We thank Dr. Worthington for thoughtful and constructive suggestions. In the following, Dr. Worthington's comments are shown in *italic fonts*, and our responses are shown in regular fonts.

This paper presents a wide range of data from a karst spring in Canada. I feel that the greatest strength of the paper is on the detailed analysis of the celerity and velocity of percolation recharge, and that the discussion on these should be expanded and better integrated with the discussion on the slow fraction of flow from isotope data. I have two major concerns with the paper:

Comment 1) Groundwater flow velocity

line 472-473 "the flow velocity through the karst conduit network is expected to be on the order of 1 m s^{-1} during May–December when Q varies between 0.3 and 3 m^3 s^{-1}."

The prediction of 1 m/s conduit velocities comes from calculations at lines 455-475. The calculations use the Darcy-Weisbach equation, which calculates flow in a pipe as a function of pipe size, hydraulic gradient, and friction (roughness) factor. Estimates of hydraulic gradient (lines 464-468) were based on values from Castleguard Cave (0.03: Ford et al., 1983), high flow conditions at Maligne (0.025: Smart, 1988), and Hölloch (0.0004-0.006: Jeannin, 2001). However, a later interpretation of Castleguard Cave (Ford, 2000; Worthington, 1991) suggested that hydraulic gradients during the formation of the cave could have been 0.0005 or less. Furthermore, a compilation of data in 20 karst aquifers showed that hydraulic gradients along major flow paths to springs are typically 0.0001-0.001 at low flow and 0.001-0.01 at high flow (Worthington, 1991). Moreover, field studies have shown that the Darcy-Weisbach friction factor can vary by more than three orders of magnitude in karst conduits (Jeannin, 2001, Table 3), and pipe size and hydraulic gradient also have a wide variation in their values. Consequently, the uncertainty in the 1 m/s conduit velocity is very large.

We acknowledge the large degree of uncertainty in estimation of the hydraulic gradient, the friction factor, and the conduit flow velocity. We will completely re-write Section 5.1. We will revise the flow velocity calculation using more conservative (i.e. smaller) values of the gradient, and put less emphasis on the actual velocity number in the revised texts.

Given the lack of information on friction factors and hydraulic gradients at the site, a better approach is to consider measured groundwater velocities from other studies. It is very rare for velocities of 1 m/s to be measured from tracer tests, and velocities are usually between 0.003 and 0.3 m/s. This is true globally (Ford and Williams (2007, p. 125) and also in the Canadian Rocky Mountains, such as in the cited references by Smart (1983, 1988) and Worthington (1991). Furthermore, conduit diameter has been measured by a scuba diver in the conduit feeding Watridge Spring (line 470), and this gives a velocity of 0.028 m/s at moderately low flow (0.3 m3/s) and 0.28 m/s at high flow (3 m3/s), assuming a circular conduit. These measured velocities give more accurate values for assessing the aquifer than the 1 m/s estimate made at line 473. The similarity of the measured velocities to velocities in other karst aquifers mean that there is no need to suggest retardation or invoke pools to explain the measured travel times.

We agree that the order of magnitude of conduit flow velocity (1 m/s) presented in the original manuscript is higher than the common range of velocity determined by tracer tests, and we will lower the number by using a more conservative estimate of hydraulic gradient (see our response to the comment above). However, we would like to point out that tracer tests measure the transport velocity, which integrates the effects of all parts of the flow system including pools and stagnant zones interacting with the conduits. In contrast, the hydraulic method (e.g., Darcy-Weisbach equation or Manning's equation) calculates the fluid flow velocity in pressurized conduits or open channels. The latter is not influenced by pools and stagnant zones and hence, expected to be greater than the former. In the completely re-written Section 5.1, we will clarify the difference between transport velocity and fluid flow velocity, and discuss their differences and implications.

Comment 2) Subsurface residence times

line 359-361 ". It is impossible to determine the residence time of water, considering the possible variability of tritium contents between Ottawa and the WKS, but in an approximate sense, it seems likely that most spring water samples had a residence time of five to ten years."

line 502 "This [del 18O variation] is consistent with the tritium content suggesting a residence time of multiple years (Figures 8d and 9)."

These two comments are the only specific references in the paper to residence times for the groundwater discharging at Watridge Spring. However, Figure 7d shows day by day residence times (which can also be referred to as transit times) for snowmelt and glacier melt from May to September 2021, with dye traces (Figures 5 and 7d) confirming the rapid transit times for specific recharge locations.

There have been several previous studies that have measured lag times between surface snow or glacier melt and variation in spring flow in carbonate aquifers, including Gremaud et al. (2009), Krainer et al. (2021), Smart and Ford (1986), Vigna and Banzato (2015), and Zeng et al. (2012). However, this study includes an exceptional data set on subsurface residence times for snow and ice melt (Figure 7d) and on the lag time for the pressure pulse for snow and glacier melt to reach a limestone spring (Figure 7c). Furthermore, seasonal variation in major ions, tritium, and del 18O (Figure 8), could help define the fractions of young water with an age of 0.4 to 4 days (Figure 4d) from older water with transit times up to several years.

The wide range of residence times in carbonate aquifers has been widely described in the literature and they are sometimes referred to as dual- or as triple-porosity aquifers. Małoszewski and Zuber (1985) and Zuber et al. (2011) presented the theory to interpret the ages of injected and environmental tracers in dual-porosity bedrock aquifers, and useful studies in carbonate rocks in mountain environments that have included transit times and the fraction of flow in each component include Maloszewski et al. (2002) and Lauber and Goldscheider (2014).

