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Characterizing Hyporheic Extent with Electrical Resistivity and Concentration Breakthrough Curves

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What is the Hyporheic Zone?

The hyporheic zone (Figure 1) is an area located around a stream that is composed of sediment saturated with stream water (Boano et al., 2014)

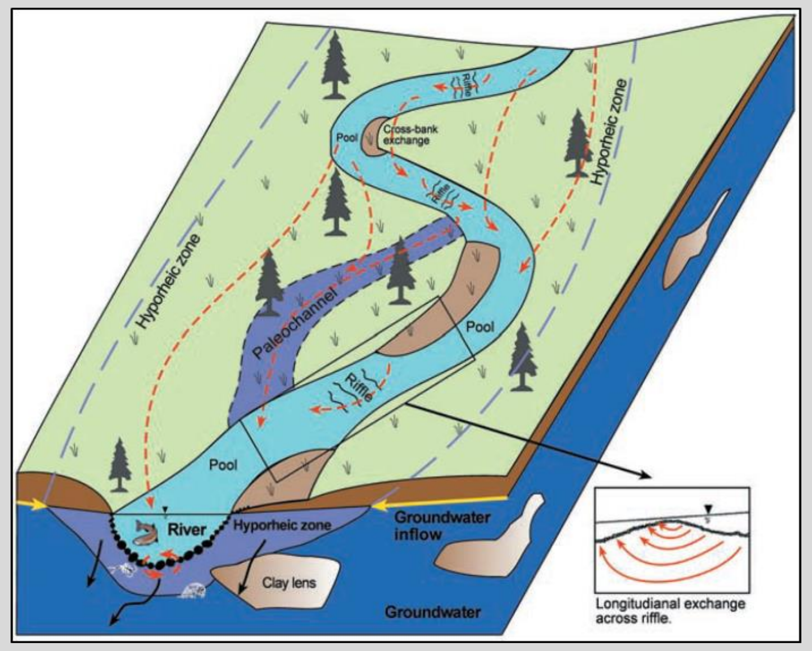


Figure 1: Diagram of a stream including hyporheic zone. From Buffington & Tonina, 2009

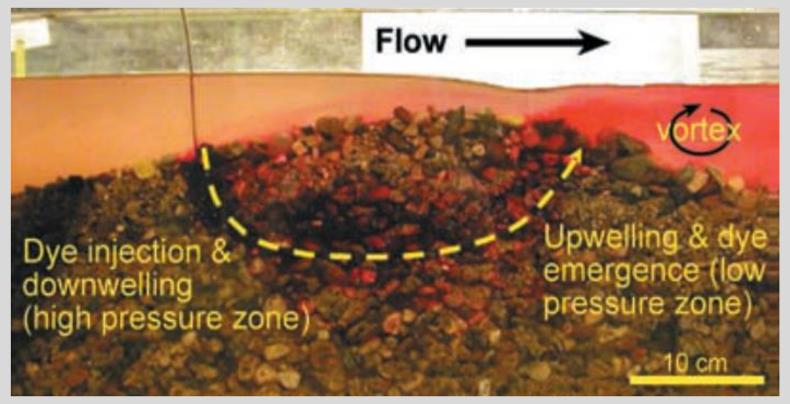


Figure 2: Hyporheic exchange is created by pressure difference in a dune-like structure in the bedform. The exchange path is highlighted in red dye where it enters the subsurface upstream and returns to the surface water downstream From Buffington and Tonina, 2009

The hyporheic zone acts as an interface where instream flow and groundwater can be exchanged

Hyporheic flow exchange (HEF) influences many aspects of a stream including: habitat, water-temperature fluctuation, nutrient exchange, and biochemical processes

Geomorphological complexity is shown to increase HEF

Characterizing Hyporheic Exchange

Injection of NaCl Stream Tracer

Conductivity Measurements
- ER Meter (Bulk)
- EC Transducers (Fluid)

