"Taking Stormwater Quality Management to New Heights"

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Predicting Ecosystem Services in Urban Streams

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Outline

- **Introduction:** Ecosystem services in streams and my research goal
- **Background:** Physical drivers of Hyporheic Exchange
- **Current State-of-the-art:** Predicting carbon removal and denitrification
- **Conclusions and Future Work**

❖ Introduction

Urban Stream Syndrome

Urbanization

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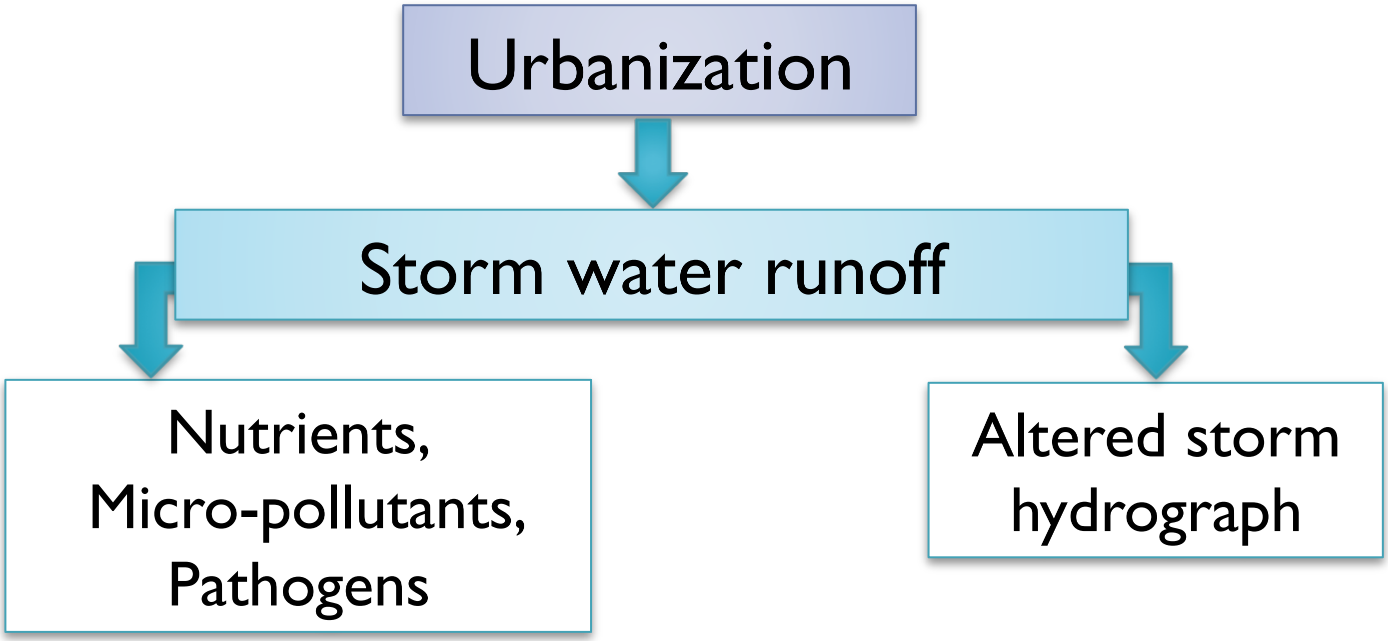
Storm water runoff

Urban Stream Syndrome



Urban Stream Syndrome

Urbanization

Storm water runoff

Nutrients, Micro-pollutants, Pathogens

Altered storm hydrograph

Reduced stream health

- Ecosystem health
- Human health

Reversing the Urban Stream Syndrome

Storm water runoff

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Capture, treat, and reuse locally

Reversing the Urban Stream Syndrome

Storm water runoff

↓

Capture, treat, and reuse locally

- LID elements
- Biofilters
- Constructed wetlands

Reversing the Urban Stream Syndrome

Storm water runoff

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Improved Stream Health

- Reduced pollutant loading
- Pre-urban storm hydrograph
- **Restore natural ecosystem services**

Hyporheic Exchange drives ecosystem services (e.g. Dissolve Organic Carbon (DOC) removal and Denitrification) in healthy streams

- **Hyporheic Zone:** the sediment beneath and immediately adjacent to a stream.
- **Hyporheic Exchange:** the circulation of water between the stream and the hyporheic zone.

