

**Author Response to Reviewer #1:  
Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-559, 2016.**

First and foremost, we would like to thank the reviewer for donating their time to review our manuscript and for providing a fair and constructive review of our work. These comments and suggestions will undoubtedly improve the impact and utility of our paper.

**Reviewer 1: General Comments**

The study deals with fractured sedimentary bedrock riverbeds and its spatio-temporal groundwater surface water exchange of the Eramosa River within the Grand River Watershed, Ontario, Canada. Surface electrical methods (ERT and EMI) were used for a quasi non-invasive assessment of the scale and temporal variability of riverbed temperature and groundwater surface water exchange beneath its sedimentary bedrock riverbed. Underpinned were the solid geophysical data sets by a network of boreholes and streambed piezometers, installed across the site. The study further contained highly relevant material for HESS, is well written, structured and cited and attested the authors' fundamental background and experiences with the selected topic. Fractured sedimentary bedrock systems and its interaction processes are very complex and difficult to describe. Hence the presented study provided a useful approach for cost-efficient investigation into the river flow regime. Still there are a few issues that needs to be addressed until the manuscript is ready for publication. Although the study impressed be the amount of high quality data and different applied methods, it lacks a little of a clear and comprehensive purpose.

**Response:** We appreciate the reviewer's encouraging assessment of our work, and agree that there are areas that will require clarification and improvement prior to publication. We acknowledge that the motivation for this work was not clearly defined in the introduction. We can definitely improve the introduction by clearly stating the problem, followed by objectives and main contributions of this work.

Studies of interaction flow processes at rivers are relatively common since about one decade; however, the presented geophysical investigation of bedrock rivers combined with ground truths core data is unique. Moreover, the economic and ecological potential of global bedrock rivers are remarkable, hence the study can be considered as a pioneer study with portable conclusions. This seems the strengths of this study, however it needs to be emphasized.

**Response:** We believe the introduction can be strengthened by highlighting these points raised by the reviewer.

It would be helpful if the authors establish somehow a relation between their investigations and findings, and a direct affected related system, such as a water supply or ecosystem services. If not available for the selected test site then relevant literature can be used. In this respect the manuscript might be slightly rearranged. Introduction should contain a clear state of the art containing the situation, the problem, the challenge and the provided response (solution).

**Response:** We can improve the problem statement through more explicit discussion of regional implications of groundwater surface water interaction within the context of bedrock aquifers. Although a direct comparison with the regional hydrogeologic system will be beyond the scope of this paper, we can definitely improve the context of this work through a more thoughtful assessment of the local groundwater problems. We can also make substantial improvements to the last three paragraphs of the introduction by clearly stating the problem, the challenges/conceptual limitations, and what our paper contributes.

Although I like the extra paragraph 2 'background', it's quite uncommon and could be incorporated into the introduction and the material and method part, respectfully. It is always helpful to read what other studies have archived at similar test sites and / or with similar approaches and where they were limited. This should be highlighted in the introduction and in the conclusion (and in the abstract too).

Response: We agree that some of the geophysical background information on rivers could be integrated into the introduction. Similarly some of the electrical properties discussion should be placed in the methods section. At this point we can definitely agree to consider some reorganization of text as suggested by the reviewer.

The conclusion should hence contain the extracted information given by the findings as kind of a 'take home message' for the scientific community rather than a second abstract. I recommend acceptance with minor revision.

Response: We agree with the reviewer. We believe a reorganization and enhancement of the introductory text (i.e., current state of the science, more definitive problem statements, and the specific contributions to our work to the advancement of the conceptual model) will set the stage for a more appropriately written conclusion section.

### **Specific Comments:**

Line 94 – 96: amount of references can be decreased by a related review

Response: There are only reference 10 studies, which isn't exhaustive considering the broad topic.

Line 126: please mention that the presented Archie's law is simplified are provide the whole equation

Response: We will make the necessary revisions.

Line 144: just mentioned the temperature correction was done by Arps (1953) might be sufficient

Response: Since the equation was used with our results (Figure 8) we think it might be best to keep the equation. We will consider moving this "background" material to the methods section.

Line 224: indicate the approx. location of the EMI lines in Figure 2

Response: We generally agree with the reviewer but the result is visually distracting in a paper. We do state in the text the orientation and spacing of the EMI survey lines and we think this is sufficient.