Breakthrough Curves
- Temporal Moment (Skew)
- Hysteresis

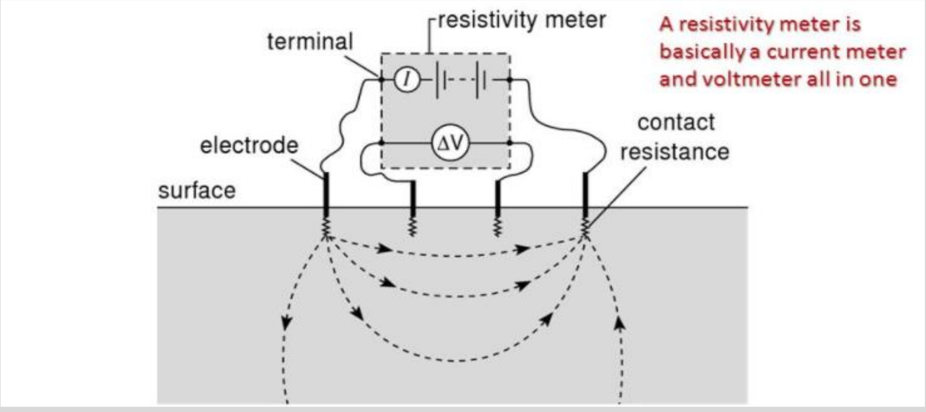


Figure 3: Diagram of a resistivity meter: Where current (I) is injected and volt (V) are measured. Image courtesy of Appalachian State University

We used the geometric factor K, ($K = \frac{2\pi}{\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}}$) where A and B are current (I) injecting electrodes and M and N are the voltage (volt) electrodes. Resistivity is the inverse of conductivity. So $\sigma_a = \frac{I}{K(V)}$, where σ_a is bulk apparent conductivity. Calculations done in MATLAB.

Study Site

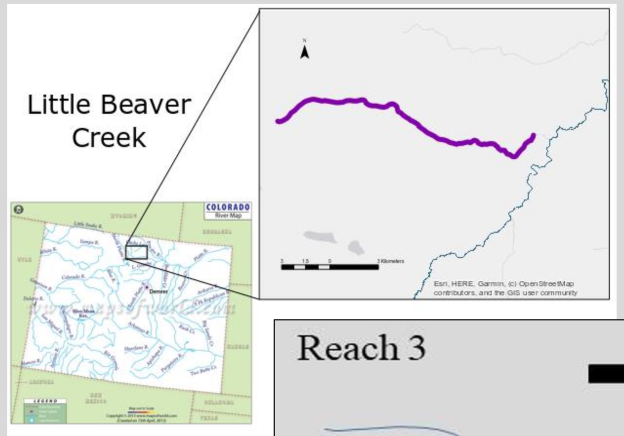
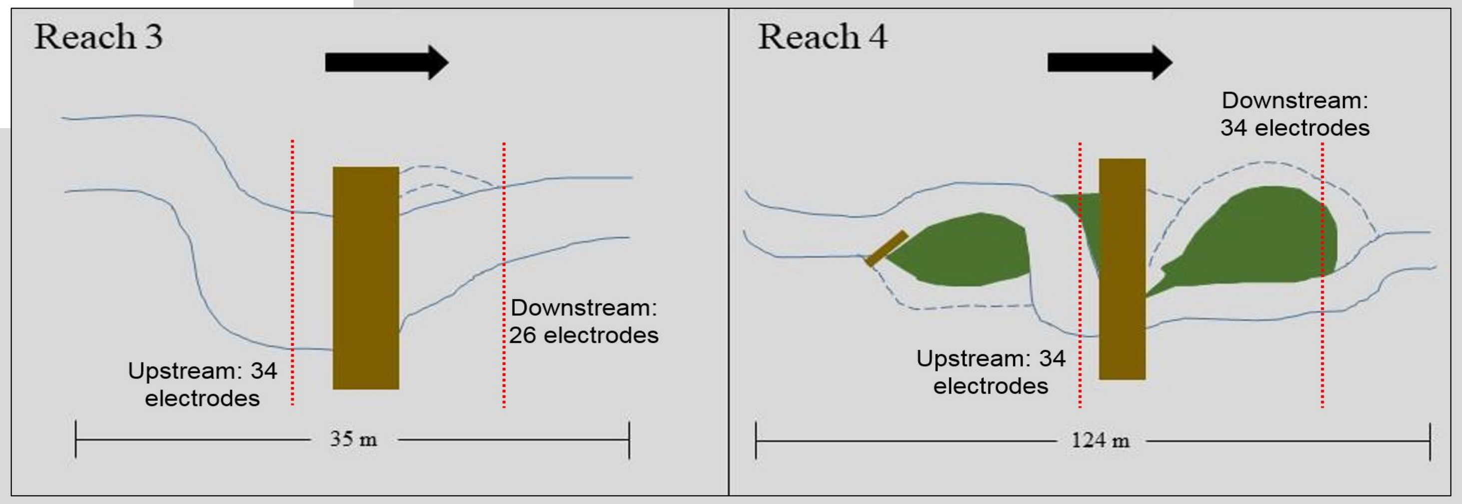


