Hydro-morphodynamic connectivity and ecosystem design in a changing environment

Release latest

Sebastian Schwindt

Apr 30, 2021

CONTENTS

This joint Sino-German research project is funded by the DFG and the NSFC in the framework of long-standing efforts to foster scientific collaboration between China and Germany. More information on funding sources will be available on the DFG's GEPRIS platform.

Fig. 1: *The Rhine in Germany on the left (image: Sebastian Schwindt, 2016) and the Yellow River on the right (image source: Jin Zhang/Xinhua News Agency, 2016).*

Tip: Download this website as ebook (PDF).

Are you a student looking for research opportunities?

Find out more about student opportunities in the framework of this project on the team website (see opportunities section).

CHAPTER ONE

MOTIVATION

Water resources engineering fragmented many rivers on earth and disrupted the continuity of aquatic ecosystems. The Yellow River in China and the Rhine in Germany emblematically testify the evolution that came along with industrialization in the last two centuries. The landscape around the two rivers changed from braided and varied pattern to monotonous navigable streams, which are split by multi-purpose dams. In the coming decades, global change is expected to enhance the destruction of aquatic habitats even more with severe consequences for the food security. Thousands of river restoration projects are currently in progress worldwide to mitigate the risks of ecosystem loss and global change. However, the communication between different domains of expertise and also between regions is often lacking. This project is building green bridges between hydrologists, engineers, ecomorphologists, as well as between China and Germany. Hydrological analyses of fluvial landscapes will be performed to guide ecologically friendly dam releases and river restoration actions toward robustness against global change.

CHAPTER TWO

COLLABORATION & GOALS

The collaboration of the Chinese North China Electric Power University (NCEPU) and Yantai University (YPU) with the German University of Stuttgart will establish a two-fold approach in two different environmental setups. The two-fold approach involves a hydrological (longitudinal connectivity) optimization of ecologically sustainable dam releases by the research team based in China and an ecomorphological (lateral connectivity) design optimization for river restoration performed at the University of Stuttgart. The project uses case studies from the Yellow River and the Rhine River. Both rivers created morphologically similar fluvial landscape pattern (large meanders) in their middle reaches, but in hydrologically and geologically different environments and different legacy.

CHAPTER

THREE

METHODS OVERVIEW

This project uses data from both the Yellow River and the Rhine to optimize hydrological connectivity and sustainable ecosystem restoration actions. The role of computers in the design of ecosystems has become increasingly important in recent years and powerful numerical models have now set the standard for planning interventions at rivers. However, objective, parametric descriptions of fluvial landscapes are lacking. Such parameters are required to sustainably design ecosystems for target species in a changing climate. This project takes up the challenge of defining relevant hydrological connectivity and morphodynamic parameters to manage and re-design fluvial landscapes sustainably. The parametric description of river ecosystems will enable a unique coupling of numerical modelling and new river design algorithms via feedback loops. Such feedback loops will involve hydro-climatic regimes and ecomorphological connectivity parameters. This Sino-German collaboration will endow its results with global relevance by merging expertise and complementary hydrological-morphological analyses.

