<u>Reply to Reviewer # 1</u>

General Comments

1. 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.

<u>Response:</u> We thank the reviewer for these positive comments.

2. However, some sections are lengthy and might be shortened.

<u>Response:</u> We will shorten the revised manuscript, as discussed below.

3. Furthermore, as indicated in the major comments below important information, definitions etc. is missing.

<u>Response:</u> We thank the review for pointing out these omissions. As detailed below, we will address this in the revised manuscript.

4. In general the authors could think a little bit more outside of the box. They are very focused on the methods that have been used in studies of groundwater-surface water interactions in braided rivers. But there are several similar groundwater-surface water interfaces and as part of a scientific paper I would expect the authors to consider additional methods that might be adapted to braided rivers in future in addition to simply summarising the literature available at present.

<u>Response:</u> As detailed below, in the revised manuscript we will discuss additional methods that have not yet been applied in braided rivers but show potential such as fibre-optic temperature sensing, active heat pulse methods, artificial tracers, remote collection of data via satellite imaging, and geophysical techniques.

5. I think the manuscript can be published after revision.

<u>Response</u>: Thank you.

<u>Major comments</u>

6. 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.

<u>Response:</u> We agree that the manuscript would benefit from more concise descriptions of the literature. We will adjust this in the revised draft.

7. 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.

<u>Response:</u> Thank you for the suggestion. In the revised manuscript we will add a discussion of techniques used in other environments that might be useful in braided rivers, including geophysical methods, additional temperature methods (DTS, active heat pulse methods), more remote sensing techniques (satellite imagery), and artificial tracers.

8. 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.

<u>Response:</u> When initially creating Fig. 1, we had considered attempting to include all instances of braided rivers globally, as suggested. However, we decided against this for a few reasons. Mainly, we were concerned that stating we had accounted for "all" braided rivers would run the risk of missing some rivers and in so doing being factually incorrect. Secondly, we felt that highlighting the locations where most braided rivers occur would be most useful to readers, as this indicates where most of the braided rivers research has been conducted. In an attempt to account for instances of braided rivers outside of the major regions, we intend to add a sentence or two at L64 noting that braided rivers also occur in small numbers in the U.S., Scotland, Iceland, China, Poland, Belarus, Colombia, Congo, Brazil, Paraguay, Argentina, and the Touat Valley in Africa. Also, we will add Russia to Fig. 1 based on

comments in studies by Chalov & Alexeevsky (2015) and Alexeevsky et al. (2013) about the high number of braided rivers in that country.

9. 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.

<u>Response:</u> Thank you for highlighting this, and we agree that this is an area where more clarity would be helpful. We propose adding text similar to the below in the revised manuscript: "This paper often refers to groundwater-surface water exchange, which in this context may include regional groundwater exchange with river water, as well as hyporheic zone exchange. Hyporheic exchange refers to downwelling or upwelling of water through the hyporheic zone, i.e., the saturated area between the streambed and shallow aquifer where stream water and shallow groundwater mix."

10. 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 approximately 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.
Response: Thank you for highlighting the issues with L134-139, and we agree that deleting these lines would improve the manuscript.

11. 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.
Response: Indeed, this is an important factor to consider. Additional to L261-263, we have mentioned this limitation in Table 1 (under River Reach Water Budgets). We will also add a comment about this in the discussion of the revised manuscript.

12. 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.
Response: Thank you for the comments here and we agree with your point that tracers need to be conservative, and this is an important consideration to make when selecting parameters to measure. Where dissolved oxygen, nitrate, sulphate and pH have been discussed, in the revised manuscript we will add comments on the limitations of these parameters. We think that these parameters are still worthy of discussion as they have been used in several previous studies to varying degrees of success.

13. 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.

Response: Indeed, we also suspect that there have been several studies using artificial tracers in braided rivers, however we have been unable to find published research other than that of Dann et al. (2008) who used dye tracers to characterise a braided river-deposited aquifer in New Zealand. We will include that study in the revised manuscript. We will also discuss some artificial tracer studies (e.g., Langston et al. (2013), Ferreira et al. (2018), Flury & Wai (2003)) conducted in other environments that may be useful to readers.

