inductance, which vary with changes in voltage. If the input to a circuit is constant, as in a dc signal, the value of capacitance and inductance is zero. If the input signal varies with time, the signal is distorted by capacitance and inductance, and Ohm's Law no longer applies. So they aren't entirely analogous without some assumptions.

5) Are the results sufficient to support the interpretations and conclusions? The interpretations and conclusions need to be significantly expanded. The conclusion that an exponential relation between hydraulic and electrical conductivity seems justified by the author's results, but more discussion of why this would be is warranted.

6) Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? Yes.

7) Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Yes and No. The authors give proper credit, but do not indicate their contribution.

8) Does the title clearly reflect the contents of the paper? The title is misleading. There is no mention of resistivity methods. "Nonlinear estimation" may make some readers think of automated inverse problems given hydraulic head data or something similar. Instead, perhaps, the author should consider something that indicates what he/she did: fitting relations between hydraulic and electrical conductivity.

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9) Does the abstract provide a concise and complete summary? The abstract could use significant tightening up. What was accomplished, and why is it important?

10) Is the overall presentation well structured and clear? No. This paper requires significant revision and editing to be more accessible to the readership of HESS.

11) Is the language fluent and precise? No.

12) Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? Yes, although equations 3 through 8 appear to add nothing to the paper.

13) Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? This reviewer believes that this paper needs to be rethought, considering: 1) what are the goals of this project? 2) What did we accomplish that has not been published before? 3) How is this work useful to the greater scientific community?

14) Are the number and quality of references appropriate? The references are generally very old, but this may be because this problem is largely not considered these days.

15) Is the amount and quality of supplementary material appropriate? Not applicable.

Specific comments:

p.918, line 10. Define “sandwiched” aquifer. p.918, line 13. “Data” is plural. Throughout paper: “Fracture rock” should be replaced with “fractured rock” in all locations.

p.919, line 16. “Recently, attempts have been madeĚ” I would argue that this work is not very recent.

p.920, line 3. Define “hidden” aquifer. p.920, line 10. Define “AB”. p.920, lines 20-21. The analogy is widely accepted, but that they should be correlated in any way is not.

p.921. Equations 3 through 8 do not appear to contribute anything to the paper. p.921,

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line 15. “larger connected pores make for better flow characteristics”. Why should there be a relationship between electrical and hydraulic parameters because of this? Clay is not very hydraulically conductive in saturated media, yet remains electrically conductive.

p.922, line 3. “directly linear relationsĚdo not exist” This is exactly the point! But explain why non-linear relationships can account for heterogeneity, and why there should be a relationship between the two properties? p.922, line 19. “rms error $<$ 5%”. Fragmented sentence. RMS is defined on line 26, so remove it here, or define it. p.922, line 27. Is this resistivity inversion in 1-D or 2-D?

Figure 4. The caption needs to be reconsidered. What “important places”? Figure 5. How was this image created?

Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 917, 2005.