CHAPTER

FOUR

BACKGROUND

Affected by global change and multiple stresses of human activities, such as dam construction, channelization, and urbanization, 47% of the earth's surface has experienced irreversible changes [1], [2]. For example, more than three thousand dams fragment the Chinese Yellow River watershed and hinder fish migration [3]. On the other side of the world, the German Rhine was "corrected" for navigation purposes already at the beginning of the 19th century [4] with dramatic consequences for the aquatic ecosystem [5], [6]. While energy production and agriculture still depend on past river "corrections", their impacts on the ecosystem increasingly endanger food security. In addition to the anthropogenic influenced changes (legacies) of rivers, the predicted hydro-climatic change is expected to amplify the stress on flora and fauna [7]. The Yellow River and the Rhine represent two characteristic waterways with legacy that had devastating consequences for the river ecosystems. Their legacies and the hydro-climatic change will impose similar challenges in both watersheds, where extended drought periods and intensified floods are expected [8]. However, the sustainable employment of hydrological control structures (e.g., dams) and nature-based engineering can mitigate the consequences of the expected climate change. Large dams at the Yellow River provide storage capacities that enable the imposition of so-called "environmental flows", which describe quantities, quality and pattern of discharge fluctuation required to sustain river ecosystems [9]. In the absence of storage capacity for environmental flow control, river ecosystems can be sustained through direct, local measures on the river reach scale (~up to 100 channel widths). Such measures involve terraforming and nature-based engineering features with indigenous vegetation and aim at the simultaneous enhancement of aquatic habitat and flood safety [10]. Both the Yellow River and the Rhine were subject of many scientific studies and this project aims to combine existing and new findings from both fluvial environments. A team of leading researchers based at the North China Electric Power University (Beijing) and Yantai University (Yantai) focused their research on the ecosystem of the Yellow River. The researchers found, for example, that since the construction and operation of the 154-m tall Xiaolangdi dam in the lower reaches of the Yellow River in the year 2000, original habitats were destroyed, the fish population reduced by more than 50% and the abundance of phytoplankton as well as zooplankton reduced by 60% and 88%, respectively [3]. The dam construction particularly endangers mollusks, benthic fish and zooplankton [11]. Also the wetlands of the Yellow River are affected by Xiaolangdi dam and studies have shown that the compensation for wetlands loss amounts to 66 million yuan per year (~8.5 million EUR) [12]. In addition to damming, global warming has led to drastic changes in the water cycle, with significant alterations of runoff pattern and increased extreme hydrological events in the region. Today, the runoff of the Yellow River has disproportionally decreased compared with the sediment discharge. While extreme flood and drought events both have occurred more frequently, the total runoff of the Yellow River into the Bohai Sea has decreased by 50% which can be attributed to a regional decrease in precipitation [13]. Reservoir management with ecologically beneficial discharge hydrographs and environmentally friendly sediment flushing are potential solutions to recover the ecosystem at the Yellow River. However, the prior characterization of dynamic, self-maintaining, and regenerating "healthy" habitats in the Yellow River is necessary. In general, a "healthy" river state is described by hydraulic, ecological, and morphological diversity [14], which can also be parametrically expressed [15]. Several approaches exist for the parametric description of hydrological and morphodynamic healthy ecosystems, but they often imply subjective expert assessments. Researchers from the University of Stuttgart have conducted comprehensive studies on parametric and objective ecosystem assessments to reduce vulnerability caused by subjective assessments. The researchers used for example structure-from-motion [16], biological index-driven habitat analyses [17], [18], fuzzy logic [19], [20], and numerically driven river restoration feature planning [18], [21]. Numerical modelling plays a key role in the parametrization of river ecosystems and the group of researchers around Prof. Silke Wieprecht (Institute for Modelling Hydraulic and Environmental Systems IWS at the University of Stuttgart) set benchmarks in hydro-morphodynamic modelling in combination with habitat suitability modelling [17], [20], [22]. However, the translation of morphodynamic modelling and ecosystem characterizations into the generation of new aquatic habitats represents a great challenge for researchers worldwide. The collaboration of researchers from China and Germany has the potential to leverage this challenge with their expertise in eco-hydrology and ecomorphology, respectively. To enable this collaboration, the Rhine offers suitable study sites in Germany for knowledge transfer from and to the Yellow River in China. The knowledge transfer becomes possible and meaningful because of similarities in the fluvial landscape pattern, but interesting dissimilarities in the river's sediment budget as an artefact of two different hydro-geological environments. Table 1 lists the main differences between the Yellow River and the Rhine, which will enable complementary insights to broaden the significance of the project results to many other rivers in the world.

Table 1: Comparison of the framework and legacies at the Yellow River and the Rhine.

