Do smaller stream reaches accurately and precisely represent larger stream segments in studies of water exchange between streams and streambeds?

Testing hidden assumptions of representativeness in reach-scale studies of hyporheic exchange

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Does water movement and exchange measured and modeled for a specific reach allow inference across an entire stream segment? The authors investigated whether the hyporheic exchange determined over a study reach of tens to hundreds of meters in length could be assumed to be representative of water movement over segments hundreds to thousands of meters long. They asked whether water movement metrics vary with location in the basin and segment measurement strategy, and whether these metrics vary more within a stream segment than among stream segments with differing geology.

Did longer sample reaches better represent the water movement over a full stream segment?

- The study segment location was equally or more important than reach length sampling strategy, 100-m or 20 times the wetted-channel-width (20WCW), for estimating accurate and precise transit time distributions for hyporheic flow.
- Increased sample reach length increased the likelihood of increased precision and accuracy of estimates of total downward flux and percent upwelling per meter. Estimates for both metrics from 100-m reach sampling had greater precision and accuracy than from 20WCW reach sampling.

Can visual inspection of a reach determine water exchange or whether a reach is representative?

- Hyporheic exchange behavior cannot be inferred from visual inspections of stream segment characteristics. Iterative field and model sampling should be used together to determine the water movement patterns.
- There is little statistical indication that certain features or locations are present in or absent from representative reaches.

What are the limitations of reach sampling?

- Researchers should be cautious about drawing broad conclusions based on results from a limited number of study reaches. Additionally, assumptions of variation within and between reaches must be clearly articulated, tested, and quantified.
- The reaction significance factor, which is the product of river connectivity and a ratio for determining whether reaction rate or diffusion rate is limiting, was not well estimated using reach-level sampling.

How can these findings be used moving forward?

- The researchers have used these findings to evaluate their own previously completed body of work that was based on reach sampling at these sites.
- Further research should focus on determining the underlying causes of variation in the metrics used to describe water movement and flow into and out of the hyporheic zone. Research should also determine the extent to which field measurements align with model outputs.

Research Approach/Methods

- The researchers collected data from topographic surveys and channel surface surveys from four stream segments. They derived values for valley slope, stream slope, drainage area and other metrics to describe the stream section. They also collected wetted channel width, valley width, and other complementary site descriptive metrics.
- Using numerical modeling, they quantified the degree to which within-reach variation in hyporheic exchange was influenced by reach location and the strategy employed to choose reaches and reach lengths.
- They also used modeling to determine the accuracy and precision of estimating values for hyporheic exchange metrics for an entire reference segment from a shorter reach within it.
- The researchers compared the within-reach variation of each of the four reference segments to variation across 29 other low-order streams in the basin with comparable data using an equality of variance test.
- To determine whether any features would be systematically included or excluded from representative reaches, the researchers calculated the frequency of a specific location being included in a representative reach relative to the number of reaches that location was a part of.

Keywords hyporheic exchange, stream segment sampling, representativeness, representative sampling, stream hydrology, hydrology modeling, reach length sampling strategy

