Mixing Downstream of Stream Confluences Alters Carbon and Nutrient Cycling in Freshwater Networks

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November 24, 2022

Abstract

Stream confluences are ubiquitous features in freshwater networks, have distinct hydrogeomorphic characteristics relative to upstream tributaries and downstream reaches, and serve as junctions of previously independent streams. Confluences may enhance or disrupt biological processes. How ecosystem functions (e.g., carbon metabolism, nutrient removal) change at confluences remains a knowledge gap in our understanding of the processes controlling water quality at the network-scale. To test how carbon and nutrient cycling may differ between confluences and their tributaries, we estimated dissolved organic carbon (DOC) and PO43- uptake in October 2018 and July 2019 in two tributary reaches as well as downstream of their confluence mixing zone using pulse injections of roasted barley leachate (a standardized, colored DOC source), K2HPO4, and NaCl (a non-bioreactive tracer). We hypothesized that biological processes would be enhanced at confluences due to the delivery and mixing of different microbial communities and/or carbon and nutrient sources. We calculated PO43- and DOC uptake velocities (vf-PO4, vf-DOC) and compared them across sites and season. In October 2018, vf-PO4 in each tributary was 10.2 and 4.9 mm/min while vf-DOC was 0.84 and 0.38 mm/min. vf-PO4 downstream (6.6 mm/min) was lower than vf-PO4 predicted from a mixing model of upstream vf-PO4 and proportional flow contributions of tributaries (10.1 mm/min), suggesting in-stream PO43- uptake was suppressed as a result of confluence mixing. Conversely, vf-DOC downstream (0.94 mm/min) was higher than vf-DOC predicted from a mixing model (0.75 mm/min). This difference in measured and predicted vf-DOC was supported by bioassay experiments, which found enhanced DOC uptake downstream of the mixing zone. DOC uptake within the confluence mixing zone was spatially heterogeneous (0.00 to 0.19 day-1) and varied more within mixing zone transects than among the two tributary reaches. Ongoing analyses are comparing uptake estimates among seasons. Our results suggest that DOC and PO43- uptake at confluences cannot be estimated from tributary DOC and PO43- uptake alone. A critical next step in this work is to identify the mechanisms behind confluence-derived changes in carbon metabolism and nutrient removal across freshwater networks.

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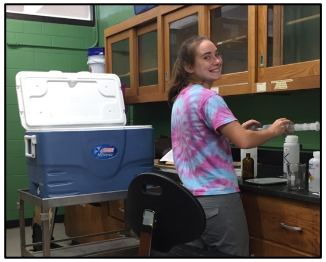
Acknowledgements

- **Funding Sources**
  - NSF Graduate Research Fellowship
  - Society for Freshwater Science Endowment
  - NSF DEB 1754237

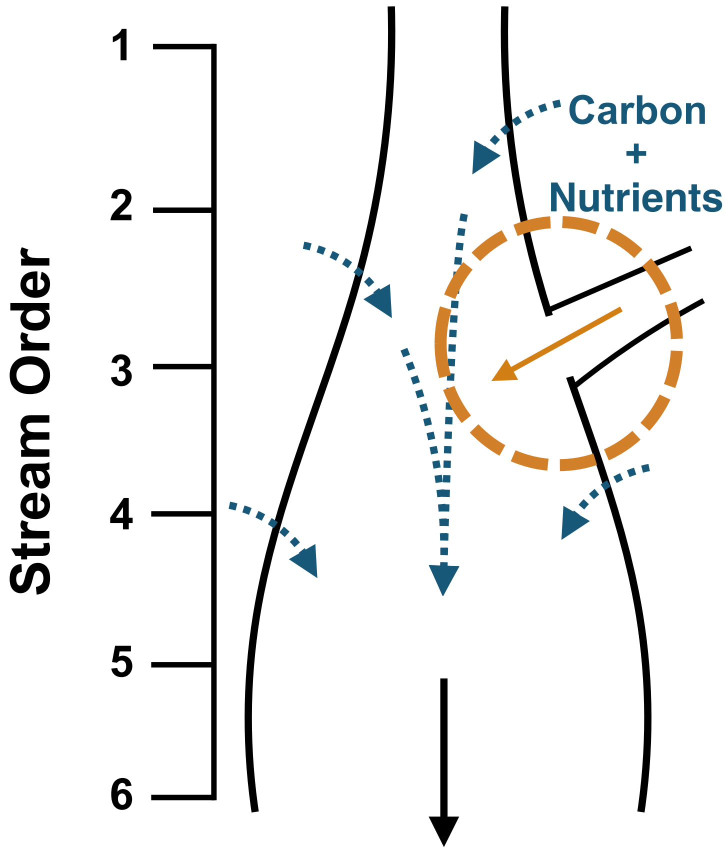
- Field and Lab Assistance from VT Stream Team, Hotchkiss Lab, Jacob Diamond