Hyporheic Exchange

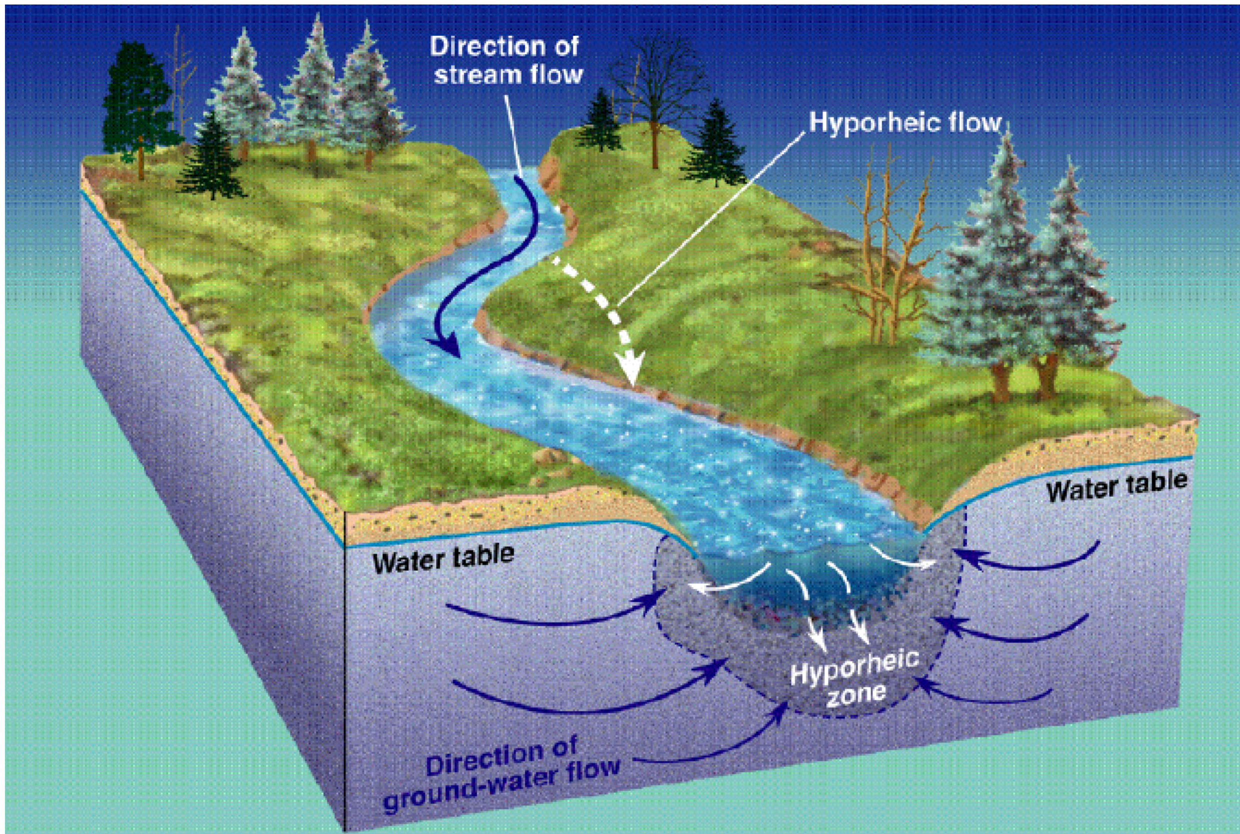
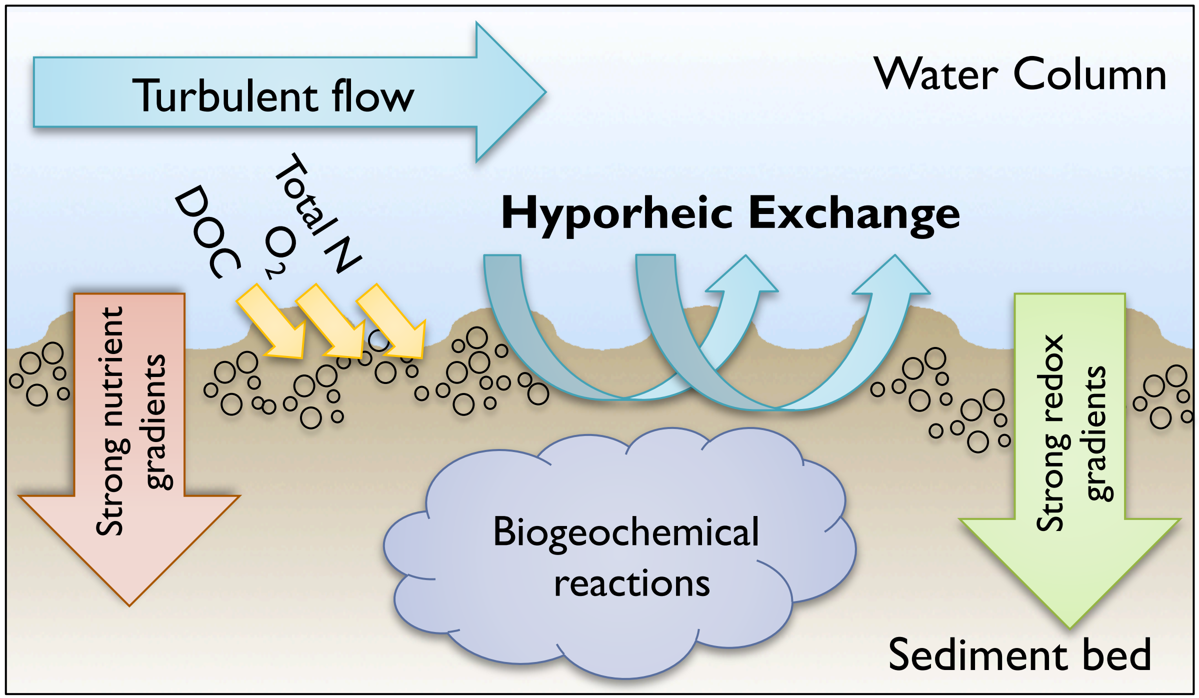


Figure from: Bencala (2005) "Hyporheic exchange flows. In: Anderson MG and Mc Donnell JJ (Eds), Encyclopedia of Hydrological Sciences."

How are ecosystem services and hyporheic exchange related?



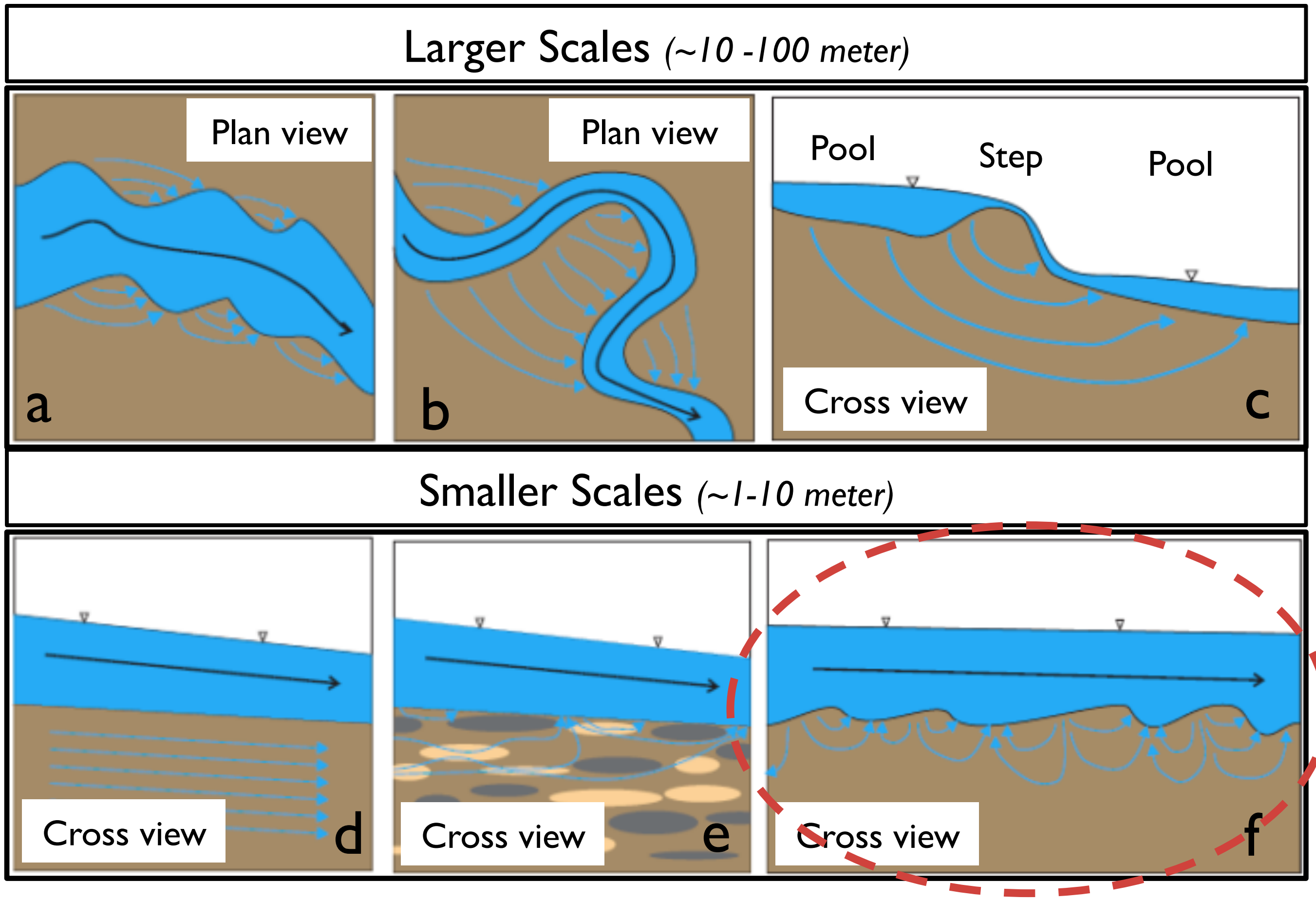
Hyporheic Zone is the ‘liver of the river”

