Hydrol. Earth Syst. Sci. Discuss.,
doi:10.5194/hess-2016-559-RC2, 2017

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Electrical Resistivity Dynamics beneath a Fractured Sedimentary Bedrock Riverbed in Response to Temperature and Groundwater/Surface Water Exchange" *by* Colby Steelman et al.

Anonymous Referee #2

Received and published: 25 January 2017

This manuscript is on the topic of geophysical and traditional measurements of a reach of river to investigate the suitability for time lapse ERT to study river bottom processes. The writing is in clear, good English, and the figures are mostly very readable and nicely drafted. The topic – either from the Hydrology or Geophysics perspective – certainly has the potential to be of interest to HESS readership. I believe the topic of this work fits into the scope of this journal. The most significant limitation I see to this work is related to the experimental design, which is largely absent from the writing. In short, it is difficult to tell what was being tested about the hydrology, and why measurements were implemented to carry out that test. The stated hypothesis is apparently related to "will

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the geophysics work," while the theme of riverbed processes appears and disappears throughout the manuscript. In the end, I remained confused about exactly what the reader was meant to take away from this given the setup of the writing and the design of the study. There is certainly lots of good data here and on some level this has the potential to be of high interest to the hydrology community, but there is a need for substantial revision for focus. There were several other notable issues/limitations related to measurement methods, data processing, and absence of some measurements that are detailed in my General and Line-by-line comments below. At this time I am recommending this manuscript be returned for major revision, however if the experimental design is not substantially clarified and the focus reworked to highlight hydrological interpretations, a second review would likely not result in a favorable recommendation.

General Comments:

There is a substantial disconnect between the topic of the science question and the posed hypotheses. Although the science question is not explicitly stated, it is my best interpretation that the following reflects the intent of inquiry: "...there remain gaps in our conceptual understanding of groundwater-surface water interaction and exchange mechanisms in bedrock rivers where discrete fracture networks will dominate groundwater-surface water flux with secondary interactions supported by the porous rock matrix." On the other hand, the hypothesis is explicitly stated, although it appears to be limited to a yes-or-no "will it work" type of speculation: "we hypothesize that a groundwater-surface water mixing zone – encompassing fracture and matrix flow and diffusion – may be identified within a fractured bedrock riverbed by monitoring spatiotemporal changes groundwater temperature and porewater electrical conductivity using minimally invasive electrical resistivity methods." Further complicating matters is the text between Line 69 and 76 that highlight the hydrological outcomes while disregarding the stated hypothesis.

Throughout the manuscript, speculative statements about river ice, river-bottom ice and frost are made, though they do not appear to be supported by any direct measure-

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ments or observations.

Estimates of loss along reaches based on calculations of discharge using rating curves in conjunction with stage height monitoring appear to be absent. This line of evidence would substantially help to support geophysical observations.

I felt that the following questions posed early on in the manuscript were not clearly answered: Do you find that groundwater-surface water interaction was restricted by poor vertical connectivity and limited âĂĺbedrock incision? Did you find that groundwater-surface water connectivity through discrete fractures was highly variable in space and time, and depended on fracture size or aperture, river stage, and the âĂĺdistribution of hydraulic head within the flow system?

There is a huge amount of data contained in this manuscript, however in some cases data was left unused in interpretations and discussion. For example, precipitation & snowfall, daily river stage, fracture content as a function of depth, atmospheric temperature, etc. Why include these data if they are not utilized?

In the end, if the hypothesis was to test “will ERT work for this” I think that was not clearly answered, and furthermore, given the high dependence on temperature, it may be that that answer is “no.”

Line-by-line Comments:

Line 55: Perhaps add a comment on what Fan et al., 2007 found here?

Line 63: There is a lot going on in the figure and it is weakly linked to the text. Are you testing these concepts?

Line 92: The Singha paper has 2014 printed on top of it, but I’m not sure which date is correct.

Line 175 – 180: Was the formation of basal ice actually observed at the site or only inferred?

Line 213 – 216: I am unfamiliar with this method of sampling temperature while the sensor is in motion. Certainly the sensor itself, however small it might be, has some thermal mass that requires time to equilibrate to the surrounding water temperature. Even though the sensor is capable of measuring at 0.5 s rate, that does not mean that the measured data are reflecting changes in the formation at that rate. A reliable reference should be included here to justify the method, and a controlled validation test and sensor calibration under laboratory conditions should be conducted to quantify sensor response.

Line 219: What is the value of measuring snowfall accumulation if snow density is not also reported with a conversion to SWE?

Line 221/Figure 4: What scale are the red dot "Resistivity Samples" on? They appear to be only temporal and unitless, however they seem to track the river stage which is confusing. Is 'snowfall" in this figure converted to SWE? If not, please do and clarify the label.