Line 270: use 'Fig' or Figure either but consisted

Response: We believe the full form of the word is used at the start of a sentence. We will ensure the final document is properly formatted.

Line 291: matrix porosities from the corehole relatively low in respect to? A short reference value for the same rock material from the literature is useful or do you mean in comparison to the weathered or broken rubble zone? If so, please mention it

Response: We can remove our qualitative referencing to avoid potential confusion/distraction. Porosities in these sedimentary particular rocks can range from <1 to >15% (i.e., matrix porosities). Inclusion of fractures and dissolution features can result in even greater and more variable porosities. We believe our description is accurate and appropriate in this section.

Line 321: see above

Response: see above.

Line 328: it is hard to follow here or maybe I missed the point how you ended up with the 46%, according to Archie in Eq.1? How do you get the Sigma w values or am I totally off? If you re-arrange the equation it needs to be mentioned if not showed

Response: The percent fluctuation represents the potential influence of temperature based on the observed ranges in groundwater and surface water. The temperature data is shown in Figure 7. Aqueous resistivity in Eqn. 1 is calculated using Arps law (Eqn 2). So the plot in Figure 8 simply shows the potential range in formation resistivity for the observed groundwater temperatures within the river bed. The % change stated in the text is the variability that is plotted (i.e., between isotherms 4-14 °C and 0-18°C) in Figure 8. We can adjust the phrasing in this section to improve clarity.

Line 332 – 349: how could you be sure that the EMI data were not affected by outside conditions, do you temperature corrected the ECa as well?

Response: Assuming the reviewer is referring to atmospheric temperature effects on the instruments performance, we do not believe, nor does the manufacturer report that ECa measurement accuracy of the EM-31 (+/- 5% at 20 mS/m) would have any meaningful effect on the reading. The ECa measurements we report in Figure 9 are, of course, sensitive to the temperature of the media as indicated by Eqn 2 and illustrated in Figure 8. ECa variations in the rock are expected to be associated with either temperature fluctuation or specific conductance of the fluid. Temperature fluctuations within the rock will indicate a zone of influence or transience. This could be due to differences in seasonal groundwater-surface temperature or mixing or changes in groundwater chemistry. The data we present identifies measurable changes in the geoelectrical conditions beneath the riverbed, whether it's temperature or EC based or some combination of the two; regardless, the spatial extent of these dynamics support the existence of a mixing zone or simply a zone of thermal variability in the rock unique to the river flow system.

Line 420: I prefer including of the discussion together with the presentation of the results. This helps to shorten the manuscript which is almost every time helpful

Response: We appreciate the reviewer's preference here. But considering the nature of the discussion in this paper we felt it best to separate it from the results to avoid potential confusion (i.e., geophysical results vs. hydrogeophysical interpretation).

Line 857: since you presented the ERT results in Figure 11 by common scale, Figure 10 is kind redundant, mention in the text that the ERT data quality (RMSE, removed data points) were higher under frozen, partly frozen conditions

Response: While we understand the reviewer's comment, we believe the information presented in Fig. 10 is highly informative. The study does contain an immense amount of information, which cannot be presented or summarized in its entirety, but the seasonal trends need to be presented in some way. The unique field conditions resulted in many challenges in data processing and interpretation. To our

knowledge, there has been no similar study performed in a river in this type of environment, let alone a bedrock rock river.

One of the unique contributions of our study is the results associated with the seasonal freeze-up and thaw of the river. This period presented many challenges, with respect to data collection, data analysis and interpretation. Yet, to ensure that this was not overlooked we wanted to provide a reasonable overview of the data trends and the impacts of varying site conditions on the measurement and analysis of data. Therefore, Figure 10 provides a critical overview of the modeled data partially shown in Figure 11 and Figure 12. This includes the data points removed from the models due to site conditions, resulting in the variable RMS errors. The Figure also provides an overview of the trends in each model (median, min, max) over the annual cycle at each location along the river. This figure also serves as a temporal reference for the models presented in Figure 11, which we believe is very important. Figure 10 also shows the seasonal limitations of the ERT method, which we believe is a significant contribution to the methodology. Therefore, we remain supportive the information summarized in Figure 10.