My Research Goal

To develop practically useful and scientifically sound models for ecological services provided by in-stream hyporheic exchange

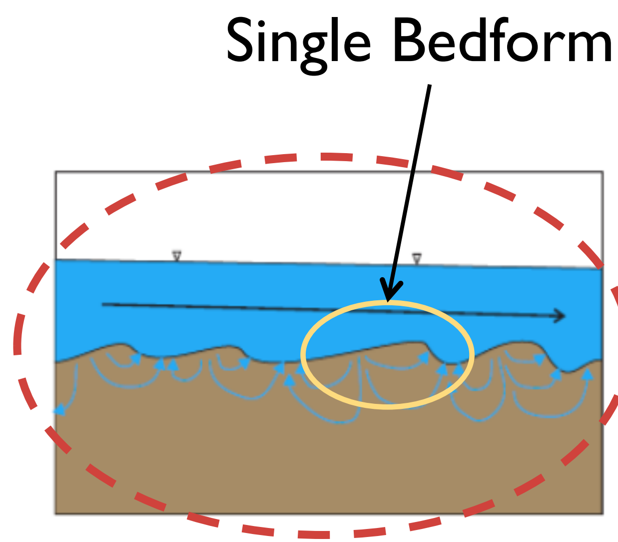
- Background: Physical Drivers of Hyporheic Exchange

Stream geomorphology controls hyporheic exchange, which occurs over a range of spatial scales

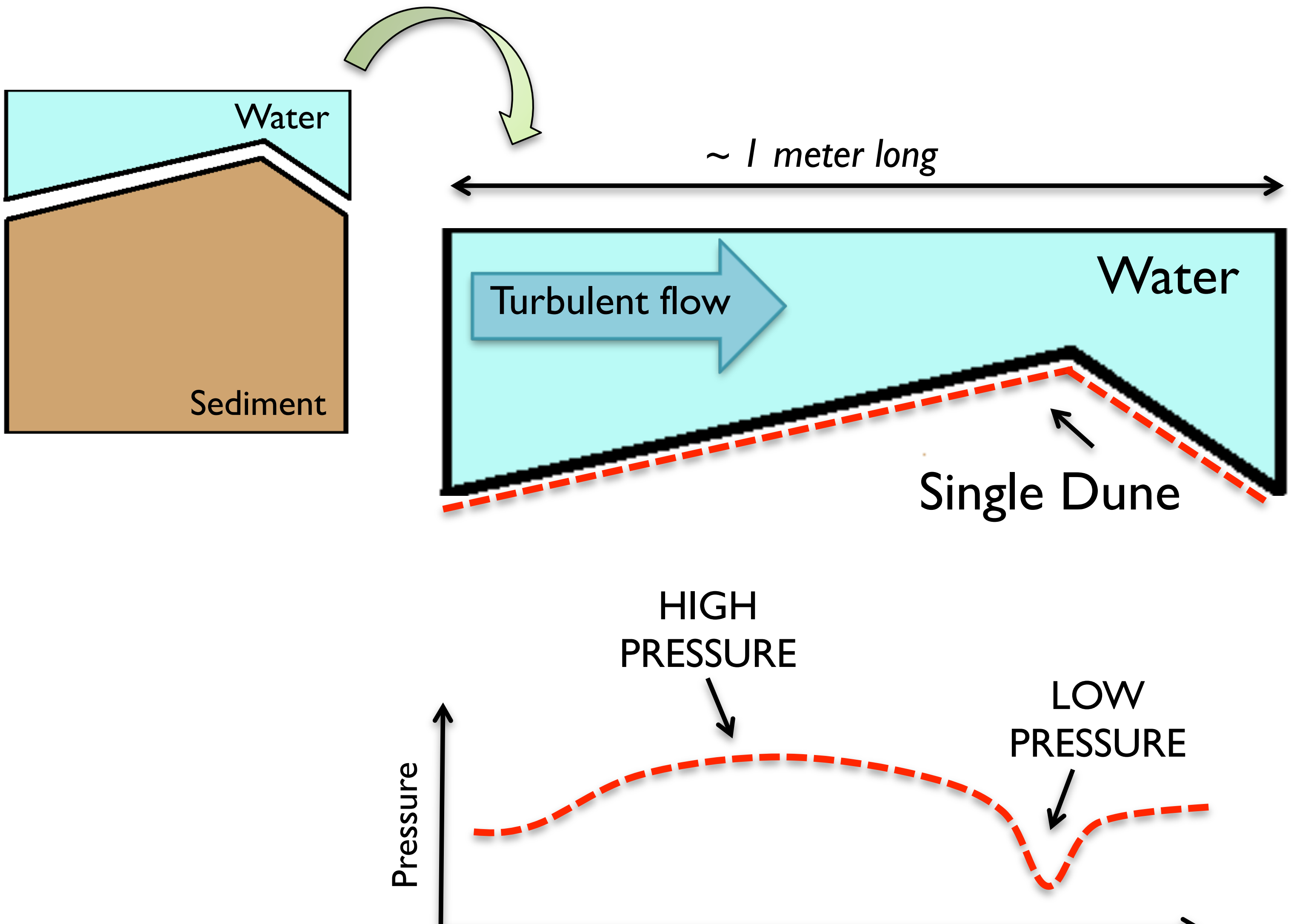


Figures from: "The Hyporheic Handbook: A handbook on the groundwater – surface water interface and hyporheic zone for environment managers"