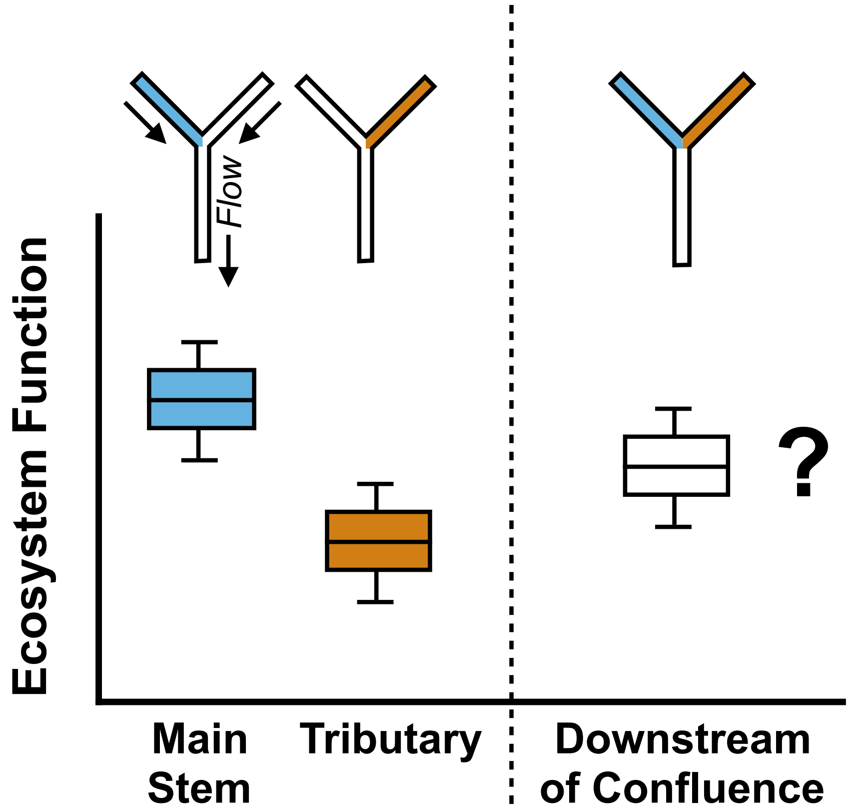
- Bob Hall, Michelle Baker for method development



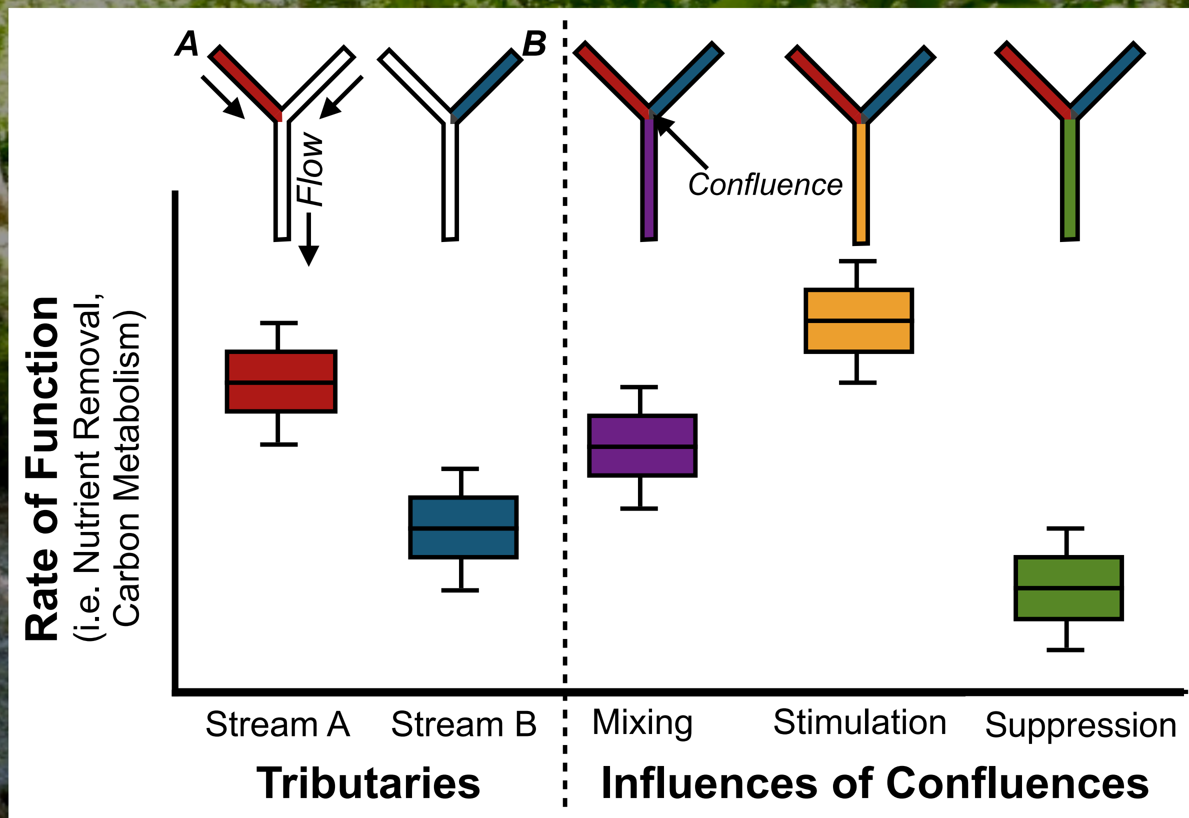
What are the roles of confluences in ecosystem function?