Images

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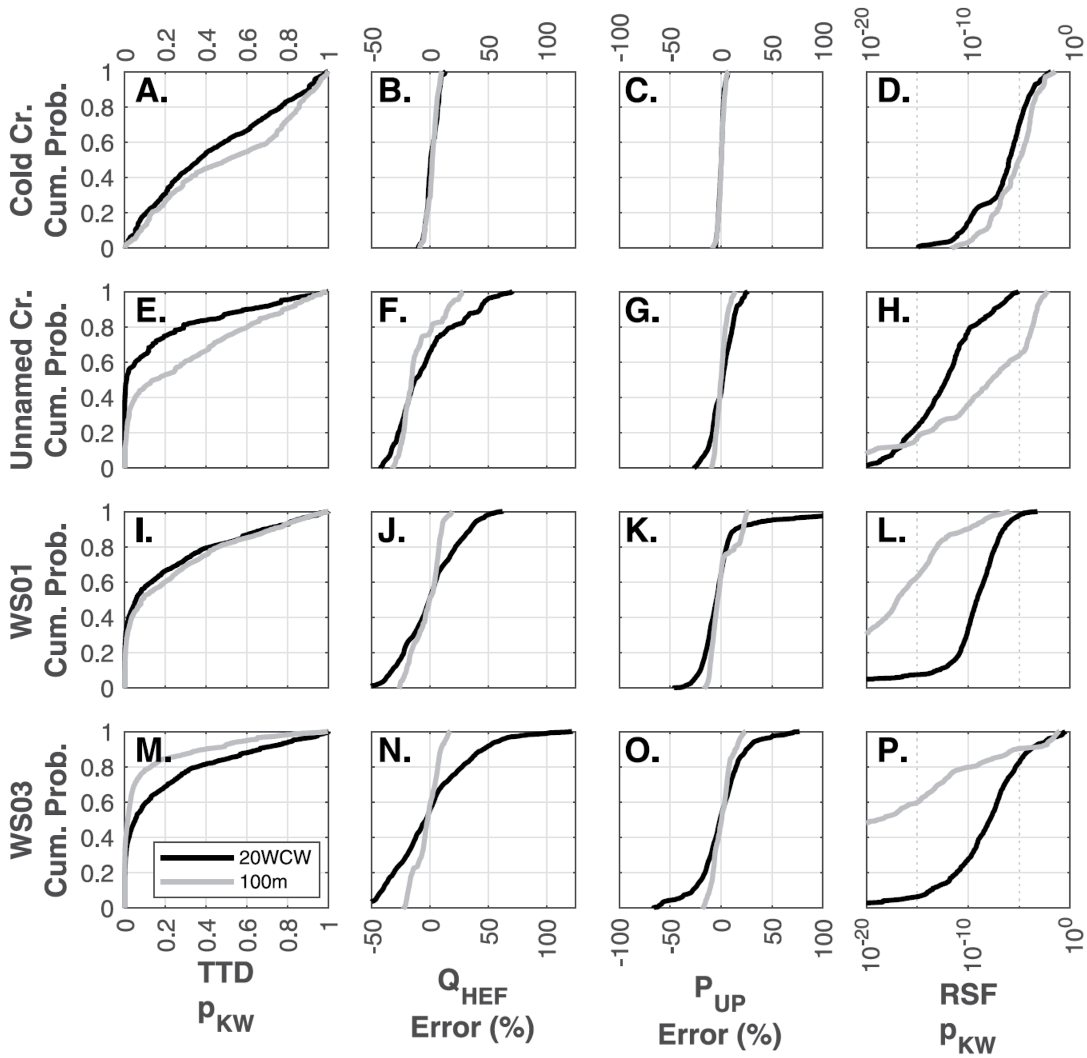

Figure 2 in Becker et al. 2023. Cumulative distribution functions of both *pkw* and percent error values for the four metrics: TTD (left column), Q_{hef} (middle-left column), P_{up} (middle-right column), and RSF (right column). Rows from top to bottom are Cold Creek, Unnamed Creek, WS01, and WS03. In all cases, results for 20WCW reaches are shown in solid black, and 100-m reaches are shown in solid gray. For panels (a, d, e, h, i, l, m, and p), a greater portion *pkw* above 0.10 indicates better representativity compared to the reference reach. For panels (b, c, f, g, j, k, n, and o), a greater portion within ±10% (the narrower the line is), indicates more representativity to the reference reach.