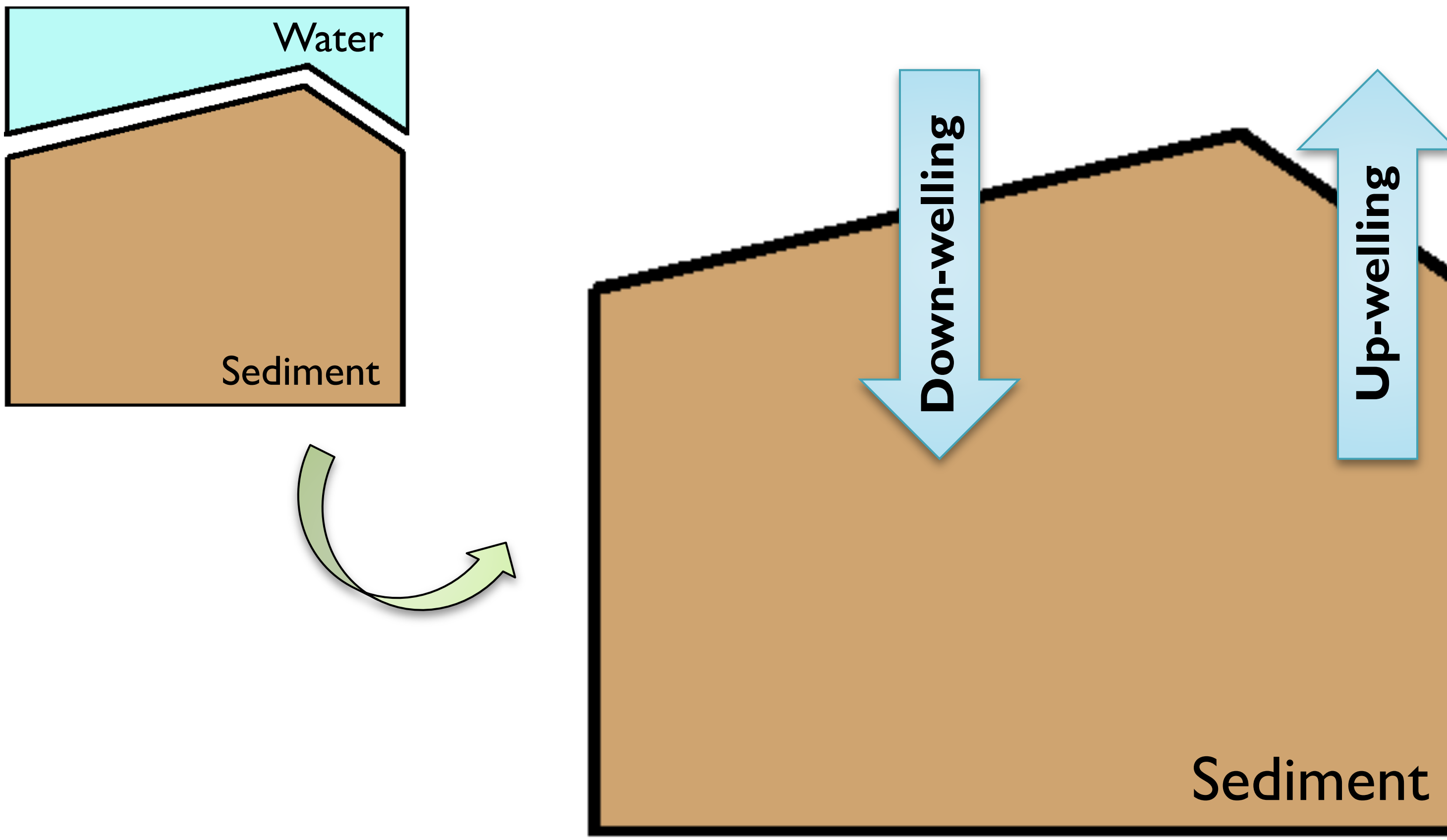
Much of the ecosystem services provided by hyporheic exchange occur at the scale of a sediment bedform (dunes and ripples)