Stream Continuum + Confluence Effects



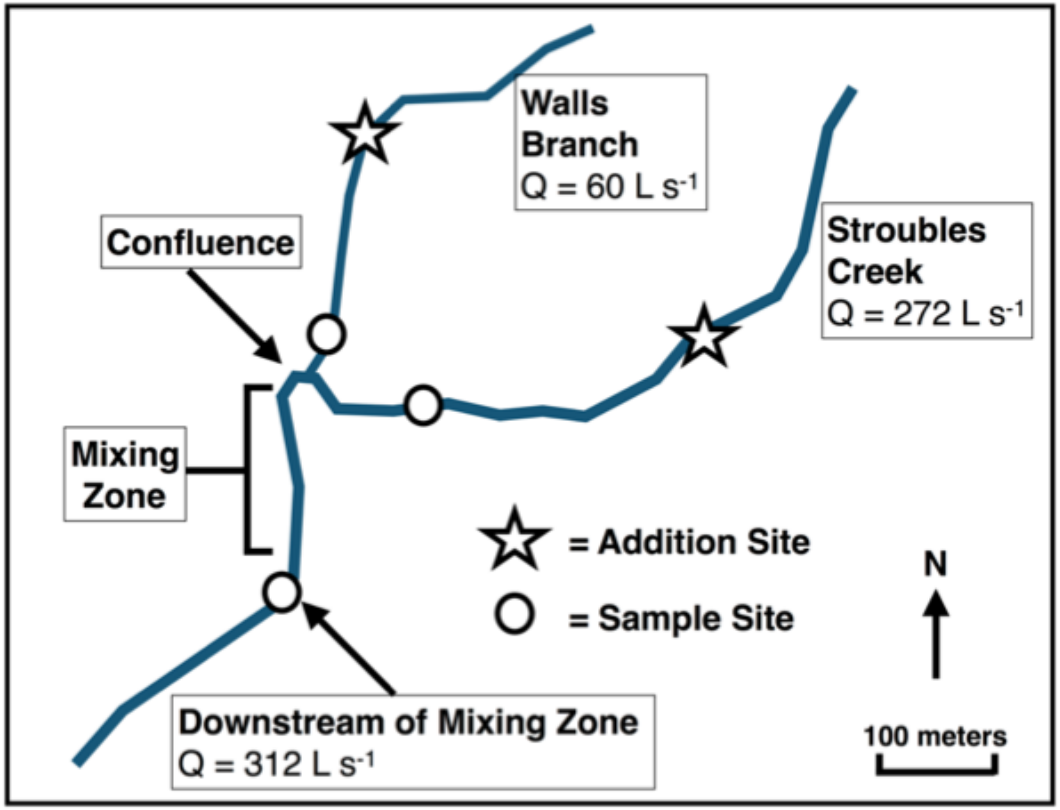


How do stream confluences influence the fate of carbon and nutrients?