River feature	Yellow River	Rhine
Channel bed	Aggrading (sediment surplus)	Incising (sediment deficit)
Channel banks	Increasingly rigid (engineered)	Rigid with local scarification in progress (restoration projects)
Floodplains	Subject to current industrial development	Industrial legacy

The highly erosive watershed of the Yellow River and sparse vegetation supply much sediment that causes sedimentation problems in downstream river reaches. Even though the Yellow River is strongly modified by dams, large amounts of fine sediment are still transported and deposited in downstream reaches (corresponds to a transport-limited-system with sediment surplus). In contrast, the Rhine is a sediment supply limited system (because of multiple dams in the river course) and requires thousands of tons of sediment injections every year to sustain its geomorphic stability [23]. The latest engineering efforts in China aimed at reinforcing the river banks to prevent flooding of the alluvial plains of the Yellow River, whereas restoration efforts at the Rhine currently scarify rigid banks more and more in river reaches where navigation is not affected [24]. The restoration efforts at the Rhine follow a two-century long industrialization with sealing of natural grounds and channelization that damaged the river ecosystem and simultaneously increase navigation as well as flood safety [25]. In the framework of restoration efforts at the Rhine, the IWS has had the opportunity to perform several research projects in the last decades. Table 2 chronologically lists the most recent projects with resulting data products at the Rhine. Figure 2 maps the position of the IWS projects at the Rhine.

From 2013 to 2017, the IWS (University of Stuttgart) analyzed sediment cores at the Upper Rhine between the barrages at Marckolsheim and Rhinau at the French-German border [26] down to Iffezheim [27]. The sediment cores were examined in the so-called SETEG flume and a highly sophisticated measurement method, called PHOTOgrammetric Sediment Erosion Detection (PHOTOSED) [28]. The SETEG flume and PHOTOSED method determine the depth-dependent erosion stability and the critical bed shear stress [29]. In addition, the sediment core samples provide data on grain size, bulk density, biological substrate characteristics, and contaminates. These data represent valuable input for this collaborative project, where numerical models may be build, calibrated, and validated with the information on bed shear stress and grain size distributions. Moreover, the sediment and water probes provide data on suspended and bed load of the Upper Rhine.

Since 2019, the IWS is investigating the evolution of water depths of the Rhine in the context of river engineering interventions since the early 19th century, which aimed at improving the navigation conditions on the river [4]. The engineering actions caused channel erosion and deteriorated the ecological state of the Rhine. Further engineering interventions have been carried out more recently with the goal of improving the ecomorphological condition of the Rhine again. In particular, the IWS studies the effects of hydraulic engineering structures (e.g., longitudinal and transverse structures such as dikes) and ecological measures on the hydraulics of the Rhine within the framework of a project funded by the German Federal Institute for Hydraulic Engineering (BfG). Through the project with the BfG, the IWS has access to large amounts of data from the BfG with information on hydraulic structures, hydrological analyses, riverbed elevations and water levels. The result of the BfG project includes a detailed student project that documents engineering interventions at the Upper, Middle and Lower Rhine between Lake Constance and the estuary in the Netherlands [30]. These data and the literature review will be available for this collaborative project. An additional collaborative project with the BfG is currently under preparation to investigate hydro-morphological indicators that classify both natural and strongly impaired water bodies regarding the habitat suitability.

CHAPTER

FIVE

OBJECTIVES

This project seeks a multi-objective river ecosystem design model to meet the needs of river health and socioeconomic development in the light of global change. It focuses on exploring the response relationship of hydro-morphodynamic river ecosystem adjustments and how those can be optimized to mitigate hydro-climatic change. The global objective is to establish robust hydrological and hydro-morphodynamic design schemes for the adaptation of river ecosystems to attenuate impacts caused by extreme droughts and floods. This superordinate objective is achieved by breaking it down to three specific objectives.

5.1 Objective 1: Synthesize Existing Methods

The first sub-objective consists of a synthesis of existing methods and data for ecosystem enhancement. The focus will be on hydrological, hydraulic, and morphodynamic parameters (including connectivity characterizations) and approaches. Within the first year, the comprehensive literature review and data assessment produces a *river database* of hydrological, hydraulic, ecological, and morphodynamic parameters characterizing both the Yellow River and the Rhine.

5.2 Objective 2: Generate Novel Models

The second sub-objective is a parametric, morphodynamic optimization of fluvial landscapes. The research team based in China optimizes river ecosystems by adjusting discharge hydrographs (e.g., by imposing environmental flow schedules) to build a hydrological connectivity optimization scheme. At the University of Stuttgart, we focus on morphological adaptations such as resilient, adaptive terraforming and nature-based engineering. The optimization aims at the application of parametric characteristics of high quality aquatic habitat previously identified in the literature (first sub-objective) to build a morphodynamic ecosystem optimization scheme.

