Universität Stuttgart

IWS
Institute for Modelling Hydraulic and Environmental Systems
LWW: Prof. Dr.-Ing. Silke Wieprecht
LS3: Prof. Dr.-Ing. Wolfgang Nowak

University of Stuttgart . Institute for Modelling Hydraulics and Environmental Systems
Department of Hydraulic Engineering and Water Resources Management
Pfaffenwaldring 61 . 70569 Stuttgart

Contact
Dr. sc. (PhD) Sebastian Schwindt
Phone
+49 - (0)711 / 685-64789
Fax
+49 - (0)711 / 685-64746
E-mail
sebastian.schwindt@iws.uni-stuttgart.de

Please forward to appropriate candidates

SUBJECT: Hybrid three-dimensional numerical and data-driven simulation of hydraulic exchange processes and nature-based solutions

Advisors

Dr. sc. (PhD) Sebastian Schwindt[1], Prof. Dr.-Ing. Wolfgang Nowak[2]

[1] Department of Hydraulic Engineering and Water Resources Management

[2] Department of Stochastic Simulation and Safety Research for Hydrosystems

Institute for Modelling Hydraulics and Environmental Systems (IWS)

University of Stuttgart

Keywords

Numerical modeling, machine learning, rivers, ecohydraulics, sediment

Introduction and background

Hydraulic research and analysis of rivers currently build on two-dimensional (2d) depth-averaged models of possibly large landscapes. Three-dimensional (3d) numerical modeling primarily serves for the simulation of engineered hydraulic structures. Such 3d simulations with a great level of detail are rarely applied to the planning of nature-based river restoration actions, such as the placement of wood structures. Yet, the success of river restoration heavily depends on small-scale processes, such as the water-driven hyporheic exchange of matter between surface water and the river substrate. In addition, nature-based solutions, such as large wood placements cause particular turbulence structures with high influence on the transport of fine particles and even oxygen. Turbulent structures and high oxygen concentrations are valuable and required characteristics of high-quality habitats for many aquatic species. However, high-resolution 3d modeling of turbulent patterns, which also accounts for the exchange of water and matter across the riverbed is hardly feasible because of high computing requirements. Therefore, this Ph.D. project aims to develop a computationally efficient 3d numerical modeling scheme for nature-based solutions in hydraulic engineering supported by data-driven techniques.

Research goals and Methods to be used

The Ph.D. candidate familiarizes with existing closures for turbulent flow and turbulent mass exchange, and with open-source 3d numerical modeling (CFD) software including pre- and post-processing tools. A literature review of nature-based river restoration including intra-institutional pre-studies rounds up the required understanding of physical processes. The preparation phase concludes with a review of data-driven (machine learning) techniques for numerical model calibration and turbulence modeling. A blend of physical process understanding, 3d numerical modeling, and data-driven model optimization constitutes the methodological toolset for accomplishing this research project.

The research goal is to use the methodological toolset for modeling particular nature-based elements for river restoration. The toolset shall be optimized regarding computing time and accuracy based on existing field data. As a result, a holistic digital twin is expected to provide novel insights into the ecohydraulic efficiency of nature-based solutions in hydraulic engineering. In addition, the successful implementation of hyporheic exchange processes potentially shows the quality of physical conditions for microbial communities that can foster or ideally reduce carbon emissions.

Research environment

The Ph.D. candidate will run numerical models on computing clusters at the IWS, and potentially participate in fieldwork to enrich the measurement data for numerical model optimization. The successful candidate will be part of an interdisciplinary working group focusing on hydro-morphodynamic processes in rivers, with connections to neighboring groups that work on stochastic simulation, porous-media flow and machine learning.

Prerequisites

Command of statistics, fluvial hydrodynamics including sediment transport, and programming; ideally, experience with Python and numerical CFD models (e.g., OpenFOAM).

Contact for questions

Dr. sc. (PhD) Sebastian Schwindt, University of Stuttgart
sebastian.schwindt@iws.uni-stuttgart.de