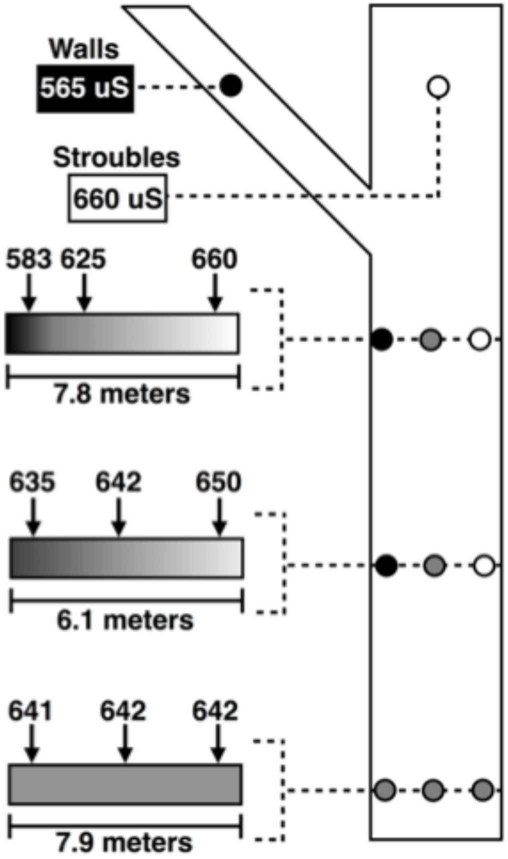


Stroubles-Walls Confluence

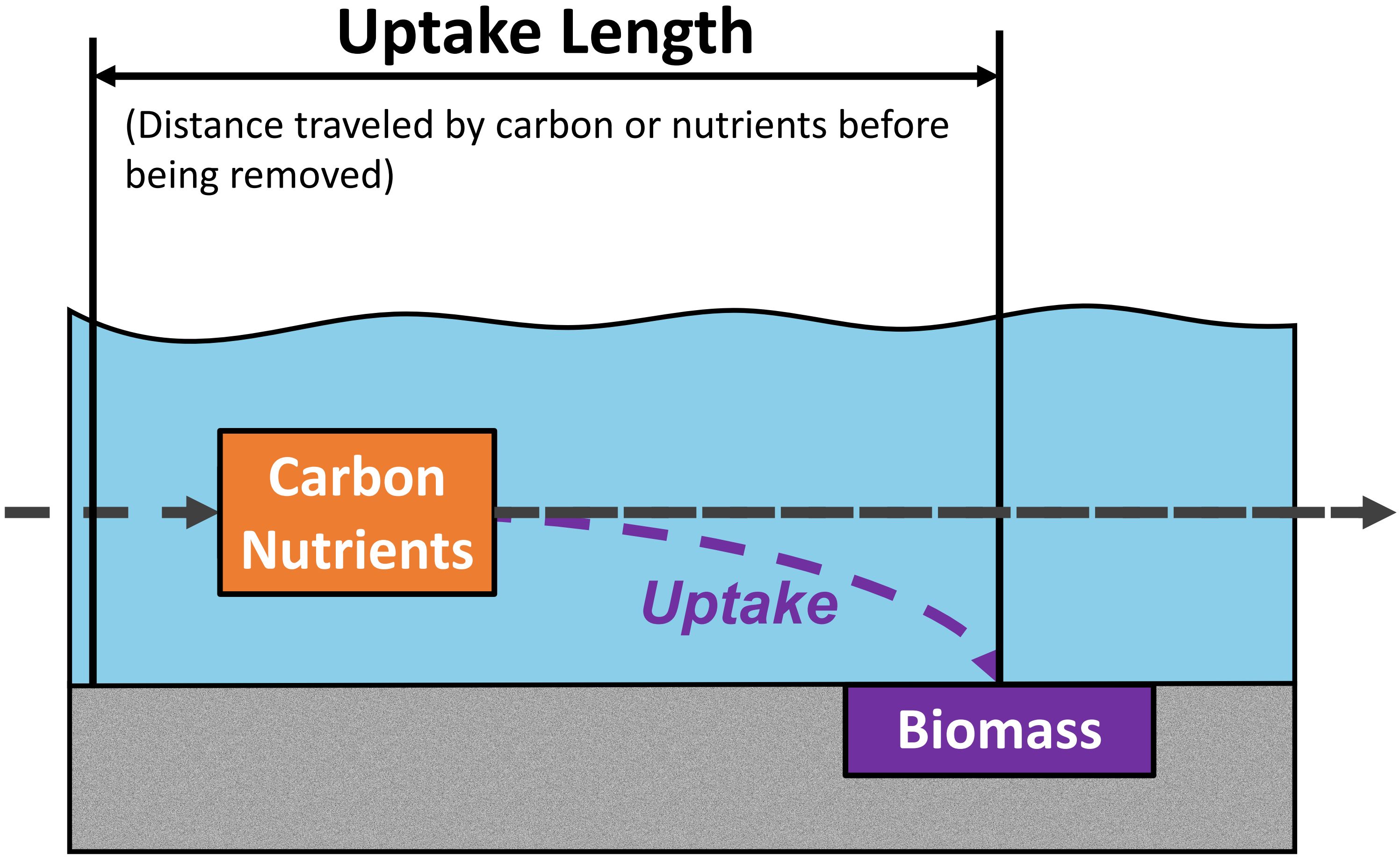
Urban/Agricultural catchment, High NO_3^- and conductivity



Confluence mixing zone mapped using conductivity



Linking Process (Biology) and Transport (Hydrology)



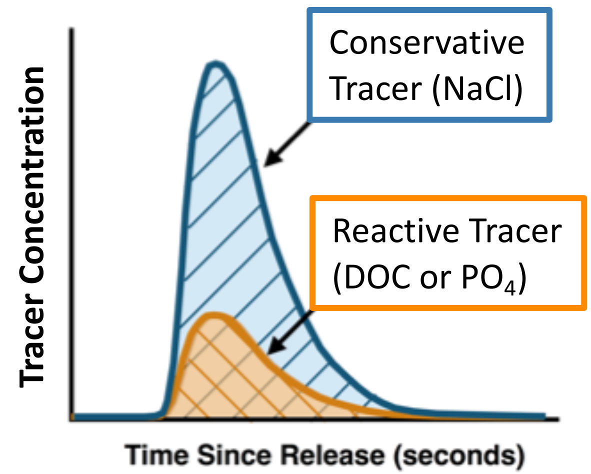
Confluence DOC and PO4 Uptake Experiments

