Responses to referees comments on "Transit times from rainfall to baseflow in headwater catchments estimated using tritium: the Ovens River, Australia"

We thank the two anonymous referees for their overall positive comments on this paper. We have considered their comments and make the following responses (in blue), which will be incorporated into the final version of the paper.

Referee #1 stated "My only criticism lies with constraining the Tritium input function. Having a high resolution Tritium rainfall data is difficult and costly to assess, however, the paper would benefit with one or two more sentences discussing the possible uncertainties involved with a lag of a high frequency input function. I could imagine that tritium would undergo significant variability with rain event magnitudes, altitude and changes in atmospheric circulations"

We agree with this point and as with many studies there is uncertainty in the Tritium input function. In reality there are very few catchments globally where a high-resolution tritium record exists and it is not something that is able to be measured retrospectively. Since we are looking at mean transit times of more than a few years, the biggest uncertainty is probably in the long-term average Tritium activity of rainfall rather than the variability in individual seasons or events (which would probably be averaged out over several years). We have an additional annual rainfall sample from a second locality in the Ovens catchment that has a Tritium activity (2.85 TU) that we can use to estimate some of the uncertainties. For example, the MTT for a water sample with a tritium activity of 2 TU from the Exponential Piston Flow model assuming that the modern rainfall input is 3 TU is 15.2 years while assuming a rainfall value of 2.85 TU the MTT becomes ~13 years. This does not change the overall conclusions of the paper but it allows some uncertainties to be put on the calculations that are valuable. The variation in modern 3H values reported by Tadros et al. (2014) for the individual Australian stations is less than this inter-sample variation and so this calculation probably captures the spatial variability.

Referee #2 was also positive about the paper and its findings but had some concerns regarding the organisation of the paper, in particular what belongs in the introduction vs. the methods sections (and elsewhere such as the discussion) together with other minor points that require clarifying.

The section "sampling and analytical methods" thoroughly describes the sampling campaign and analysis. But a section describing the general approach, the choice of the particular methods to evaluate the results, and their application is missing. This makes the results and figures (e.g. the grey shading in Figs 4 and 8) difficult to understand and to evaluate for the review. I strongly recommend collecting the method descriptions provided at various parts of the manuscript (introduction, results, discussion) in a separate methods section including a description of the workflow to elaborate why the methods were chosen and why in this particular order

The locations of sections that provide the background to scientific studies vary from paper to paper. We agree that removing some of the material that describes the equations from the introduction to the methods would make the introduction more focussed and adding a short section on the mass balance in the methodology would also be useful. The discussion of how these techniques are applied to the Ovens catchment (e.g., the discussion of the input function of tritium), however, need to be in the latter sections as they rely on interpretation of data. This is a relatively minor

reorganisation, and grouping both the analytical and analysis techniques into one section would certainly help the flow of the paper.

The following are responses to comments made directly on the paper by Referee #2 (in the supplement file).

Introduction (P5249). Our comments regarding the context of the study can be clarified. We agree that there has been much hydrology carried out in headwater catchments; however, there is still considerable uncertainty over MTTs in headwater catchments, which is what we were trying to convey in this paragraph. Probably due to not being a common landform in Victoria, we'd ignored karst systems but agree that they are important elsewhere. We will reword this paragraph to more clearly convey the background to the study and to outline what our objectives are.

Section 1.1 (pages 5430-5434). The reviewer suggests moving some of this material to the methods section to shorten the introduction and to prevent the reader from losing focus. Material such as this can legitimately appear in the introduction, methods, or discussion sections (and different papers present it in different places). We consider that the more general material from this paragraph (eg the utility of tritium in the southern hemisphere) should be retained here, but that the bulk of the details of the calculations can go into the methodology. In this way we separate the important background material from the mechanics of the calculations, it will also illustrate the workflows of the study better.

Section 1.2 (page 5434, line 22-23). We will reword this sentence to make it clearer.

Section 2 (page 5436, line 13). Late autumn and winter rain (June- September) is ~45% of the annual rainfall; however, rainfall occurs throughout most of the year (March is the driest month but still has 5-6%) of the annual total. We will add these details to this section.

Section 3 (page 5438). The referee suggests that we add more to this section. As discussed above, it is straightforward to move the details of the calculations to the end of the methods section. However, a discussion of "how the collected data will be used to understand the varying transit times" would be out of place here. Such statement belongs where the aims of the paper are explained (section 1, page 5434, line 16 onwards) and we can integrate this material into that section.

Na and Cl were the chosen as monitors of the major ion geochemistry because they are the major cation and anion in the river water and groundwater and also they are commonly measured in the routine river geochemistry monitoring programs (eg data in Fig. 8); we will explain that in this section.

Section 5.1 (page 5442). Weighting by water volumes would be needed if one were interested in the mass flux of Na derived from weathering (eg for defining weathering rates) but not for the compositions (ie the number of mg of Na per litre of water). The mixing curves are from a mass balance calculation where the predicted Na concentration is calculated from the relative volume of surface runoff assuming all the increase in discharge over baseflow conditions is due to surface runoff. This can be better explained with the details of the mass balance going into the methods section (as also suggested by Referee #2).

Section 5.1 (page 5443). We agree that the upstream vs. downstream categorisation is difficult to follow in the figures. However, since the samples are derived from a variety of tributaries that enter the main Ovens River at varying locations and which have different lengths, it is difficult to assign a distance to the sites. With much of the other data we have made the distinction between the samples from the tributaries and those from the main Ovens River and that distinction would be probably useful for the stable isotope data in Fig. 6. In addition we will be more precise in our terminology in the text and refer to tributary sites vs. those on the main Ovens River rather than upstream and downstream.

Section 5.2 (page 5445). We disagree that the discussion of the tritium input function can be part of the methods. This section requires interpretation of data and also is reliant on the measured tritium rainfall values which are not presented until Section 4.

Section 5.3 (page 5446). Morgenstern & Daughney (2012) discuss this and is a suitable reference (we reference it elsewhere in the paper).

Table 2. As discussed in response to Referee #1, it is probably most useful to assign uncertainties based on uncertainties in the input function, and this we will do. We can also add a measure of the range of the different techniques to the table.

Figure 1. Should be “localities” not “locations”.

Figure 3. The p value is 0.005 (we will add this to the figure)

Figures 4, 8. As with the tritium input function much of Figs 4 & 8 cannot be explained in the methods section as it requires discussion of data presented in Section 4 (e.g. to estimate the range of rainfall values). It is possible to add a section at the end of the methods section that explains the mass balance calculations (which we never explicitly do); this would be useful in indicating to the reader what we subsequently discuss in the paper.