Figure 4: Little Beaver Creek. A third-order tributary to the Cache la Poudre River, which lies within the Poudre Canyon

Two experimental reaches that both contain channel-spanning logjams and complex geomorphological and spatial heterogeneity

Figure 5: Aerial view of Reaches 3 and 4 (approximation). Arrow indicates flow direction, solid blue lines are main channels, blue dotted-lines are side channels, brown squares are logjams, red dotted-lines are transects. Modified from Ader, 2019



Results

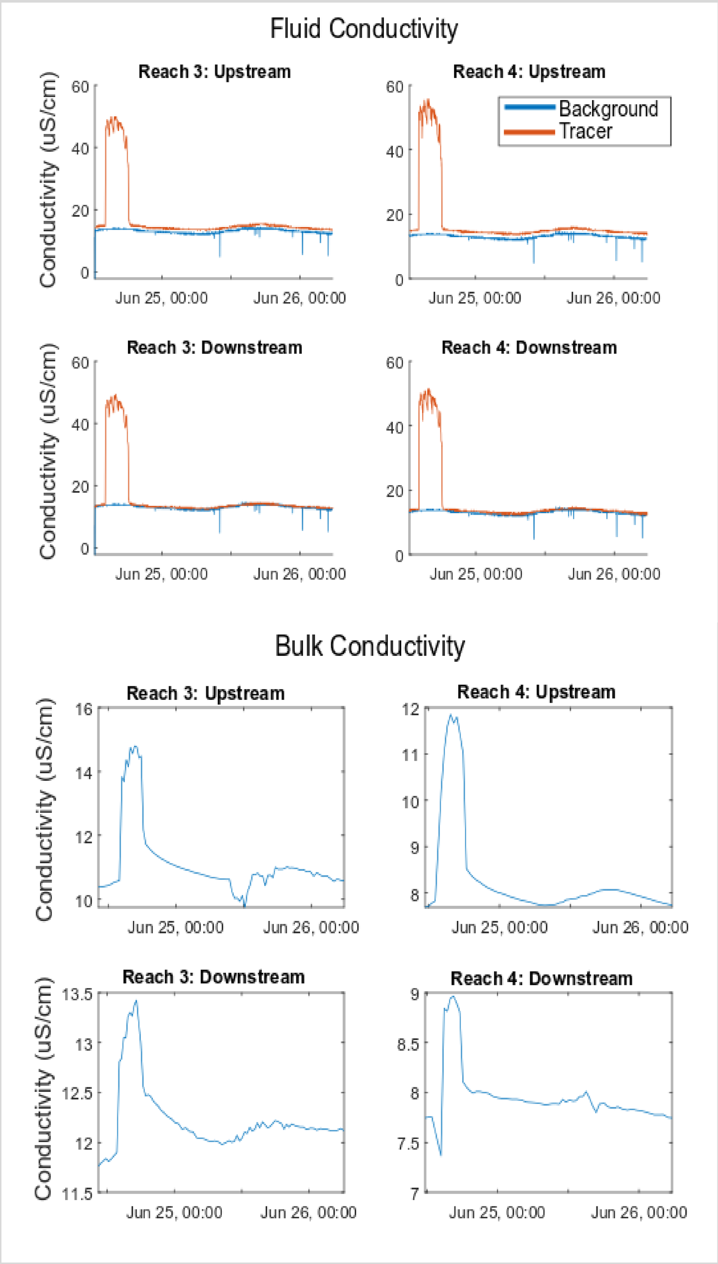


Figure 6: Breakthrough curves (BTC) created by plotting conductivity (Y-axis) through time (X-axis) from second tracer test