I think that it would be well worth adding a new section to Section 5 that specifically discusses subsurface residence times and fractions of spring flow involved. This would consider both vadose zone residence times and groundwater residence times and use most of the data sets collected, thus providing a suitable concluding section to the Discussion. If the authors adequately address the above comments, then this paper would be a fine contribution to the literature.

We thank Dr. Worthington for highlighting the uniqueness of our data set and for pointing out the need to examine further the significance of different time scales indicated by different tracers and develop an improved understanding of the overall behavior of the karst system. We have read the suggested literature and noted relevant ideas and concepts that can be applied to our study. In the original manuscript, we did not effectively describe how the old water stored in the fractured matrix interacts physically and chemically with snowmelt infiltration. In the revised manuscript, we will add a new section in the discussion describing these processes using all data presented in Figures 7, 8, 9, and 11.

Other comments

Comment 3 - line 359-361 "It is impossible to determine the residence time of water, considering the possible variability of tritium contents between Ottawa and the WKS, but in an approximate sense, it seems likely that most spring water samples had a residence time of five to ten years."

This statement needs to be clarified that it is referring to tritium, and so reflects the residence of the slow-moving water through the matrix and narrow fractures. The residence time of snow and glacier melt has been very well determined in this aquifer. The three tracer tests give subsurface residence times of some days (Figure 5a), and the EC signal at the spring during the spring freshet demonstrates a snowmelt residence time of 0.5 to 2 days, rising to 3-4 days later in the summer when glacier melt predominates (Figure 7d). This strength of the study needs to be better emphasized, such as by adding a section to the Discussion that describes residence times.

We agree that different residence times associated with different processes need to be described more explicitly and discussed more effectively. We will add a new section to the discussion (see our response to Comment 2 above).

Comment 4 - line 465 ", a map of the Castleguard Cave (Ford et al.,1983, Figure 3) suggests a gradient of ~0.03".

This needs to be updated with the conclusions on gradients in Ford (2000), as noted above, or else omitted.

We read Ford et al. (2000), but did not find specific information on the gradient (0.0005 or less). Figure 3C in Ford et al. (2000) gives a gradient of ~0.04 (= 300 m / 7600 m) for a tortuosity of 1 and ~0.03 for a tortuosity of 1.5. Nevertheless, we will use a smaller value of gradient in the new calculation of fluid velocity in the revised texts.

Comment 5 - line 484-485 "meaning that the diel fluctuations of discharge would have a delay of less than an hour between BP14 and WKS. This is contrary to the observed delay of 12–15 h (Figure 7c)"

The radon data suggests that "most of the conduit flow occurs under pipe-flow conditions" (lines 453-454), and active karst conduits are frequently predominantly below the water table, so the lag time of <1 hour along the main conduit seems probable. However, BP11 and BP14 are 593 m and 575 m above Watridge Spring, respectively, suggesting that there is a vadose zone that is likely to be hundreds of metres thick at these locations. Thick vadose zones are typical in karst aquifers in mountain settings, and the more than 400 caves around the world that are >600 m *deep provide a graphic illustration of the widespread presence of deep vadose zones in carbonate aquifers (Burger, 2025).*

Flow peaks in karst springs due to snow or glacier melt in mountain areas usually occur in the evening or night, reflecting a lag that is typically 6-12 hours after the mid-afternoon peak of snow or ice melt (Gremaud et al., 2009; Krainer et al., 2021; Smart and Ford, 1986; Vigna and Banzato, 2015; Zeng et al., 2012). These lags predominantly reflect the much slower hydraulic responses in the vadose zone compared to the saturated zone. Consequently, most of the 12-15 hour lag shown in Figure 7c is likely to be in the vadose zone, such as the several hundred metres from the surface at BP14 down to the water table. Thus, the alternative explanation for the 12-15 h lag offered at lines 491-492 is the most probable explanation.

We agree that the vertical flow through the thick vadose zone plays an important role in transport processes. The vertical infiltration of snowmelt water through the vadose zone was depicted in Figure 14a in the original manuscript, but it was not effectively described in the discussion. We will expand the discussion of this process in the new discussion section.

Comment 6 – line 525 – " transport velocity (0.05 – 0.15 m s-1) is much slower than the order of velocity (1 m s-1) expected for conduit flow or open-channel flow. Therefore, there likely are many pools within the conduit network, causing the physical retardation of solute transport."

See Comment 1.

We will use a smaller value of the hydraulic gradients in our new velocity calculation and more effectively discuss the interplay between the fluid velocity through pipes and narrow channels and the transport velocity reflecting the behavior of the entire system.

Additional references cited above, to consider for inclusion

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Lauber, U., Goldscheider, N., 2014. Use of artificial and natural tracers to assess groundwater transit-time distribution and flow systems in a high-alpine karst system (Wetterstein Mountains, Germany). Hydrogeol. J. 22, 1807-1824.

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Zuber, A., Różański, K., Kania, J., Purtschert, R., 2011. On some methodological problems in the use of environmental tracers to estimate hydrogeologic parameters and to calibrate flow and transport models. Hydrogeol. J. 19, 53-69.

We thank Dr. Worthington for the suggestion. We will include these in the revised texts.