5.3 Objective 3: Integrate Novel Hydro-Morphological Models

The third sub-objective is to combine and test our jointly developed design schemes and algorithms for hydro-morphodynamic optimization and hydrological connectivity of aquatic habitat. The tests include the previously defined hydro-climatic change scenarios (longer drought periods and amplified floods). Moreover, we develop programmatic tools that can be used in central Europe as well as in Asia for the development of ecologically healthy rivers under different constraints and hydro-climatic uncertainty. Thus, we consider the different environmental constraints at the Yellow River and the Rhine (see table top of the page). We analyze the preparedness of rivers for hydro-climatic change scenarios with the constraints of different sediment budgets (aggrading or incising rivers), and different degrees of freedom for instream and floodplain river restoration (flow regulation or morphological impairment).

CHAPTER

SIX

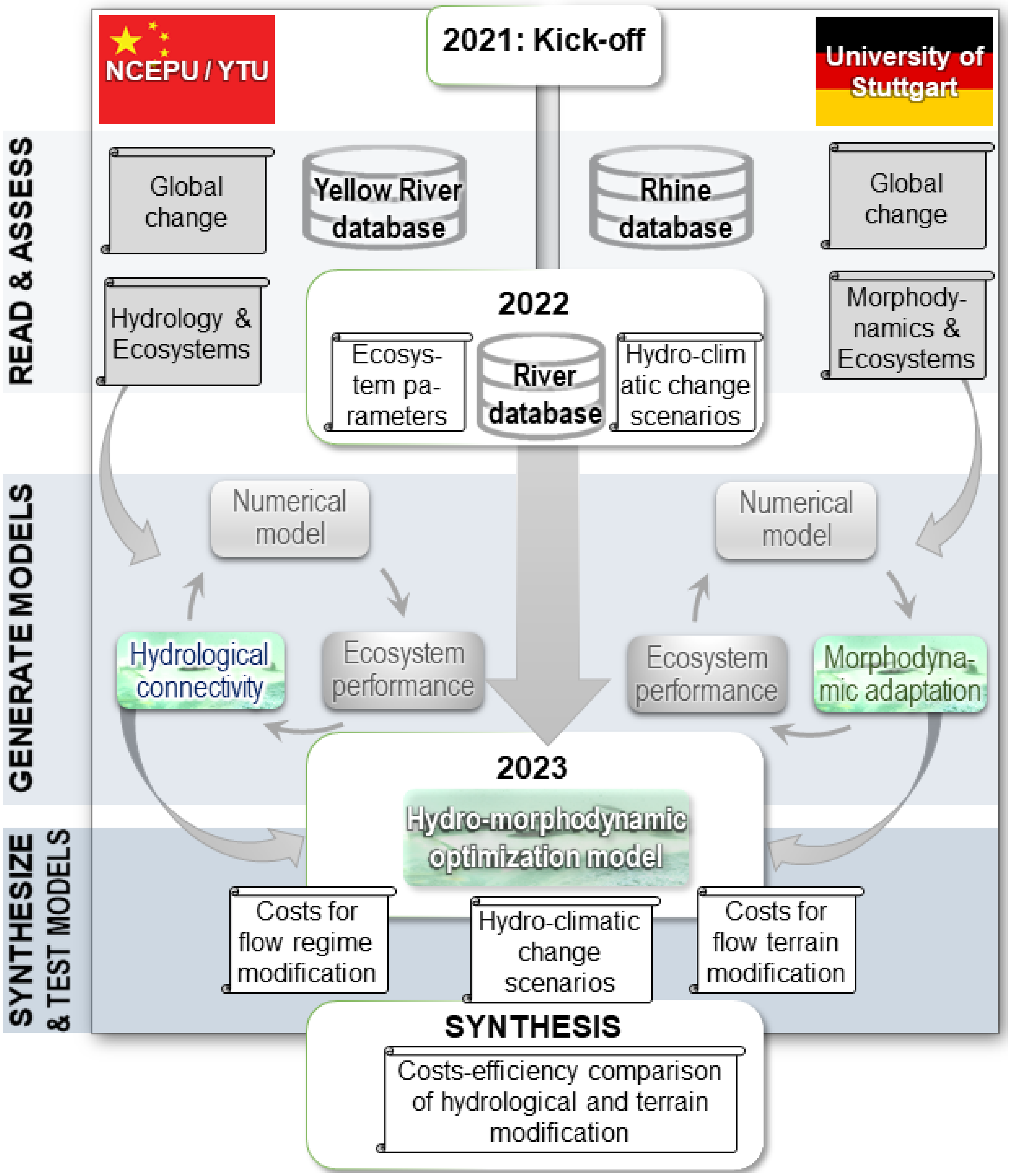
WORK PROGRAM & PRINCIPLE

6.1 Milestones

The three-years work program starts in 2021 and annual milestones are to planned to be implemented for achieving the three objectives:

- 2021. GET STARTED
  - Literature review
  - Data acquisition & creation of a database
  - Model preparation
- 2022. GENERATE MODELS
  - Decision on hydro-climatic scenarios (based on literature and data review)
  - Development of an ecomorphodynamic optimization scheme (team IWS)
  - Development of an eco-hydrological connectivity optimization scheme (team NCEPU/YPU)
  - Deliverables: Morphodynamic and hydrologic connectivity ecosystem optimization
- 2023. SYNTHESIZE & TEST MODELS
  - Aggregation of eco-hydrological and ecomorphodynamic optimization scheme
  - Model synthesis and publication of digital products

The first project phase involves a detailed literature and data review. The literature review will focus on the ecosystem of the Rhine, its past evolution, target species and restoration activities. We will identify all possible data resources (e.g., flow series, hydraulic data, habitat suitability curves, substrate classifications, and existing terrain models), which are needed for numerical models of the Rhine and ecosystem optimization algorithms. An analysis of the hydro-climatic environment of the Rhine will mostly use existing data and classifications of the current flow regime, as well as an assessment of hydro-climatic change scenarios with their consequences for extreme hydrological events. The hydro-climatic analysis will consider extreme events in the shape of extended drought periods and amplified flood events. During longer periods of drought, lateral riparian habitats are expected to dry out. In contrast, during major flood peaks, greater