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

Response: Thank you for highlighting this, and we agree that this study was not specifically related to investigating groundwater-surface water interactions, and thus should be removed. However, given this is an example of thermal infrared imaging used in a braided river setting, we will include it as a proposed method for highlighting temperature gradients in riverbeds as an indicator of groundwater-surface water exchange.

15. 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.

Response: Thank you for the constructive comments on these studies. We will delete these two paragraphs. The two studies mentioned in these paragraphs (i.e., Acuna and Tockner, 2009; Malard et al., 2001) used multiple methods to assess groundwater-surface water exchange, and thus we feel that these are useful references to include, albeit only in Table 1 within the revised manuscript.

16. 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.*

Response: We agree that it would be useful to include some more detail on how temperature depth profiles may be collected and analysed. We will amend this in the revised manuscript.

17. 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.

Response: This is a very good suggestion, thank you. At the beginning of Section 2.3, we will clarify the difference between temperature methods to detect patterns and those used to measure fluxes. We agree that it is important to note the differences in the methods, and we have referenced papers that use methods in both categories. We will also discuss this in more detail in Section 2.3.1 under Advantages/Limitations of heat tracers.

18. 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.

Response: We agree that it would be useful to have a brief explanation of typical approaches to measuring temperature while noting which ones are used for pattern recognition or flux estimates (as per the comment above). We will discuss fibre-optics in the "Key Gaps and Possibilities" section in the revised manuscript (citing studies in other environments such as Lovett et al. (2015), Meijer (2015), Briggs et al. (2014), Rosenberry et al. (2016), Busato et al. (2019), Klinkenberg (2015)).

19. 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.

Response: Thank you for the suggestion, and we agree that it would be useful to include active heat tracers (such as the 3D heat pulse array used in Banks et al. (2018)) in the revised manuscript. To our knowledge, these methods have not yet been used in a braided river setting, but they do have potential and thus may be beneficial for readers. We will include these methods in the "Key Gaps and Possibilities" section of the revised manuscript.

20. L524: "Hydraulic property measurements" is no suitable chapter headline for the subchapter "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".

<u>Response:</u> Thank you for the suggestions and we propose to amend the section headings to the following:

2.4 Darcy approach

2.4.1 Hydraulic gradient

2.4.2 Hydraulic conductivity

Advantages and Limitations

21. 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.

<u>Response:</u> Thank you for highlighting this. We will delete lines 525 to 530 as these points are covered in sections 2.4.1 and 2.4.2. This will also serve to shorten the manuscript.

22. 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.
Response: In L559 we intended "groundwater well" and "piezometer" to be synonymous. To clarify this, we will modify the sentence to read: "In terms of specific methods that can be used for measurements, existing piezometers (i.e., monitoring wells) near rivers can be useful for conducting these types of studies, particularly given the high cost of drilling new wells." At L561 we will add the sentence: "Please refer to standard text such as Fetter (2001) for a definition of piezometers". In L561 we have defined "mini-piezometers" as "scaled-down versions of piezometers and typically installed no deeper than about two metres". With respect we prefer not to include reference to installation methods as these are detailed in the cited references. Also, for the sake of brevity, we prefer not to detail other piezometer designs.

In the revised manuscript, we will comment in section 2.4.3 about the need to consider the diameter of wells being used with downhole equipment (e.g., loggers). Also, at the beginning of section 2.4.1 we will briefly detail the way in which water levels are measured.

23. 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).
Response: This is a good suggestion, thank you. In the revised manuscript, we will discuss new methods for use in braided rivers in the "Key gaps and possibilities section". For the sake of brevity, we will discuss geophysics in that section.

24. L642ff: Mention that loggers require a certain diameter of wells/piezometers as a further disadvantage.
Response: We will add this to the revised manuscript.

25. 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.