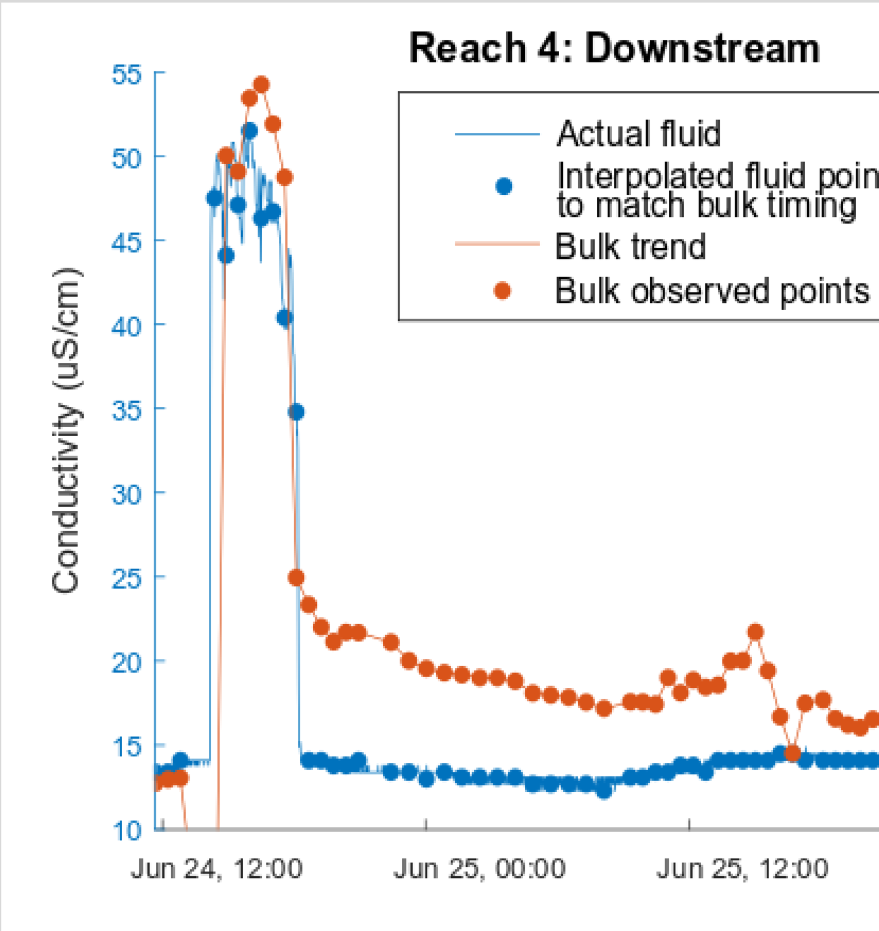


Figure 7: Fluid (blue) and bulk (orange) conductivity breakthrough curves overlain. Both Y-axis scales in uS/cm. Measurements from second tracer test, transect downstream of logjam in Reach 4