hydraulic forces must be assumed, which can have destructive effects on habitats. Our project partners from the North China Electric Power University (NCEPU) and the Yantai University (YPU) will perform a similar literature review on the Yellow River. However, while we are looking at possibilities to optimize fluvial landscapes, the NCEPU/YPU research team in Beijing will investigate ecosystem improvements through modifications of discharge releases from dams (hydrological connectivity optimization). Their literature review encompasses the spatio-temporal evolution of hydrological connectivity, the assessment of climate change scenarios and human impact on the Yellow River basin, and the analysis of the current longitudinal hydrological connectivity of the Yellow River. Based on the available datasets, we identify two to three study sites at the Rhine, each about 2-3 km long, which we then model numerically. After the establishment and the numerical, hydraulic-morphodynamic modelling of the current state of the selected sites, we improve and newly develop landscape modelling schemes and algorithms (e.g.,


NCEPU / YTU
2021: Kick-off
University of Stuttgart
READ & ASSESS
Global change
Yellow River database
Rhine database
Global change
Hydrology & Ecosystems
2022
Ecosys-tem pa-rameters
River database
Hydro-climatic change scenarios
Morphody-namics & Ecosystems
GENERATE MODELS
Numerical model
Numerical model
Hydrological connectivity
Ecosystem performance
Ecosystem performance
Morphodyna-mic adaptation
2023
Hydro-morphodynamic optimization model
SYNTHESIZE & TEST MODELS
Costs for flow regime modification
Hydro-climatic change scenarios
Costs for flow terrain modification
SYNTHESIS
Costs-efficiency comparison of hydrological and terrain modification

similar to River Architect [18]) to enhance the habitat quality for target species. We identify climate change scenarios and agree on relevant scenarios within the entire Sino-German research team. The climate change scenarios constitute alternate (drought and flood) hydrographs (upstream boundary conditions) that we are modeled with a current-state morphology. With the model results, we analyze how river landscapes can be modified to provide robust habitat in the case of prolonged drought and emphasized floods. The researchers based in China have already developed models and methods needed for the numerical and physical analyses of the Yellow River in the past. The study on the Yellow River contributes the hydrological counterpart to our morphodynamic optimization. As a result, the Chinese research team will benefit from the morphodynamic ecosystem optimization scheme produced by the IWS and the IWS will benefit from the hydrological connectivity model elaborated by the Chinese research team.