- DOC, PO_4, and NaCl pulsed in each tributary

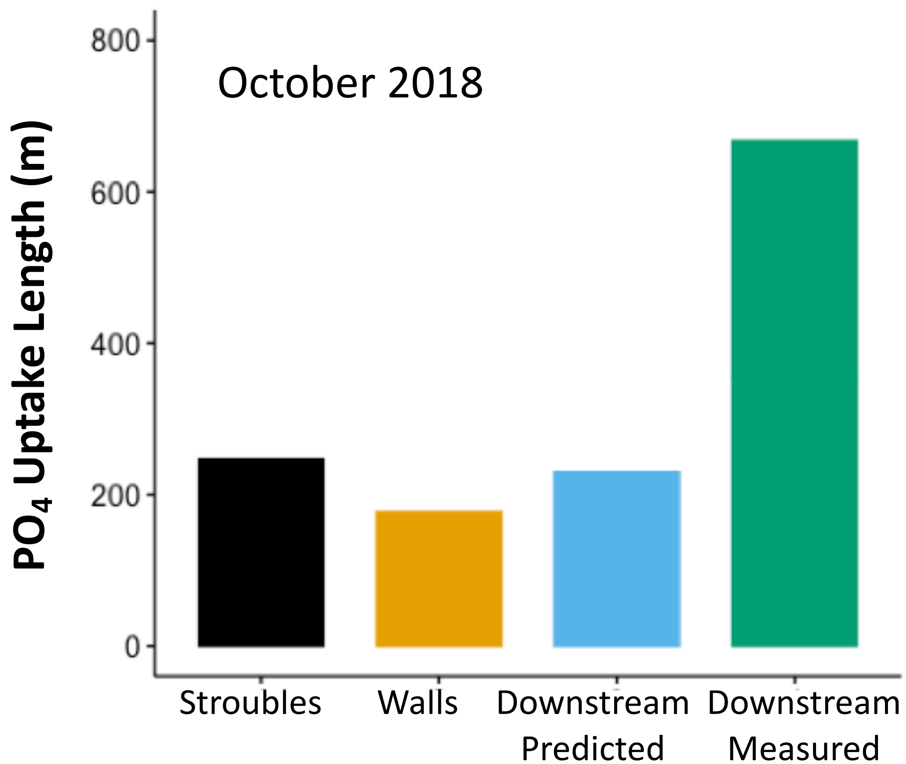
- Measured changes in concentration in tributaries and downstream of confluence mixing zone

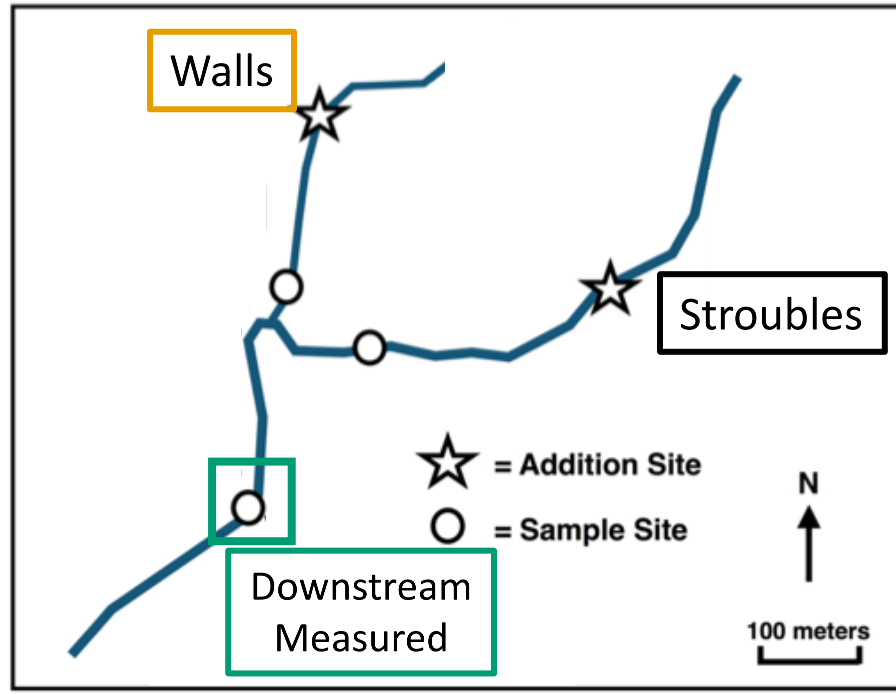
- Roasted Barley Leachate as a DOC source
  - Similar bioavailability to ambient stream DOC