Discharge (m^3/s)	
June 04	0.58
June24	1.1

Figure 8: Average discharge during both tracer tests. Measured by stream gauging

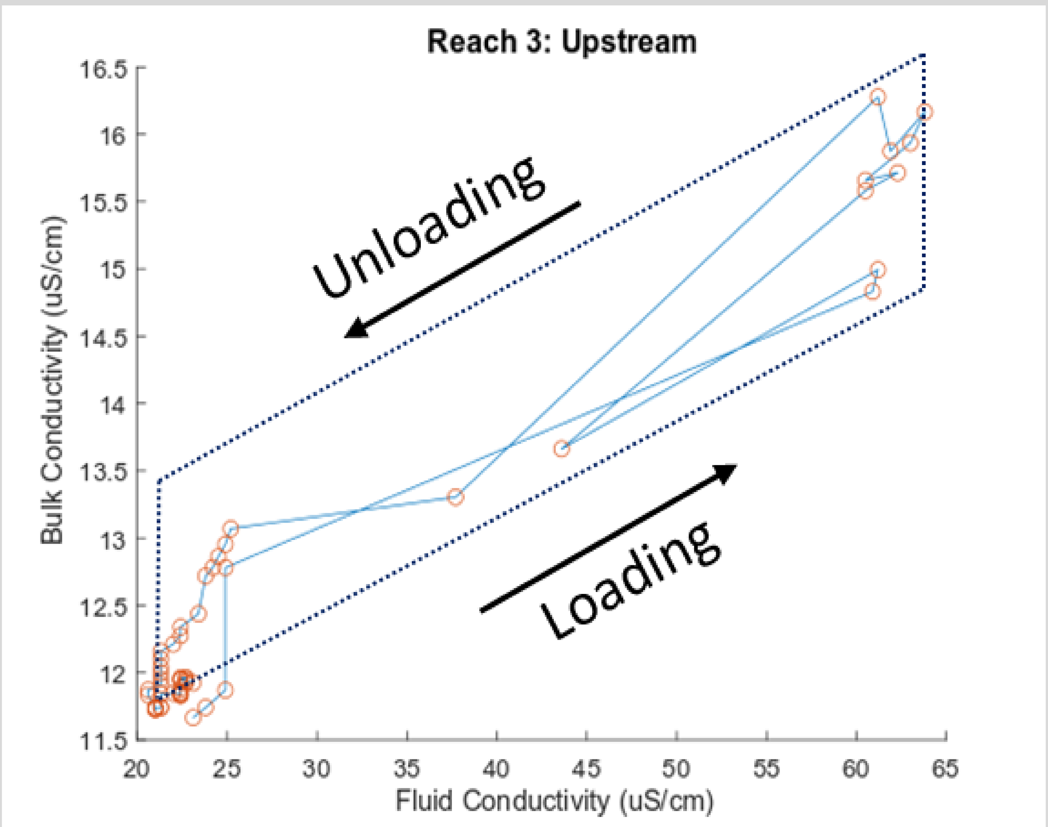


Figure 9: Hysteresis plot. Red circles represent data points. Blue line represents interpolation. Violet dotted-line represents approximation of ideal hysteresis loop

Fluid Conductivity Skew Calculations			Bulk Conductivity Skew Calculations		
	June 04	June 24		June 04	June 24
R3: Lower	1	230	R3: Lower	620	680
R3: Upper	0	22	R3: Upper	800	1000
R4: Lower	0	54	R4: Lower	700	630
R4: Upper	0	53	R4: Upper	700	1000

Figure 10: Skew calculations describe the asymmetry of the curve. Larger, positive values indicate more tailing behavior (Ward et al., 2010).

Conclusions

- Using electrical resistivity and conductivity measurements, coupled with a conservative stream tracer, is an **effective method** that allows for the characterization of hyporheic exchange flow
- All our **breakthrough curves** using measured conductivity from experimental reaches have **similar patterns**:
    - When comparing fluid versus bulk conductivity there is noticeable **tailing,** or slower gradual return to background levels in bulk conductivity which indicates **solute retention** and **slower transport**
- By plotting breakthrough curves and analyzing the temporal moments and hysteresis, we can characterize hyporheic exchange flow in **complex** reaches of a stream
- Higher average **discharge** rate and **more geomorphological complexity** produced more **tailing** and **higher skew** calculations which suggests **higher hyporheic flow exchange**
- Data we have collected can be used as a comparison to any river or **stream remediation/sustainability** efforts including engineered stream beds and contaminant transformation

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