Response: Thank you for your thorough comments on Table 1. The intention of this table was to summarise all the methods discussed in the review, both for identifying patterns and for estimating fluxes. Perhaps the table title has created the confusion here, so we will amend the title to read "Advantages and disadvantages of various methodologies for **measuring** groundwater-surface water interactions in braided rivers".

We are not convinced that organising the methods according to scale of measurement would be helpful as there would be overlap amongst methods (i.e., some methods could be used at multiple scales, see Fig. 1 in Kalbus et al. (2006)). The proposed revised categories for Table 1 are: Water budgets, Hydrochemistry, Temperature studies, Darcy approach, Modelling, Artificial tracers, Geophysics and Remote sensing.

26. 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.

Response: Thank you for highlighting that we may need more clarity around scales of measurement. However, we are not sure why there is confusion here. Depending on how they are carried out, the methods mentioned in L781-783 (pumping tests, flow gauging, stable isotope analysis, solute tracers and chemical analysis) can provide broad spatial scale information, as can TIR imaging, geophysical methods and satellite data. As we mentioned in the response to the comment on Table 1 above, many of these methods can be used to collect data at various scales, while some indeed are point methods only (e.g. permeameter tests or 1-D temperature profiles).

27. 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.

Response: Indeed, this is an important point to make. In this section of the manuscript, we attempted to illustrate this with the example of temperature time series data in L801-803, but in the revised manuscript we will make it clearer that time series data for a range of parameters can be very useful to collect to observe changes in groundwater-surface water interactions over time.

28. 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.

Response: Thank you for highlighting this. We propose to change the numbering of Section 3.1 (Key gaps and possibilities) to Section 4.

MINOR COMMENTS

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

Response: Thank you for the relevant suggestion. This reference will be added in the revised manuscript.

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

Response: Better knowledge of historic states and patterns of braided rivers would be very helpful for understanding the implications of modifications to natural systems in order to set water allocation limits and minimum flow levels in rivers (Reigler, 2012; Burbery et al., 2010). For example, many irrigation schemes have artificially raised groundwater levels due to land surface recharge, or lowered groundwater levels due to abstraction in comparison to their natural (pre-irrigation) states. In some rivers this has affected the losing/gaining patterns.

31. L118: A more scientific reference would be great here.

Response: The reference in the previous draft will be replaced by references to Caruso (2006); Larned et al. (2008); Tockner and Stanford (2002), which are all peer-reviewed publications in international journals.

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

Response: This is a very useful reference, and we will add it to the revised manuscript, along with Brunner et al. 2017, which is a useful review of the latest advances in methods for characterising and modelling river and groundwater interactions and specifically mentions braided streams in some parts.

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

Response: Thank you for the suggestion, and we agree that amending the wording to "an even groundwater concentration" would be more accurate.

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

Response: Thank you for highlighting this oversight. Oxygen-17 will be added to this discussion of stable oxygen isotopes.

35. 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.
Response: Thanks for pointing this out. We will amend this sentence to read: "The process is largely driven by temperature, whereby precipitation is increasingly depleted in ^{18}O at colder temperatures (which tend to occur at higher elevations) (Sharp, 2007)".

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

Response: Thank you, this will be added to the revised manuscript.

37. L560: Only deep wells/piezometers are expensive.

Response: Agreed. We will amend the text to reflect that cost of installing wells or piezometers may only be prohibitively high in some situations.

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

Response: As detailed in our response to point 22 above, we will modify the text at L559 so that it is clear that we consider piezometers to be monitoring wells. We will also make it clear that mini-piezometers are small versions of piezometers. In light of this we think that the labelling of this figure as a conceptual diagram of a mini-piezometer is no longer confusing.

39. 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.
Response: Thank you. We will add a sentence to this effect.

40. L 674: "interactions" instead of "interaction"

Response: Thank you. The text will be amended.

41. L687: Delete: "and will not be repeated here."

Response: Thank you. This text will be deleted.

42. L704: "They used" instead of "The used"

Response: Thank you. This suggested change will be made.

43. L754: You are not investigating groundwater and surface water but their interactions:
"... for investigation of groundwater-surface water interactions, and there ..."