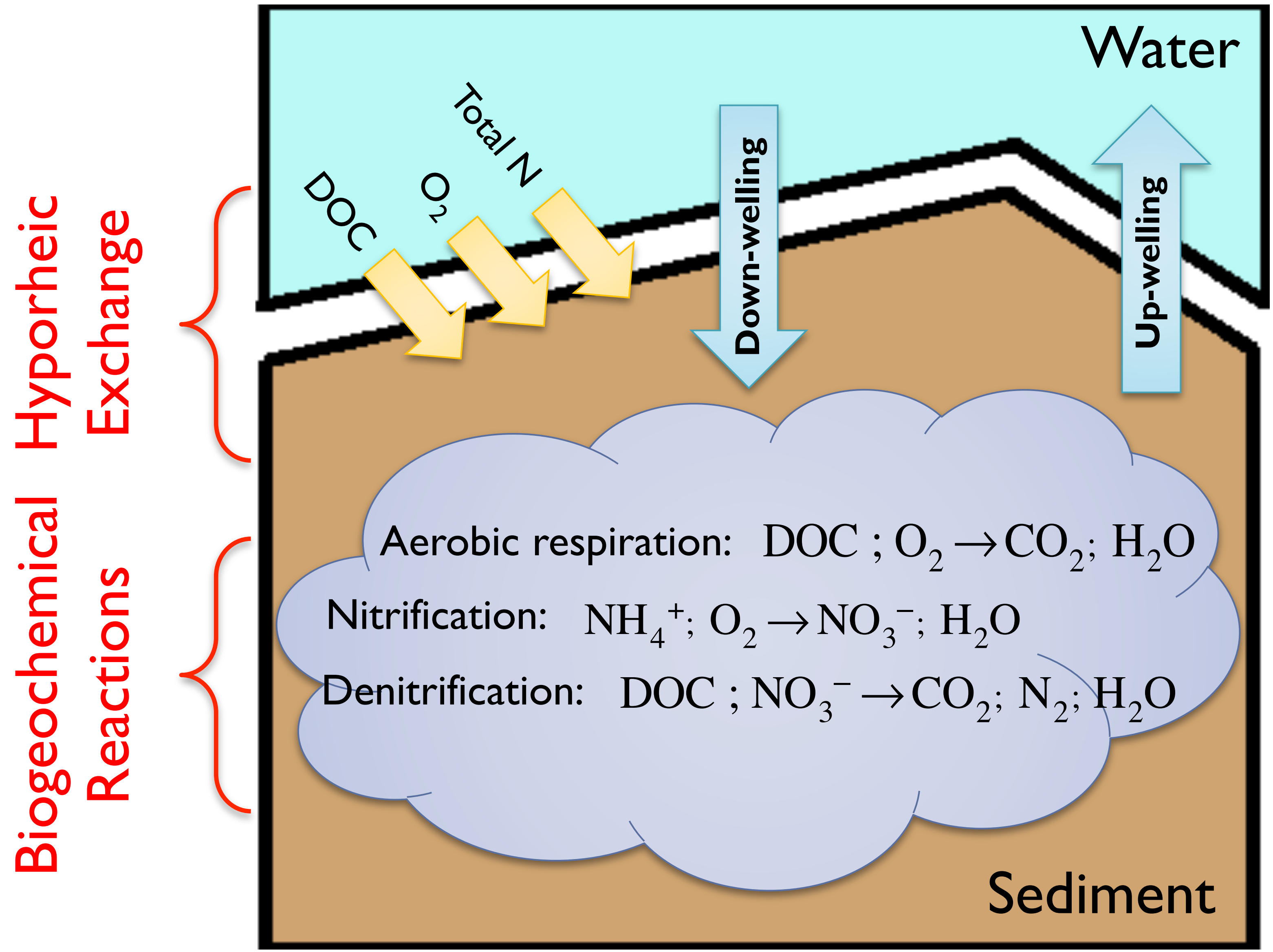
Hyporheic Exchange over a dune



Hyporheic Exchange over a dune

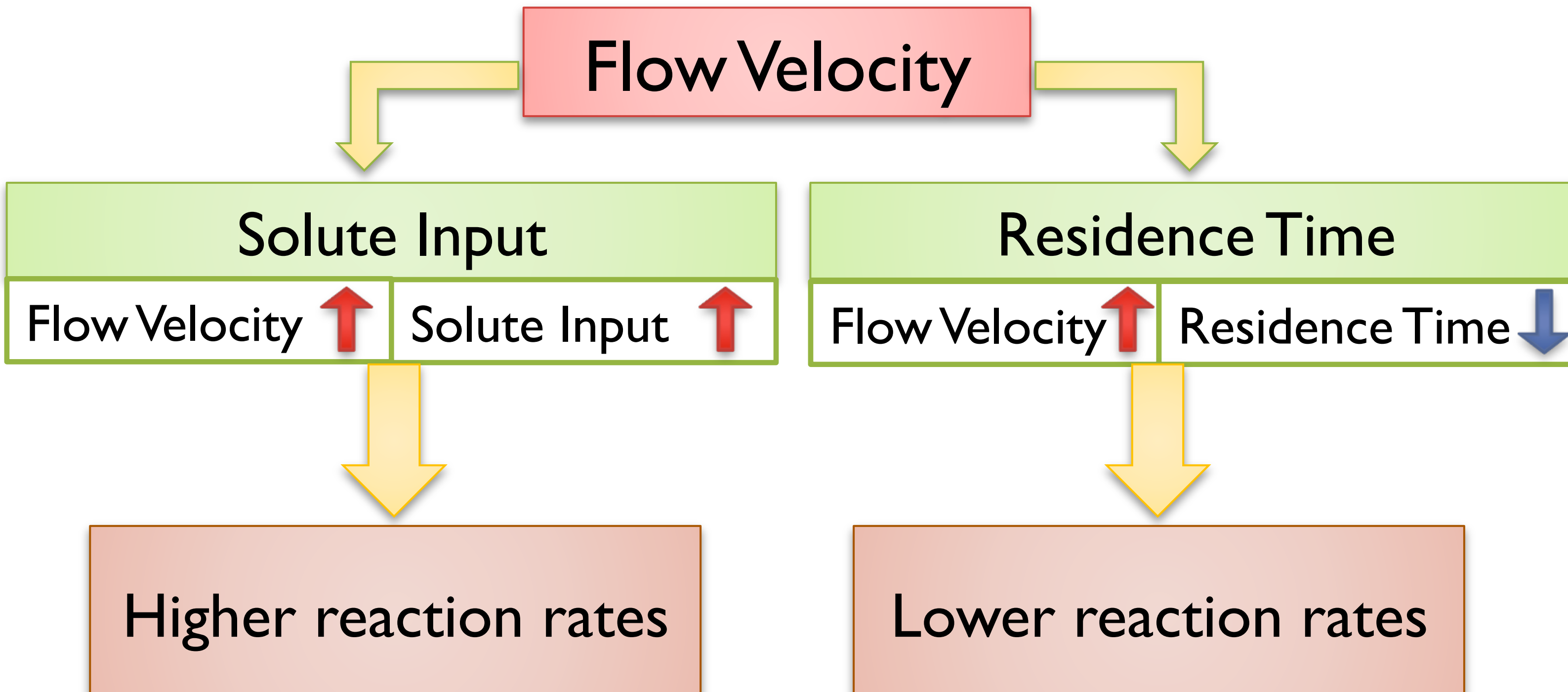


What does DOC and Nitrogen removal in the stream (ecosystem services) depend on?



❖ State-of-the-art Models for Hyporheic Exchange

What is the effect of stream flow on ecosystem services?



What is the effect of stream flow on ecosystem services?

