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Hydrology and Earth System Sciences
Discussions

Interactive comment on "A review of methods for measuring groundwater–surface water exchange in braided rivers" *by* Katie Coluccio and Leanne Kaye Morgan

Anonymous Referee #1

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The manuscript "A review of methods for measuring groundwater-surface water exchange in braided rivers" by Katie Coluccio and Leanne Kaye Morgan is a review paper. As the title suggests it is about measuring methods for groundwater-surface water exchange in braided rivers. In general, the manuscript is informative, provides an overview about the current literature, is well structured and well written. However, some sections are lengthy and might be shortened. Furthermore, as indicated in the major comments below important information, definitions, etc. is missing. In general, the authors could think a little bit more out of the box. They are very focused on the methods that have already been used in studies of groundwater-surface water interactions in braided rivers. But there are several similar groundwater-surface water

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interfaces and as part of a scientific review paper I would expect the authors to consider additional methods that might be adapted to braided rivers in future in addition to simply summarizing the literature available at present. I think the manuscript can be published after revision.

MAJOR COMMENTS:

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Entire manuscript: Try to shorten your manuscript and avoid lengthy descriptions of the literature, e.g. L173-L213, L216-242, L289-325, L328-L379, L382-402, L533-603, L606-L640, L667-L739.

L60 & entire manuscript: Suggest also methods that have been successfully used at other groundwater-surface water interfaces and that might be adapted to braided rivers and might be used in braided rivers in future. Reporting only what has already been done in braided rivers is a little bit thin.

L64 & Fig. 1 & L882: I strongly recommend adding all additional instances of braided rivers outside of the major regions. You might use different symbols for major regions with braided rivers and single instances.

L100f; L791f, L855: I think there is a need for clear definitions of "groundwater-surface water interactions" and of "hyporheic exchange". Often, the term "groundwater-surface water interaction" is used in literature in a wide sense including hyporheic exchange as one process of groundwater-surface water interactions. However, according to line 100f you consider both as separate processes with some impacts on each other.

L134ff: Even though I agree that there is little research about groundwater-surface water interactions in braided rivers your "Web of Science" search is meaningless. I tried to reproduce it. First of all "groundwater and surface water interactions" with ". . ." results in much smaller numbers than the ones reported by you, e.g. only three papers for lakes instead of 437 reported by you. Repeating the search without ". . ." resulted in approx-

imately the numbers reported by you. However, having a closer look at those papers revealed that most of the hits are not about groundwater-surface water interactions at all but that the separate words of the phrase are used in separate sentences and in different context. Furthermore, at many of the interfaces mentioned by you (lakes, ocean, stream) specific terms are used, e.g. “lacustrine groundwater discharge”, “submarine groundwater discharge” and “hyporheic zone” instead of “groundwater and surface water interactions”. Sometimes the word “interactions” is substituted by “exchange” or by “interfaces”. Also, there are different spellings for “groundwater” such as “ground water”. I am quite sure that the largest number of studies focusing on groundwater-surface water interactions is about stream, followed by (coastal) oceans followed by lakes and finally by braided rivers. You might also have a look at review papers focusing on the different interfaces. There are several of them. I recommend either deleting lines 134-139 or repeating this literature search with a set of different keywords to get a more comprehensive overview of the literature of interest.

L158ff: From my experience budgets are often quite error-prone because accurate measurements of river discharge are challenging. Often changes in river discharge between stations are much smaller than the error inherent to the measurements. You should mention this shortcoming more clearly than only in lines 261-263.

L272ff/L284ff: I think it is important to introduce here also the concept that tracers need to be conservative (on the scale of the investigation). In this context, I doubt that dissolved oxygen (L284), nitrate (L285), sulphate (L286) and pH (L404) are useful tracers. pH might be acceptable in the context of alkanity but that also needs more discussion. The concentrations of oxygen, nitrate, sulfate and H+ will be altered due to many different biogeochemical processes. They might be used under certain circumstances and on small scales on which little turnover takes place. But this is something very critical. If you list these compounds you need to discuss them critically.

L272ff: In addition to environmental tracers I recommend to discuss also artificial tracers that might be added to the system. There are multiple studies using artificial tracers

and I am quite sure that the also have been used in braided rivers. However, even if not they are an option that should be considered.

L457-468: I don't see any connection of this paragraph to the topic groundwater-surface water interactions. Therefore, I recommend deleting this paragraph.

L469-484: The topic of the present review is measurement methods for groundwater-surface water interactions. Thus, these two paragraphs don't fit to the topic of the review paper. They are about impacts of groundwater and surface water on temperature (and ecological consequences) but not how to use measurements to identify groundwater-surface water interactions.

L502ff: I think it is important to measure temperature depth profiles as you do in this paragraph. However, you should go into a little bit more detail here and also mention typical evaluation methods for temperature depth profiles such as the steady state approach (e.g. C. Schmidt, M. Bayer-Raich, and M. Schirmer. Characterization of spatial heterogeneity of groundwater-stream water interactions using multiple depth streambed temperature measurements at the reach scale. Hydrology and Earth System Sciences 10:849-859, 2006) or VFLUX.

L443ff: I think at one point in this subchapter you should clearly differentiate between methods that are used to determine fluxes (e.g. temperature depth profiles) and methods for pattern identification (aerial TIR, fo-DTS). This applies also to lines 513-515. TIR is a method for pattern identification. However, you need to describe this already before and not only in Advantages and Limitations. See also comment regarding this topic below.

L443ff: Furthermore, you should briefly mention typical approaches to measure temperature and in this paragraph you should also include fibre-optic distributed temperature sensing even if it has not been used in braided rivers yet.