Response: Thank you for recognising this error. The text will be amended to reflect your comment.

44. L764: "a study" instead of "the study"

Response: Thank you. The suggested change will be made.

45. L808: "by the study objective and the study object

Response: Thank you. The suggested text will be added.

46. L820: Only during storms???

Response: This is a fair point. Our intention in specifically mentioning storms was to highlight mass sediment movement during flood events, but indeed, sediment transport at other times may equally damage equipment. The mention of storms here will be removed.

47. L851: "One of the most ..." – I do not understand this sentence.

Response: In the revised manuscript we will amend L851-853 to the following: "One of the most significant gaps in this area relates to how hyporheic flow processes operate and how they impact river flow levels and water quality in braided rivers."

48. 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.
Response: This is an excellent suggested reference for this line, as well as to enhance the discussion of the hyporheic zone in the present paper. This reference will be added here.

49. L869: the present paper

Response: This suggested text will be added.

50. L895: You might add here DTS and geophysics

Response: We agree that it would be helpful to add DTS and geophysics to this line.

References

Acuña, V., & Tockner, K. (2009). Surface-subsurface water exchange rates along alluvial river reaches control the thermal patterns in an Alpine river network. *Freshwater Biology, 54,* 306–320. doi: 10.1111/j.1365-2427.2008.02109.x

Alexeevsky, N. I., Chalov, R. S., Berkovich, K. M., & Chalov, S. R. (2013). Channel changes in largest Russian rivers: Natural and anthropogenic effects. *International Journal of River Basin Management, 11*(2), 175-191. doi: 10.1080/15715124.2013.814660

Banks, E. W., Shanafield, M. A., Noorduijn, S., McCallum, J., Lewandowski, J., & Batelaan, O. (2018). Active heat pulse sensing of 3-D-flow fields in streambeds. *Hydrology and Earth System Sciences, 22*, 1917–1929. doi: 10.5194/hess-22-1917-2018

Briggs, M. A., Lautz, L. K., Buckley, S. F., & Lane, J. W. (2014). Practical limitations on the use of diurnal temperature signals to quantify groundwater upwelling. *Journal of Hydrology, 519,* 1739-1751. doi: 10.1016/j.jhydrol.2014.09.030

Brunner, P., Therrien, R., Renard, P., Simmons, C. T., & Franssen, H.-J. H. (2017). Advances in understanding river-groundwater interactions. *Reviews of Geophysics, 55*, 818–854. doi: 10.1002/2017RG000556

Burbery, L., & Ritson, J. (2010). *Integrated study of surface water and shallow groundwater resources of the Orari catchment.* Environment Canterbury Report Number R10/36. Christchurch, New Zealand. Retrieved from http://docs.niwa.co.nz/library/public/ECtrR10-36.pdf

Busato, L., Boaga, J., Perri, M. T., Majone, B., Bellin, A., & Cassiani, G. (2019). Hydrogeophysical characterization and monitoring of the hyporheic and riparian zones: The Vermigliana Creek case study. *Science of the Total Environment, 648*, 1105–1120. doi: 10.1016/j.scitotenv.2018.08.179

Caruso, B. S. (2006). Project River Recovery: Restoration of Braided Gravel-Bed River Habitat in New Zealand's High Country. *Environmental Management, 37*(6), 840-861. doi: 10.1007/s00267-005-3103-9

Chalov, S. R., & Alexeevsky, N. I. (2015). Braided rivers: Structure, types and hydrological effects. *Hydrology Research, 46*(2), 258-275. doi: 10.2166/nh.2013.023

Dann, R. L., Close, M. E., Pang, L., Flintoft, M. J., & Hector, R. P. (2008). Complementary use of tracer and pumping tests to characterize a heterogeneous channelized aquifer system in New Zealand. *Hydrogeology Journal, 16*, 1177–1191. doi: 10.1007/s10040-008-0291-4

Ferreira, V. V. M., Moreira, R. M., Rocha, Z., Chagas, C. J., Fonseca, R. L. M., Santos, T. O., . . . Menezes, M. A. B. C. (2018). Use of radon isotopes, gamma radiation and dye tracers to study water interactions in a small stream in Brazil. *Environmental Earth Sciences, 77*(19), 1-12. doi: 10.1007/s12665-018-7879-3

Fetter, C. W. (2001). *Applied Hydrogeology* (4th ed.): Pearson Education.