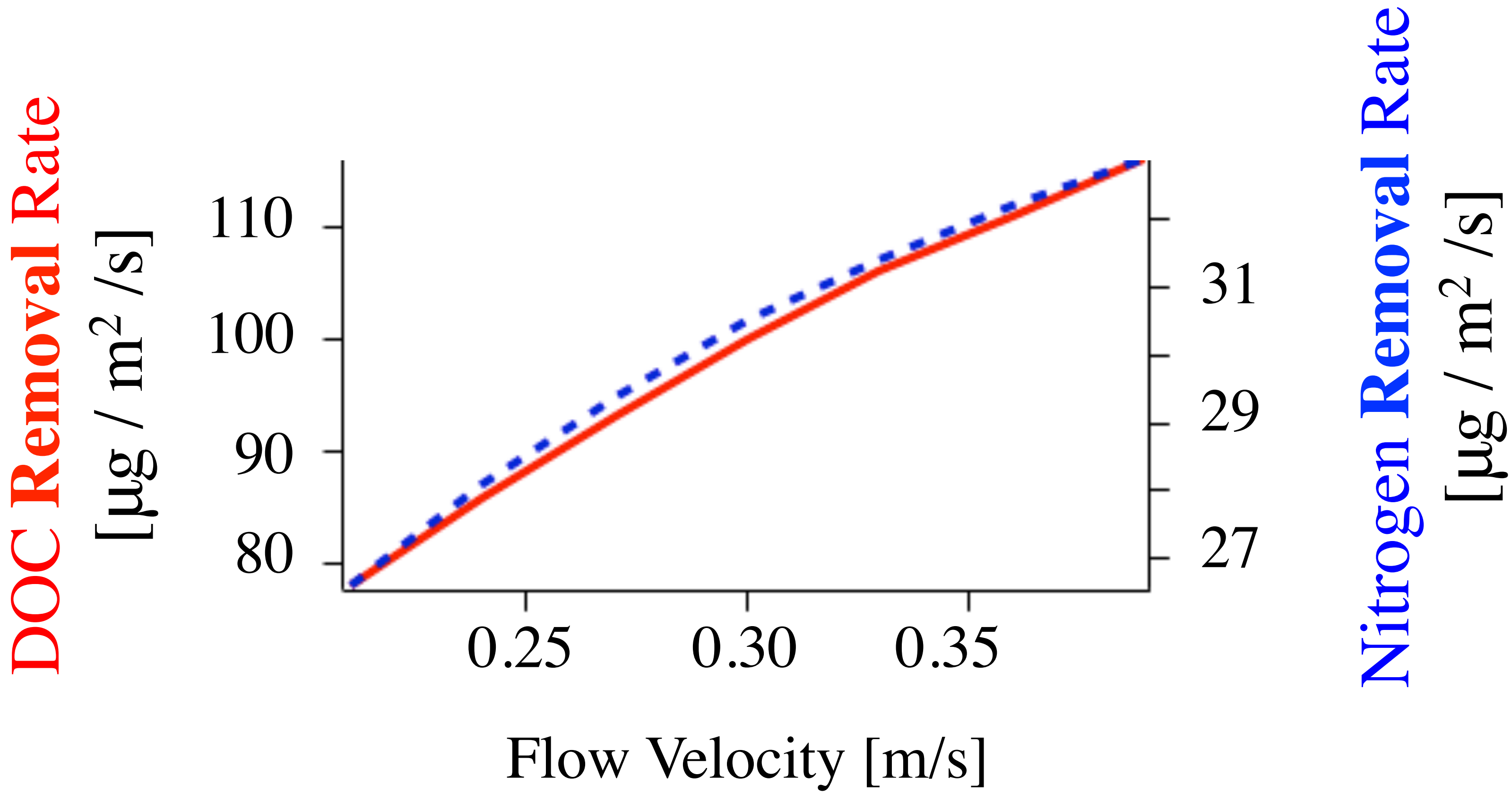
Flow Velocity

Solute Input	
Flow Velocity ↑	Solute Input ↑

Residence Time	
Flow Velocity ↑	Residence Time ↓

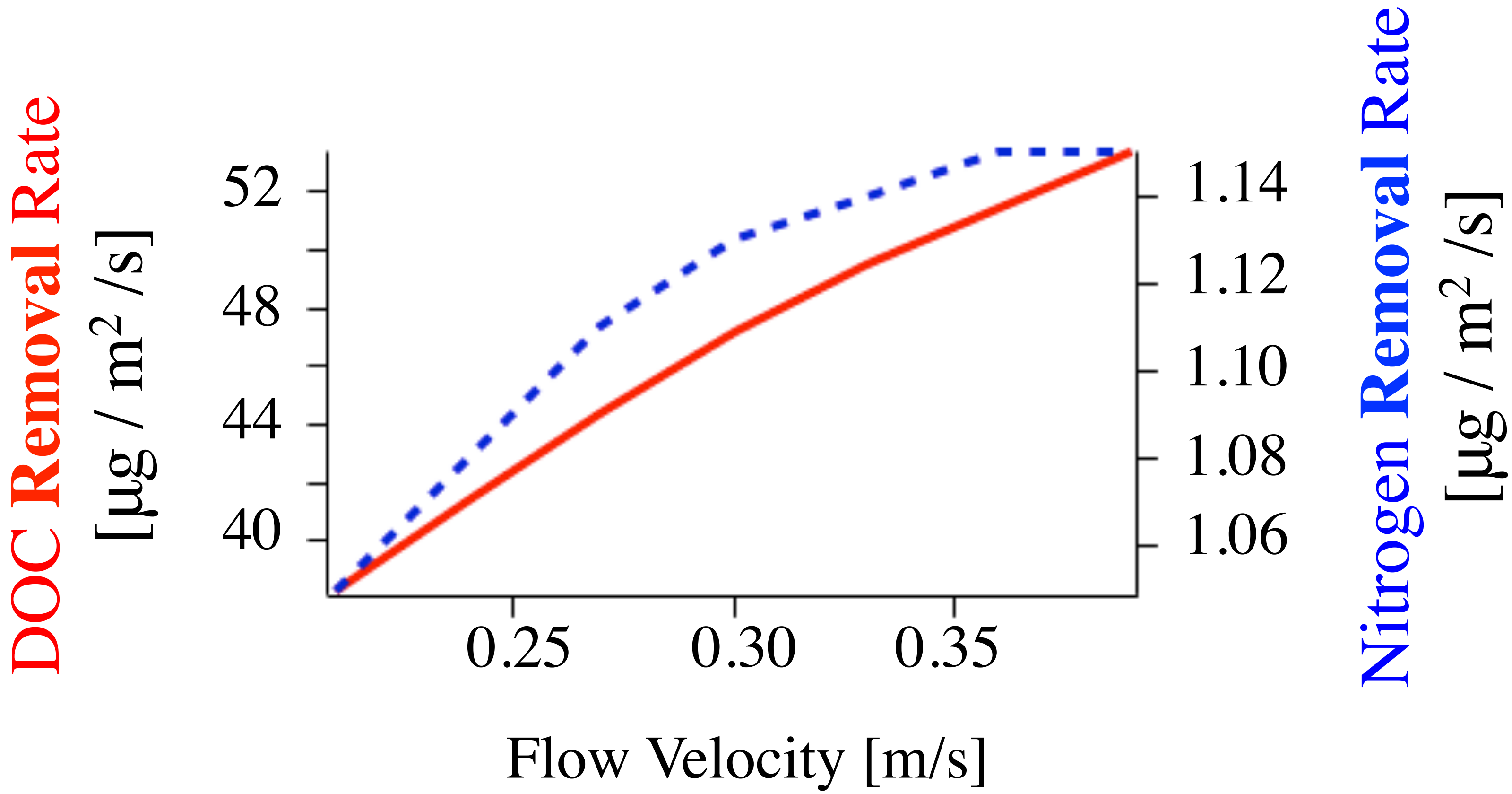
Example
Paper: L. Bardini, et al. "Nutrient cycling in bedform induced hyporheic zones".
Numerical simulation of polluted and pristine turbulent flow over a single dune