6.2 Software

We use exclusively open-access and open-source software for the following purposes:

- Numerical modelling: open TELEMAC
- Geospatial data processing: QGIS
- Codes and algorithmic solutions: Python

Moreover, we have a strong commitment to open-access publishing of any results. All codes and algorithms will be provided on publicly available git repositories and referenced on this website at the time of publishing.

Instructions for getting ready to use models, codes, and algorithms provided are available at the online learning platform hydro-informatics.github.io, which represents the baseline for online teaching contents of IWS' hydro-morphodynamics research group

6.2.1 Project Team

University of Stuttgart (Germany)

The permanent team of researchers working on this project from the University of Stuttgart includes:

- Dr. sc. Sebastian Schwindt (Principal Investigator of the project)
- Stefan Haun (PhD) (Head of Hydraulic Laboratory)
- Prof. Dr.-Ing. Silke Wieprecht (Full professor, Department Head)
- MSc. Maximilian Kunz (Doctoral researcher)

In addition, the project will be aided by the university's innovative graduation students.

Sebastian Schwindt

Dr. sc. Sebastian Schwindt is the head of the hydro-morphodynamics research group Institute for Modelling Hydraulic and Environmental Systems (IWS, University of Stuttgart). His research focuses on numerical analyses, Python programming, sediment transport, ecohydraulics, and ecosystem design. He completed his Bachelor (2010) and Master (2012) studies at the Technical University of Munich (Germany) in Environmental Engineering and accomplished his doctorate at the Ecole Polytechnique fédérale de Lausanne (EPFL, Switzerland). Between 2017 and 2019, Sebastian Schwindt pursued postdoctoral research at the University of California, Davis (USA) with Prof. Greg Pasternack. The emphasis of his postdoctoral research was on the ecohydraulic enhancement of the Yuba River (California, USA). In this project, he is the PI on behalf of the research team from the University of Stuttgart.

Silke Wieprecht

Prof. Dr.-Ing. Silke Wieprecht is the Head of the Department of Hydraulic Engineering and Water Resources Management (LWW) at the IWS (University of Stuttgart). She has long-standing experience in hydraulic engineering with a focus on sediment transport since her early career. Silke Wieprecht completed her doctorate at the University of the Federal Armed Forces in Munich and afterwards worked at the Federal Institute of Hydrology in the field of water morphology. Since 2003, she is the head of LWW. Her outstanding scientific contributions in the field of erosion and sedimentation research along with her proficiency in project planning, design, and implementation were awarded with the Qian Ning Prize in 2019. Recent research highlights from Silke Wieprecht involves novel findings about riverbed clogging (also known as *colmation*), which relates to vertical connectivity. Find out more about Silke Wieprecht and her awarded research on her personal website.

Stefan Haun

Dr. Stefan Haun is the head of the Hydraulic Laboratory of the Department of Hydraulic Engineering and Water Resources Management (LWW) at the IWS (University of Stuttgart). Stefan Haun completed his PhD at the Department of Hydraulic and Environmental Engineering of the NTNU (Norwegian University of Science and Technology, Norway) with a focus on three-dimensional numerical modelling. Since he joint the LWW in 2014, his research focuses on reservoir sedimentation, experimental methods in the field and in the lab, and sediment transport in general. Highlights of his recent research include the PHOTOgrammetric Sediment Erosion Detection (PHOTOSED) method and the AMSTEL project on micro plastic in rivers. He and his team of the hydraulic lab support this project with their expertise in fieldwork methods for collecting essential data such as grain size information or the degree of riverbed clogging.

Maximilian Kunz

MSc. Maximilian Kunz is a doctoral researcher at LWW. He focuses on the development of numerical models, ecomorphological assessments (vertical and lateral connectivity), and automation techniques in the model chain with principle component analysis (PCA). He studied Civil Engineering on the Bachelor and Master level at the University of Stuttgart, with Water and Environment as his main field of study. During his Master studies, he spent one semester at the Norwegian University of Science and Technology (NTNU) to broaden his knowledge in the field of Hydropower Development. In his Master thesis he focused on 3-D numerical modelling of reservoir flushing with partial drawdown. Parallel to his studies he gained professional experience by working for Wald + Corbe Consulting GmbH in Stuttgart. His work included the assistance in all work phases of several construction projects in the field of flood protection and ecological connectivity.