Flury, M., & Wai, N. N. (2003). Dyes as tracers for vadose zone hydrology. *Reviews of Geophysics, 41*(1), 1002-1037. doi: 10.1029/2001RG000109

Langston, G., Hayashi, M., & Roy, J. W. (2013). Quantifying groundwater-surface water interactions in a proglacial moraine using heat and solute tracers. *Water Resources Research, 49*, 5411–5426. doi: 10.1002/wrcr.20372

Larned, S. T., Hicks, D. M., Schmidt, J., Davey, A. J. H., Dey, K., Scarsbrook, M., . . . Woods, R. A. (2008). The Selwyn River of New Zealand: A benchmark system for alluvial plain rivers. *River Research and Applications, 24*(1), 1-21. doi: 10.1002/rra.1054

Lovett, A., Cameron, S., Reeves, R., Meijer, E., Verhagen, F., van der Raaij, R., . . . Morgenstern, U. (2015). *Characterisation of groundwater-surface water interaction at three case study sites within the Upper Waikato River Catchment using temperature sensing and hydrochemistry techniques* (GNS Science Report 2014/64). Retrieved from http://shop.gns.cri.nz/sr_2014-064-pdf/

Kalbus, E., Reinstorf, F., & Schirmer, M. (2006). Measuring methods for groundwater–surface water interactions: A review. *Hydrology and Earth System Sciences, 10*, 873–887.

Klinkenberg, J. (2015). *Characterising groundwater-surface water interaction using fibre-optic distributed temperature sensing and validating techniques in Whakaipo Bay, Lake Taupo, New Zealand.* Masters Thesis. Utrecht University. Retrieved from https://dspace.library.uu.nl/handle/1874/324367

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.

Malard, F., Mangin, A., Uehlinger, U., & Ward, J. V. (2001). Thermal heterogeneity in the hyporheic zone of a glacial floodplain. *Canadian Journal of Fisheries and Aquatic Sciences, 58*(7), 1319–1335. doi: 10.1139/cjfas-58-7-1319

Meijer, E. C. (2015). *Using fibre-optic distributed temperature sensing and heat modelling to characterize groundwater- surface water interaction in Whakaipo Bay, Lake Taupo, New Zealand.* Utrecht University, Utrecht, The Netherlands. Retrieved from https://dspace.library.uu.nl/handle/1874/311429

Riegler, A. (2012). *Influence of groundwater levels on zero river flow: North Branch, Ashburton River, New Zealand.* University of Vienna, Austria. Retrieved from http://othes.univie.ac.at/22451/1/2012-06-17_0600876.pdf

Rosenberry, D. O., Lewandowski, J., Meinikmann, K., & Nützmann, G. (2015). Groundwater - the disregarded component in lake water and nutrient budgets. Part 1: effects of groundwater on hydrology. *Hydrological Processes, 29*, 2895–2921. doi: 10.1002/hyp.10403

Rosenberry, D. O., Briggs, M. A., Delin, G., & Hare, D. K. (2016). Combined use of thermal methods and seepage meters to efficiently locate, quantify, and monitor focused groundwater discharge to a sand-bed stream. *Water Resources Research, 52,* 4486–4503. doi: 10.1002/2016WR018808

Sharp, Z. (2007). *Principles of Stable Isotope Geochemistry*. Upper Saddle River, NJ: Pearson Prentice Hall.

Tockner, K., & Stanford, J. A. (2002). Riverine flood plains: Present state and future trends. *Environmental Conservation, 29*(3), 308-330. doi: 10.1017/S037689290200022X

Winter, T. C., Harvey, J. W., Franke, O. L., & Alley, W. M. (1998). *Ground Water and Surface Water: A Single Resource* (US Geological Survey Circular 1139).