Flow Velocity Effect: Polluted Stream



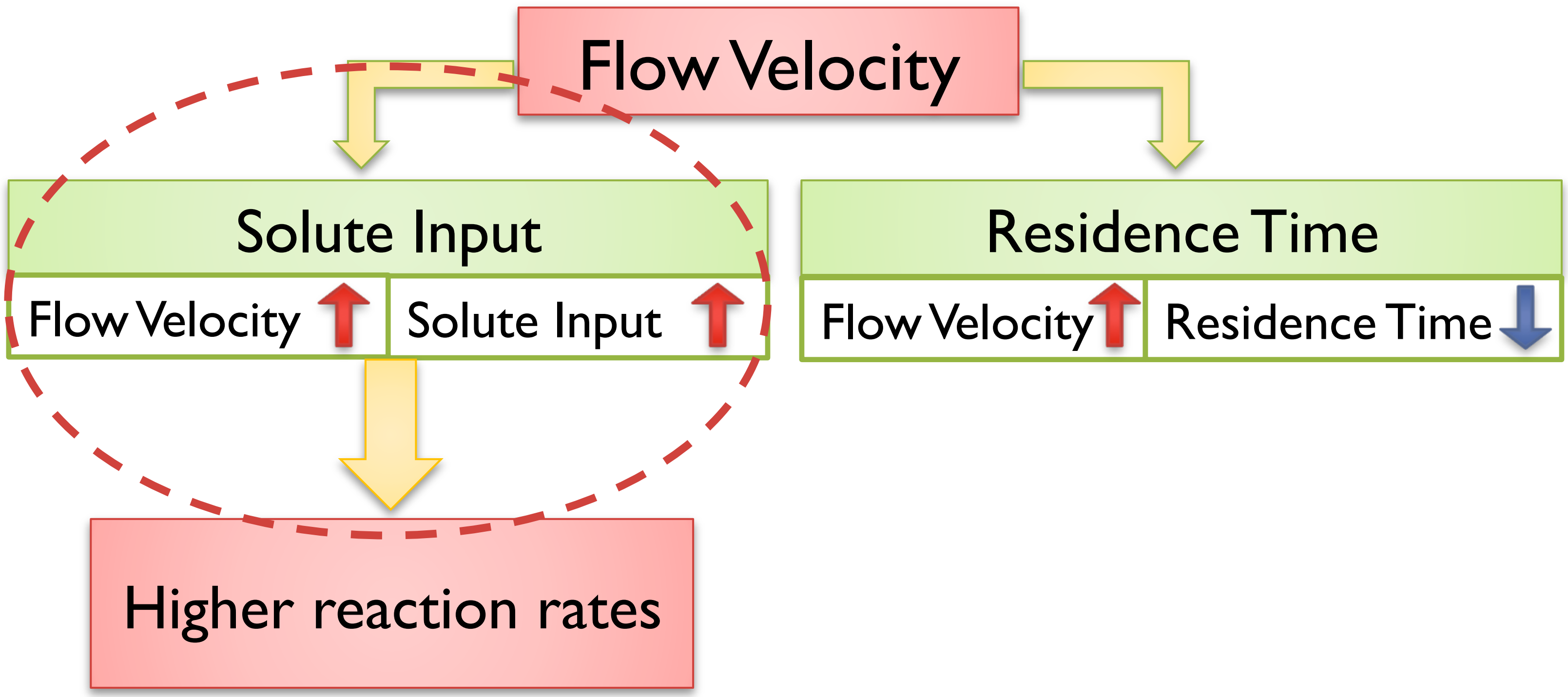
From: L. Bardini, et al. "Nutrient cycling in bedform induced hyporheic zones".

