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Hydrology and Earth System Sciences Discussions

Interactive comment on "Measuring methods for groundwater, surface water and their interactions: a review" *by* E. Kalbus et al.

E. Kalbus et al.

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First of all we thank both referees for their critical but constructive points addressed in their review. They raised a number of interesting questions and made helpful suggestions to which we respond below.

General comments

Interactions between groundwater and surface water include discharging groundwater, infiltrating surface water, and hyporheic exchange. Therefore, we believe that methods to determine the groundwater flux approaching a stream are very important and should be part of this review. However, we agree that many of these methods can be found in standard textbooks and will condense the description of the groundwater methods. We understand that the paper should be restructured to improve the readability and

usefulness for the reader. We thought that a classification according to the zone the methods are applied in would be most useful, because this would give a clear structure to the paper. However, this seems not to be the case. Therefore, we will reorganize the paper and drop this classification which will reduce repetitions.

The paper was not intended to provide descriptions of the methods which are sufficient to apply the methods without obtaining further information. It was intended to present an overview of the methods to enable the reader to decide whether the method is useful for his study or not, and if yes, where to find detailed information. However, we understand that methods that are not yet well known or covered in textbooks should be described with more detail and will expand the respective sections.

The problem of contaminated water resources is of growing concern worldwide. The exchange of contaminants between groundwater and surface water has important implications for the fate and behaviour of the contaminants in ecosystems. The estimation of contaminant fluxes is crucial for the development of remediation strategies. Therefore, we believe that methods related to the determination of contaminant concentrations should be included in this manuscript. However, if the editor suggests to drop this topic in order to focus the scope of the paper, we will agree.

It was suggested by both referees to pay more attention to the transient storage concept. Transient storage comprises the detainment of water parcels in stagnant zones in the water column as well as in the pore space of the streambed sediments. It covers hyporheic exchange, but it does not include water exchange with the groundwater. Therefore we decided not to include this method in our review, because we wanted to show methods to determine water exchange between groundwater and surface water, not between surface water and water in the sediment pore space. We discussed the problem of distinction between groundwater discharge and hyporheic exchange in section 5.2, where we also mentioned the transient storage concept. We fully agree that a part of the transient storage occurs in the hyporheic zone, but the role of groundwater discharge is not addressed in the tracer data interpretation with transient storage.

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Interactive Comment

However, we see the point of both referees that hyporheic exchange is an important process at the groundwater - surface water interface and that the transient storage concept is frequently used to study hyporheic exchange. Therefore, we will include a paragraph covering transient storage in the revised manuscript.

First, we will respond to the specific comments of referee #2 below:

(1) The paper was in fact intended for anyone starting to work on groundwater - surface water interactions, no matter what background he or she has. Of course, for hydrogeologists the typical groundwater methods will be well known, as will be the surface water methods for surface water hydrologists. But we experienced that the methods "from the other side" may not be well known, and that scientists with different backgrounds sometimes "speak different languages". Therefore we felt the need to summarize methods from "the different sides" in a review paper. We agree that we did not sufficiently define the intended audience in the paper; we will add that in the revised manuscript.

(2) We refer here to the transition zone as the zone between aquifer and stream that contains both groundwater and stream water, which indeed is synonymous with the term hyporheic zone. We agree that not every groundwater - surface water interface meets the definition of a hyporheic zone. However, we refer to streams in this section, and streams usually have hyporheic zones. Even in stream reaches which are generally gaining, small-scale topographic features on the streambed may induce downwelling of stream water leading to hyporheic exchange. Therefore, we do not agree that we used the term wrongly. Fig. 2 is a part of section 5.2 and intends to illustrate the problem of distinction between groundwater discharge and re-emerging stream water when performing measurements in the shallow streambed sediments and does not relate to the definition of the transition zone. The figure indeed shows the case of groundwater discharging to a stream that experiences downwelling of stream water due to streambed topographical features (hyporheic exchange). It is not meant as a general illustration of the scope of the paper. However, we agree that we focused on streams as surface waters without declaring that in the paper. We will clarify that in the

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revised manuscript.

(4) The integral pumping test method is a relatively new method and not yet well known. It is a very interesting method to obtain representative contaminant concentrations and mass flow rates, which overcomes problems associated with heterogeneous contaminant distributions in the aquifer. Applied to aquifers connected to streams, it can be very useful for the determination of contaminant mass fluxes that are approaching a stream, and therefore we believe that it is relevant to the scope of the manuscript.

(6) Since there has been a recent comprehensive review by Anderson (2005) concerning heat as a groundwater tracer, we wanted to keep this section short. However, we agree that the basic principles could be useful for the reader and will expand the section.

The other specific comments will be fully considered in the revision of the manuscript.

Below we will respond to the specific comments of referee #1:

Paragraph 3: When we restructure the paper, the title of paragraph 3 will be removed, since there will be no extra section for surface water methods. However, we agree that we mostly refer to streams when using the term surface water. We will explain that.

Discussion: The first paragraph of the discussion is titled “measurement scales”. Therefore, it should be clear that we discuss the scales of the various methods here. However, we will add an introductory sentence to make clear that we start with a discussion of the spatial scales. We will also move the consideration of the heterogeneity to this section.

All other specific comments will be fully considered in the revision of the manuscript.

References

Anderson, M.P.: Heat as a ground water tracer, Ground Water, 43 (6), 951-968, 2005.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 3, 1809, 2006.