- Calculated DOC and PO_4 uptake length
  - Breakthrough curve integration method (Tank et al., 2008 Ecology)



PO_4 Uptake Suppressed Downstream

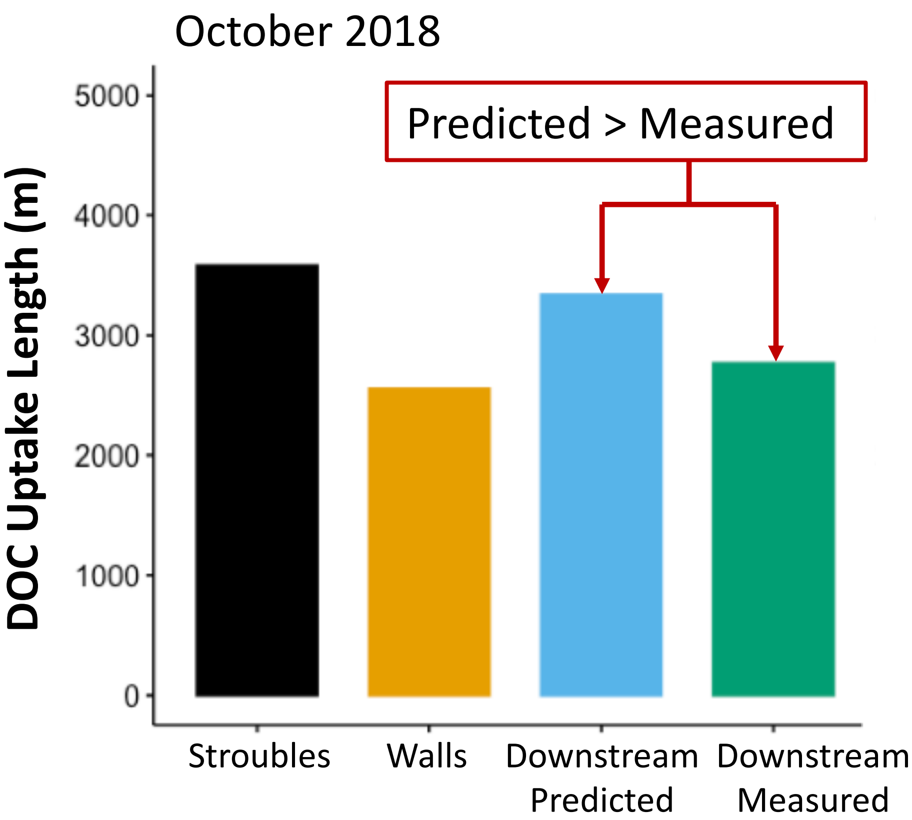


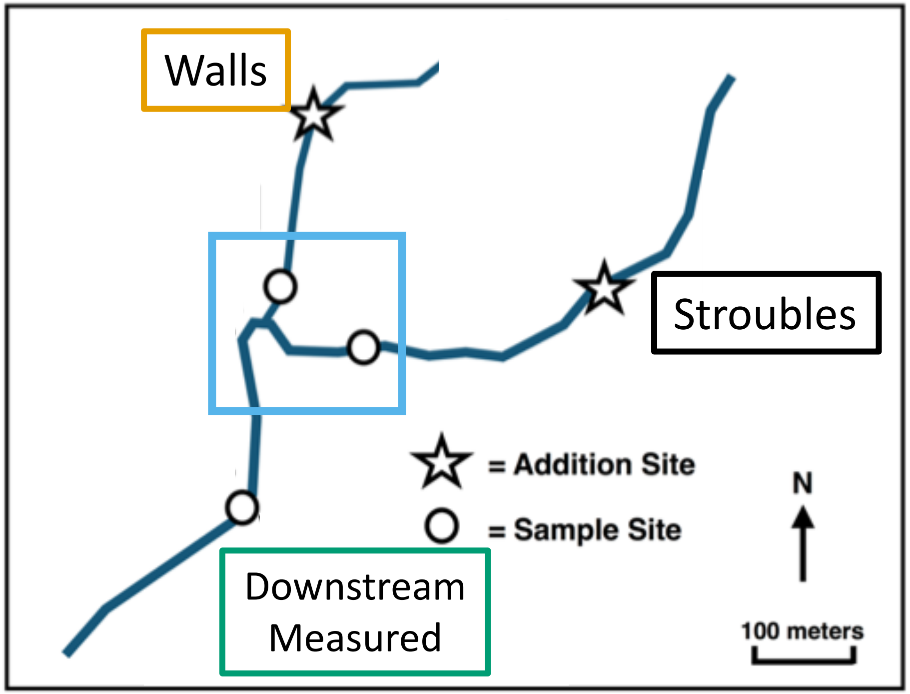


Downstream Predicted Uptake* = Stroubles Uptake* + Walls Uptake*

*corrected for changes in discharge

DOC Uptake Stimulated Downstream



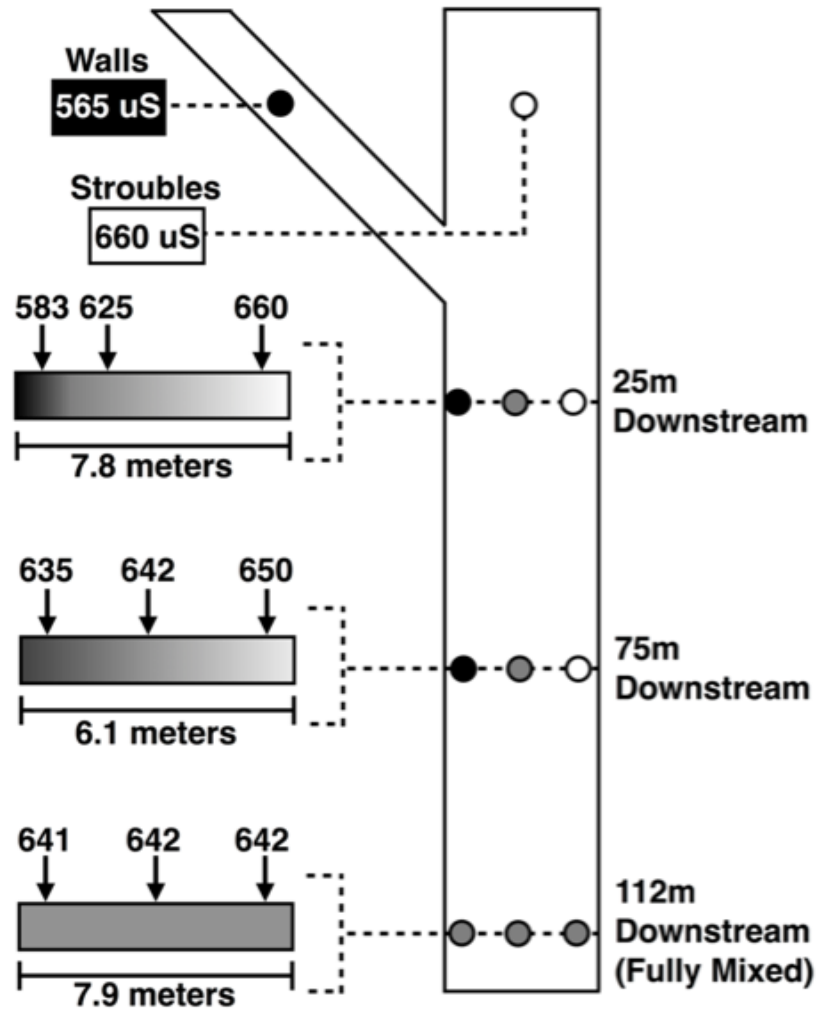