Flow Velocity Effect: Pristine Stream

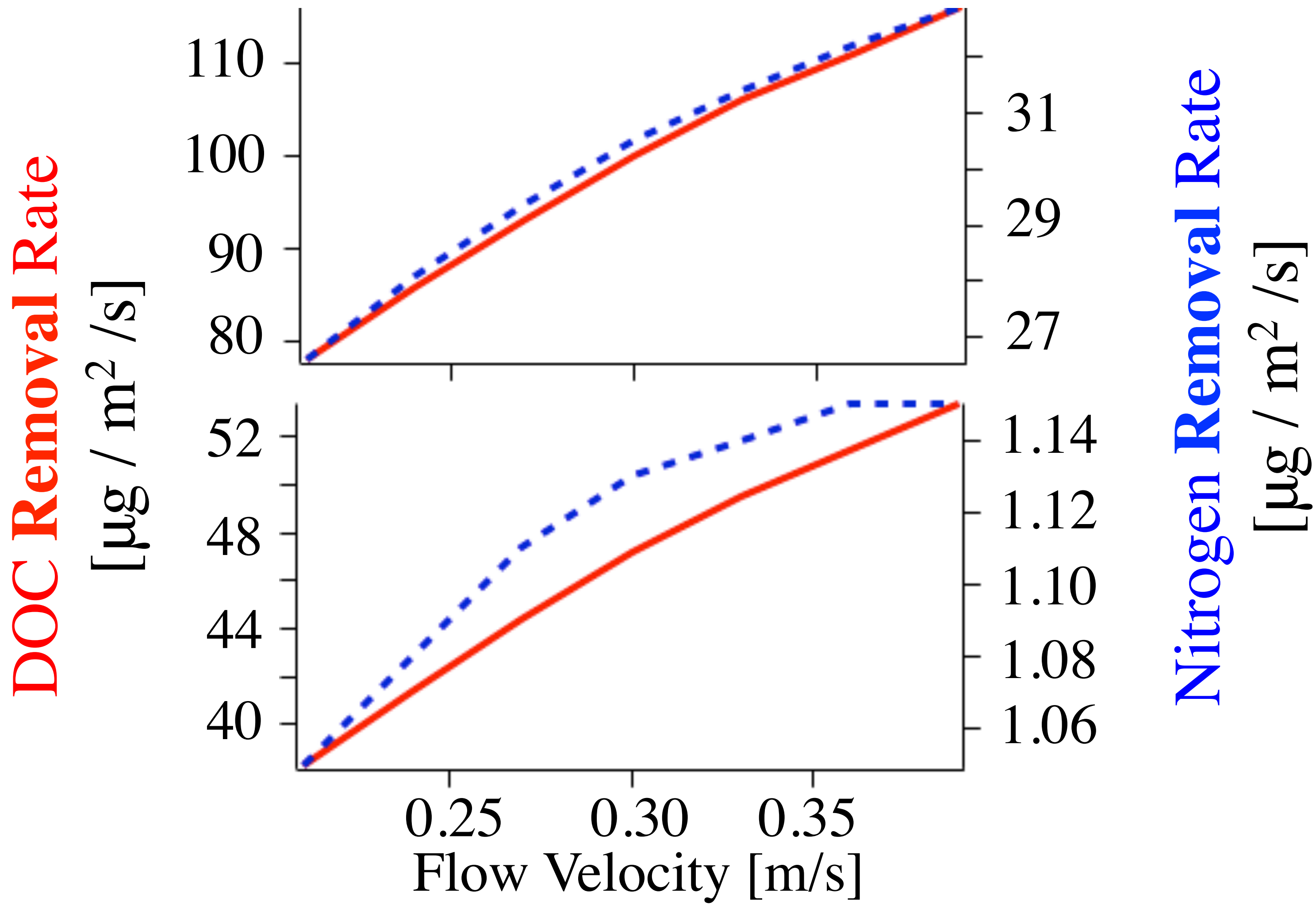


From: L. Bardini, et al. "Nutrient cycling in bedform induced hyporheic zones".

What is the effect of stream flow on ecosystem services?



Removal Rates: Polluted vs. Pristine Stream



From: L. Bardini, et al. "Nutrient cycling in bedform induced hyporheic zones".

Why simple models?

Numerical simulations:
too complex and impractical

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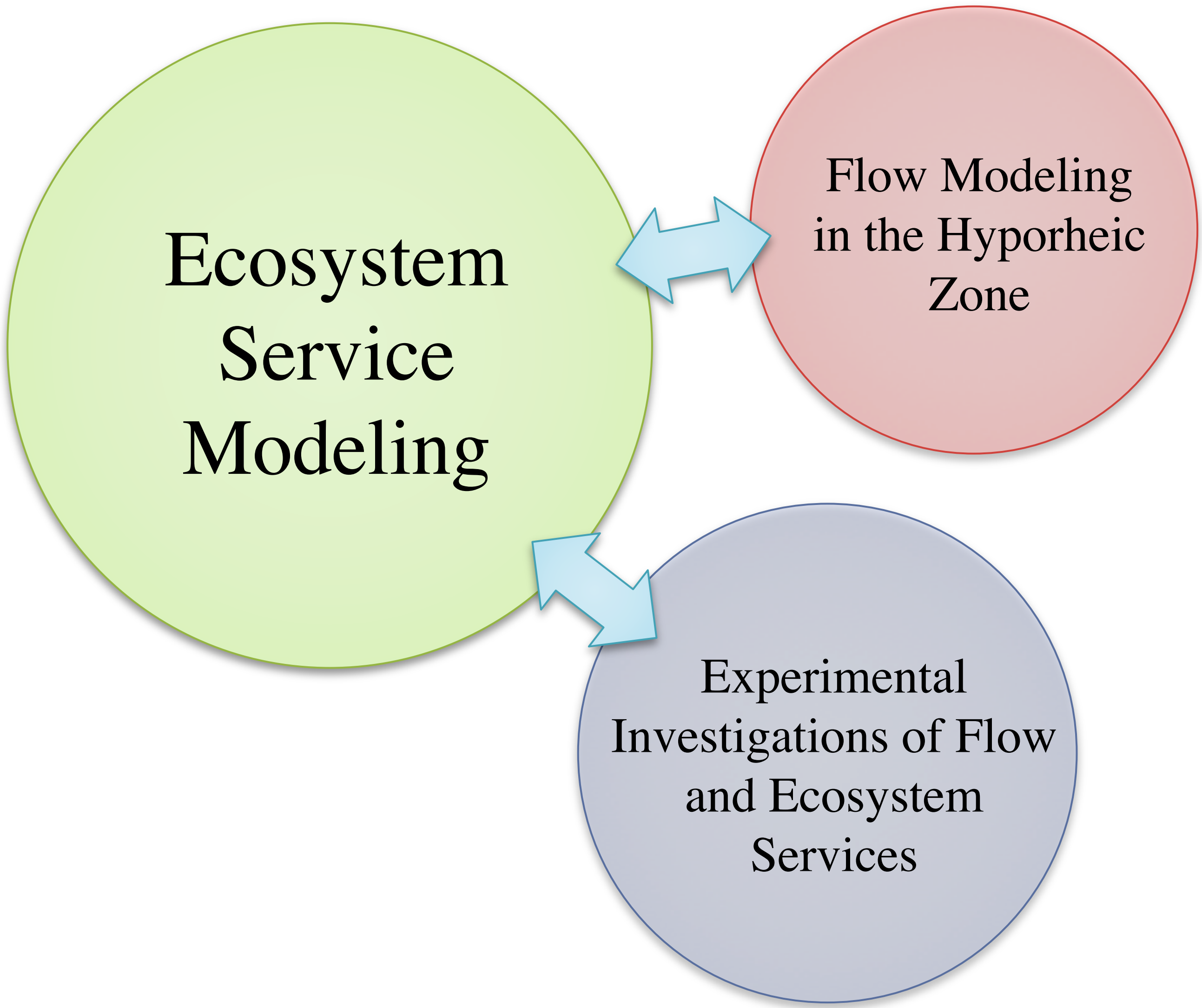
Simple models

Conclusions

- Mathematical models can predict ecosystem services generated by coupling hyporheic exchange with biogeochemical reactions in the sediment.
- Existing models are very complex and there should be some more simple model which management could benefit from.
- There is more work to do on two fronts:
  - Simple mathematical models are needed that can be incorporated into existing flow modeling packages (HEC-RAS, SWMM).
  - More scientific studies are needed to better understand how ecosystem services in a stream are determined by the coupling between physical, biogeochemical, and ecological processes in streams.

❖ Future Research

Future Research



Collaborating Institutions

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THANK YOU FOR YOUR ATTENTION!
ANY QUESTIONS?