L443ff: You could also consider adding temperature methods that don't rely on natural

temperature differences but use temperature as an active tracer, e.g. active (heated) DTS, heat-pulse sensors etc.

L524: “Hydraulic property measurements” is no suitable chapter headline for the sub-chapter “Groundwater observation wells”! Alternatives might be “2.4 Flow-net analysis” or “2.4 Darcy approach”. I would call 2.4.1 “Hydraulic gradients” and 2.4.2 “Hydraulic conductivity”.

L525ff: The second sentence of the paragraph is wrong: The groundwater level/hydraulic gradient is no hydraulic property. Hydraulic properties are the hydraulic conductivity, the porosity etc. The rest of the paragraph belongs to 2.4.2.

L559ff: You use the terms well, piezometer and mini-piezometer but I have not seen a definition of those terms. Consider to include also other designs, e.g. M. O. Rivett, R. Ellis, R. B. Greswell, R. S. Ward, R. S. Roche, M. G. Cleverly, C. Walker, D. Conran, P. J. Fitzgerald, T. Willcox, and J. Dowle. Cost-effective mini drive-point piezometers and multilevel samplers for monitoring the hyporheic zone. Quarterly Journal of Engineering Geology and Hydrogeology 41:49-60, 2008. However, in this paragraph with its focus on groundwater level measurements either sufficient diameter for a logger or an electric contact gauge is useful even though some scientists used innovative approaches for very small diameters (transparent tubes, suction to increase water level differences to an easily visible height, colored strings ...) Also, you should consider describing at least in brief typical installation techniques for the different designs and different depth depending on substrate quality. Furthermore, report at least in one sentence how water tables are measured/logged.

L605ff: Consider to add also in brief the use of geophysics to characterize the subsurface pattern (together with some core for calibration of geophysical methods).

L642ff: Mention that loggers require a certain diameter of wells/piezometers as a further disadvantage.

Table 1: You have split the first method (water budget) into two budget methods. Why haven't you also split the following methods as in the text (e.g. environmental tracers, heat tracers, ...). In fact heat tracers are also an environmental tracer. Why are River reach budgets suitable only for relatively homogenous aquifers? Remove pH and DO from environmental tracers (see corresponding comments above). As far as I understand the table and its table capitations it is about methods for quantifying water fluxes. The point "Aerial surveys can be faster than in-stream surveys" does not fit. This is a method for pattern identification and not for flux determination. As described above I doubt that "Hydraulic Property Measurement" is an adequate headline for this type of method. I don't think that this applies only to minipiezometers. Piezometers are also easy and quick to install.

In general other authors have grouped their methods into three categories and I think this would be advantageous here as well:

+ point methods to estimate fluxes at a discrete location

+ methods for pattern identification don't yield numbers for fluxes but can help to identify representative sites and the most extreme sites to conduct the point methods at the most interesting sites. Under certain circumstances also transfer functions possible that combine methods for pattern identification and point methods

+ integrating methods over large areas that result in total fluxes, but without any information about local fluxes or distribution of patterns

L783ff: Please keep the three points above in mind. Remote sensing is not gathering the same information as the point methods mentioned in L781-783! The same applies to Line 870-872.

L797f: Please mention here also that time series that might be recorded with loggers can be very useful to gain system understanding because groundwater-surface water interactions might vary with time and even the flow direction might reverse over time.

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L849: It is definitely strange to have a subchapter 3.1 but no 3.2. Also, it is confusing that the introduction before 3.1 is about 5 pages long and 3.1 less than 1 page long.

MINOR COMMENTS:

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L48: Cite also Winter et al. (1998) (https://pubs.usgs.gov/circ/circ1139/)

L57: .

L102f: Why is improved knowledge of historial patterns needed? In addition, can you please cite a reference.

L118: A more scientific reference would be great here.

L147: Consider adding Rosenberry et al. (2015) (https://onlinelibrary.wiley.com/doi/full/10.1002/hyp.10403)

L279: I think what is much more important than evenly distributed groundwater discharge or recharge is an even groundwater concentration.

L289ff: Please correct: there are three stable oxygen isotopes including O-17!

L291f: "The process is largely driven by temperature, whereby . . . at higher elevation due to colder temperatures" The process is not driven by elevation but the elevation effect is a result of decreasing temperatures with increasing depth. In case you really want to mention processes in addition to temperature you can add humidity and salinity as further processes.

L519: I think the most important point that should be measured here is season!

L560: Only deep wells/piezometers are expensive.

L565: Isn't this also a conceptual diagram of a well?

L656: You might want to mention that it is nearly impossible to take undisturbed

cores/rings for KSat analysis if the sediment contains coarse gravel as this is the case in most braided streams. L674: “interactions” instead of “interaction”

L687: Delete: “and will not be repeated here.”

L704: “They used” instead of “The used”

L754: You are not investigating groundwater and surface water but their interactions: “. . . for investigaton of groundwater-surface water interactions, and there . . .”

L764: “a study” instead of “the study”

L808: “by the study objective and the study object”

L820: Only during storms???

L851: “One of the most . . .” – I do not understand this sentence.

L854: Consider adding here S. Krause, D. M. Hannah, J. H. Fleckenstein, C. M. Heppell, D. Kaeser, R. Pickup, G. Pinay, A. L. Robertson, and P. J. Wood. Interdisciplinary perspectives on processes in the hyporheic zone. Ecohydrology 4 (4):481-499, 2011.

L869: the present paper

L895: You might add here DTS and geophysics

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