Downstream Predicted Uptake* = Stroubles Uptake* + Walls Uptake*

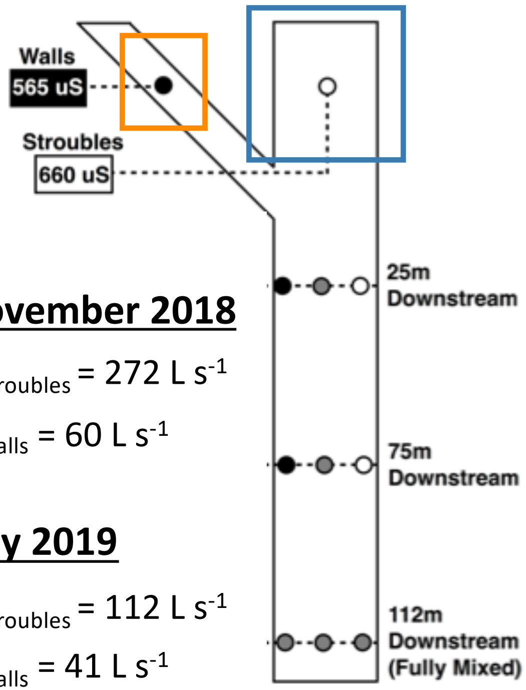
*corrected for changes in discharge

Removal within Confluence Mixing Zone

- Mixing of tributaries assessed using conductivity
- Water collected from transects in confluence mixing zone
- Bioassays to measure water column DOC uptake
- Enriched with roasted barley leachate (2 mg DOC L^{-1})
- Mixing model of tributaries for **predicted DOC uptake**