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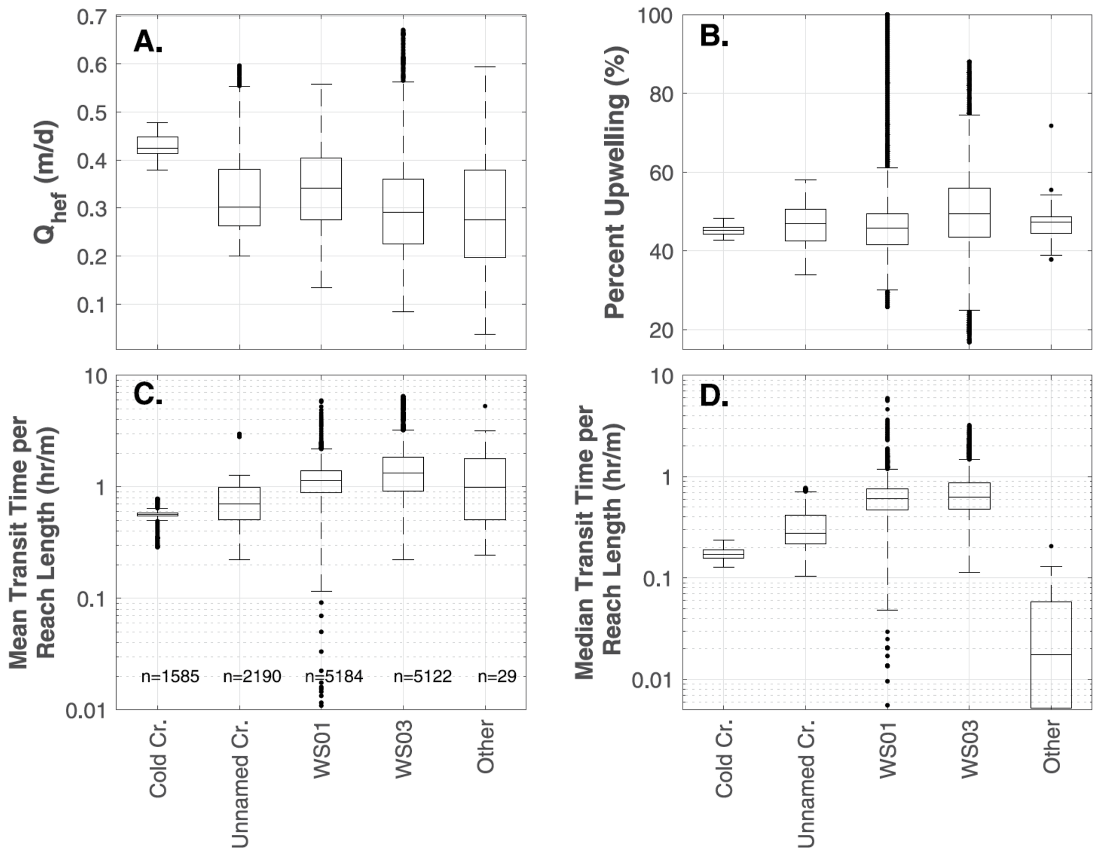

Figure 4 in Becker et al. 2023. Comparison of exchange metrics between and within sites of a fifth order basin for 20WCW reaches. Panel (A) is showing *Q*hef (m/s) for all 20WCW windows of the four reference segments and the 29 other sites. Panel (B) is percent of particles upwelling (*P*up). Panel (C) is average transit time distribution normalized by reach length (hr/m), and (D) is median transit time distribution normalized by reach length (hr/m).

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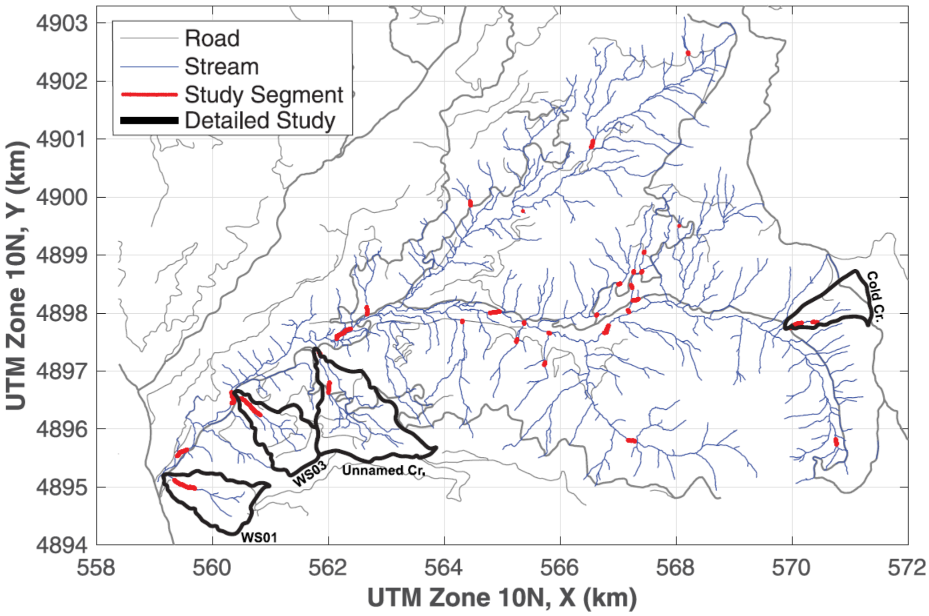

Figure 1 in Becker et al. 2023. Maps of the HJ Andrews including the road network (gray), stream network (blue), and study sites (red). The four catchments outlined in black are those where more detailed surveys and simulations were included to assess within-site variation. Catchments, roads, and streams follow exactly those detailed in Ward, Wondzell, et al. (2019).