Line 228: "effective sensing depth" does this mean measurements are reflective of the 6m depth zone, or the entire aggregated zone 0 to 6m depth?

Line 237: "BLANKED by bedrock rubble" I am not familiar with this usage of "blanked" in this context. Suggest rewording for clarity.

Line 239 – 244: Does the electrode construction method have any particular importance to this study? This sounds like very typical ERT cable construction, albeit by the end-user rather then a professional fabricator. Probably could be deleted.

Line 261: How was the measurement time determined? It is known that diurnal fluctuations in stream water temperature may be of magnitude in excess of 10C, similar to your annual range of groundwater temperatures. Also you acknowledge the affect of temperature on the ERT readings; how does the timing of the measurements affect the data due to daily fluctuations?

Constantz, Jim, Carole L. Thomas, and Gary Zellweger. "Influence of diurnal variations in stream temperature on streamflow loss and groundwater recharge." Water resources research 30.12 (1994): 3253-3264.

Constantz, Jim. "Interaction between stream temperature, streamflow, and groundwater exchanges in alpine streams." Water resources research 34.7 (1998): 1609-1615.

Line 262: “manually filtered” What criteria was used for manually filtering? Why was this approach used rather than the common quantitative method of envelope filtering based on an error model?

Slater, Lee, et al. "Cross-hole electrical imaging of a controlled saline tracer injection." Journal of applied geophysics 44.2 (2000): 85-102.

Line 264: “moderate to high damping” – Does this mean different damping factors were used on each dataset? What is the numerical value of damping used and how is this value incorporated into your inversion scheme?

Line 267: What parameters, how were they optimized, and were identical settings used for all datasets?

Line 268 – 269: Certainly achieving the lowest possible RMS is not the optimal approach to achieve the most “believable” geophysical result. How does the RMS relate to observed measurement noise/errors? At what point is the inversion fitting noise?

Line 280: Is there a reference for this Resistivity Index? What is the justification for manipulating the data in this way?

Line 293 – 294: Where is the data demonstrating upward head shown?

Line 307/Figure 6b: It would be helpful to grade the colors of the lines linearly to more easily show the temperature trend. Even better would be to present these data as a matrix/grid where time is on the x-axis, depth is on the y-axis, and color represents temperature.

Line 308: “correspond to areas” I cannot tell from the figure how the fracture patterns correspond to the temperature results. Perhaps some annotation, or another approach to presenting these data would help.

Line 321 – 331: [Figure 8] This seems more like a discussion point rather than a result.

Line 356 – 358: “greater number of measurements. . .” why would the number of removed data cause higher RMS? Presumably if the data were removed, they would no longer be included in the RMS calculation.

Line 374: What are the observed thicknesses of basal ice and floating ice?

Line 415-416: “groundwater discharge in this section” I don’t follow the logic why the relationship between substrate resistivity and “surface water response” indicates magnitude of discharge that could be interpreted in this way. Also, correlation is not demonstrated or quantified.

Line 432: “strong upward hydraulic gradients” please indicate where this is demonstrated by data.

Line 436: “likely dominated the bulk electrical response” Why ‘likely’? Based on the evidence shown, temp is clearly dominating the ERT signal.

Line 445: Where is ground frost or riverbed ice formation measured data shown?

Line 459 – 473: As previously stated, data showing the frost and ice should be shown.

474: I’m not sure what evidence directly supports this statement. The provided sensitivity analysis appears to only vary the river water electrical properties; this doesn’t seem to directly simulate the presence of ice as claimed in this statement.

479 – 480: Quantify this? Why would inputting a one-half of true river water resistivity lead to “substantial overestimates of river resistivity” – wouldn’t the river water resistivity be fixed so that the output = the input?

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486: What about a synthetic model example?

510: How does geoelectrical transience translate into hydrological processes?

Line 511 – 452: The conclusions section contains substantial summary and could be reworked for improved focus.

Figure 5: The purpose of this figure is unclear and I suggest that it could be deleted. The A/B/C/D locations are already indicated on Figure 12; the river stage information is presented on Figure 4; the location of the model block midpoints does not appear to be substantially important to the manuscript.

Figure 9: Perhaps showing only the difference between these two maps would make interpretation easier? If not only difference, then perhaps just adding a third difference panel. Also, isocontour labels are too small to read.

Figure 10: What is the model error relative to the measurement errors? What is the purpose of showing these vast bulk averages when that eliminates any of the valuable spatial information yielded by using tomographic methods? Figure 12 seems to be much more useful than this.

Figure 11: Very nice layout and presentation of this figure, however certainly this needs to be replotted to show the difference between (b) through (h) relative to (a) in both columns.

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