DOC Uptake Spatially and Temporally Variable in Mixing Zone



November 2018

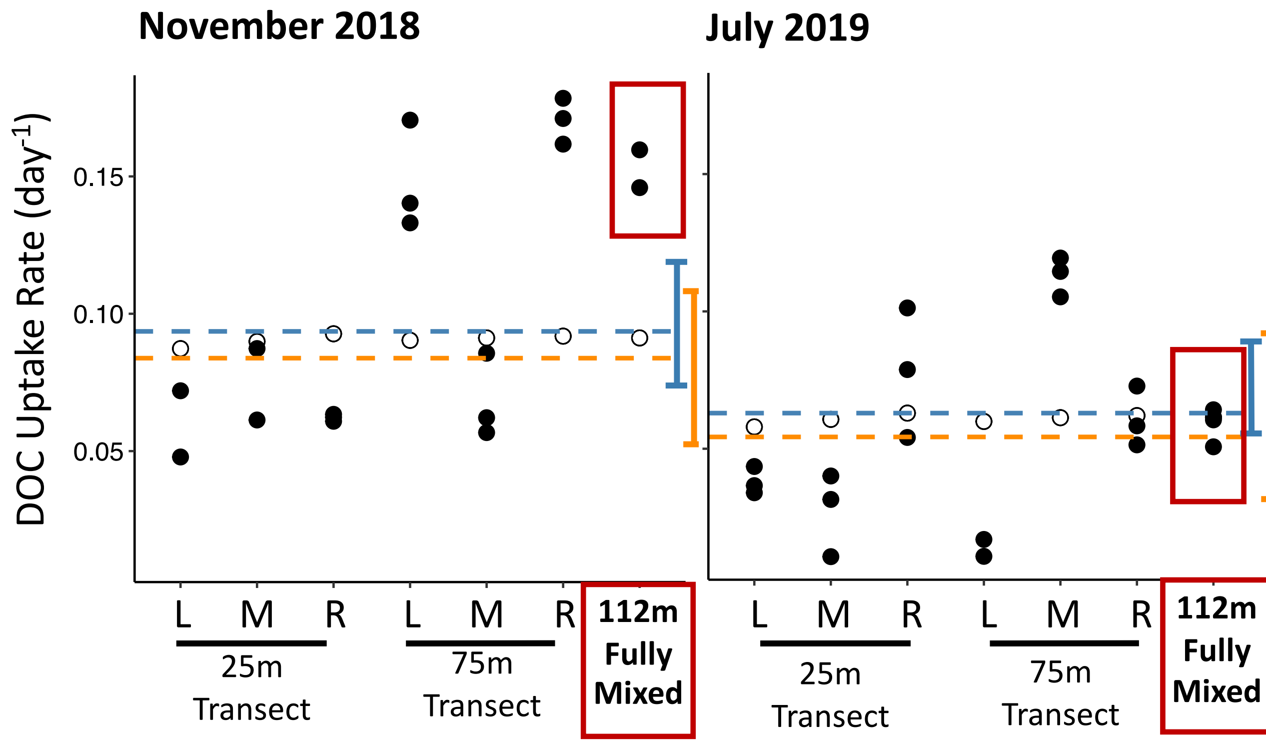
$Q_{stroubles} = 272\ L\ s^{-1}$

$Q_{walls} = 60\ L\ s^{-1}$

July 2019

$Q_{stroubles} = 112\ L\ s^{-1}$

$Q_{walls} = 41\ L\ s^{-1}$



● = Measured DOC Uptake Rate

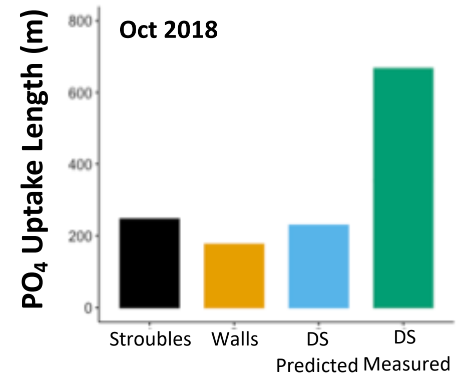
○ = Predicted DOC Uptake Rate

= Stroubles Creek DOC Uptake Rate Range

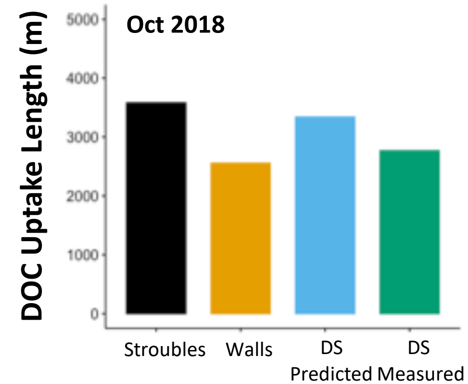
= Walls Branch DOC Uptake Rate Range

Concluding Remarks

- PO_4 uptake length was longer downstream of confluence than predicted → suppression?



- DOC uptake length was shorter downstream of confluence than predicted → stimulation?



- Bioassay DOC uptake was spatially and temporally dynamic and more variable in mixing zone than tributaries