Grad Students: Opportunities for Bachelor and Master Theses within this project are already available on IWS' website. Currently, we are looking for undergrad or grad students who want to write a study thesis on the following topics:

- Ecosystem analysis of the Rhine

NCEPU and YTU (China)

Researchers from NCEPU (North China Electric Power University) and Yantai University (YTU) include:

- Prof. Dr.-Ing. Shanghong Zhang (Principal investigator at NCEPU)
- Prof. Dr.-Ing. Changming Ji (Professor at NCEPU)
- Prof. Dr.-Ing. Baohui Men (Professor at NCEPU)
- Prof. Zhang Cheng (Associate professor at NCEPU)
- Prof. Dr.-Ing. Jin Zhang (Associate professor at YPU)
- Prof. Shiyang Yin (Associate professor at NCEPU)
- Prof. Caihong Tang (Assistant professor at NCEPU)
- Dr. Wang Le (Lecturer at NCEPU)
- Dr. Changqing Meng (Lecturer at NCEPU)
- Dr. Wei Miao (Lecturer at NCEPU)

Shanghong Zhang

Prof. Dr.-Ing. Shanghong Zhang is the Head of the School of water resources and hydropower engineering at North China Electric Power University (NCEPU). In this China-Germany collaborative project, Prof. Zhang is the principle investigator (PI) to lead the Chinese team (NCEPU & YTU) on the implementation of this program. Prof. Zhang received his BEng and PhD degrees in Hydraulic Engineering at the Tsinghua University between 2000 and 2004, then he held a Postdoctoral Research Associate position at the Tsinghua University between 2004 and 2008 before he moved to NCEPU. Highlights from Prof. Zhang research primarily focus on the development of hydrodynamic modelling, digital watershed simulation, and decision supporting system. Recently, Prof. Zhang was also PI for key research programs funded by NSFC (National Natural Science Foundation of China) and MOST (Ministry of Science and Technology, China), and he was awarded the China Navigation Science and Technology Prize, and the DaYu Water Conservancy Science and Technology Prize. Read more on his institutional profile.

Changming Ji

Prof. Dr.-Ing. Changming Ji is a distinguished pioneer in establishing the discipline of water resource & hydrology and honorable member in founding the school of water resources and hydropower engineering at NCEPU. He is an engineering undergraduate and postgraduate (Master & Doctorate) of Wuhan University of Hydraulic and Electrical Engineering between 1978 and 1988. In 1990, He completed his postdoctoral research at the University of California, Davis (USA). Since 1978, He was devoted to the research and courses of water resources management & hydrology as well as management of hydraulic engineering works. Prof. Changming Ji is a Fellow of China Society of Natural Resources and Editorial member of Journal of Hydroelectric Engineering, etc. He is a highly respected consultant to hydropower engineering in Ministry of Water Resources and his great contribution is officially praised by the State Council. Read more on his institutional profile.

Baohui Meng

Prof. Dr.-Ing. Baohui Meng completed his doctorate at Sichuan University and joined NCEPU in 2006. His study interests cover a wide field within fluvial water system, including time series analysis, management, optimal allocation of water resources, healthy river assessment and ecological water demand, optimal reservoir operation scheme, water environmental capacity, and water contamination tolerance capacity, etc. He was an invited expert in evaluating submitted scientific programs in National Natural Science Foundation of China (NSFC), Beijing Municipal Natural Science Foundation, etc. He was also the principle investigator of several sub project of National High Technology Research and Development Program of China. In this collaborative program, Prof. Men and Associate Prof. Yin will work together on the healthy river assessment and flow regulation refinement based on multiple purposes in the downstream of Yellow River. Read more on his institutional profile.

Zhang Cheng

Dr. Zhang Cheng is a member of the School Water Resources and Hydropower Engineering for Modelling Hydraulic and River Mechanics (North China Electric Power University). His research focuses on numerical analyses, the operation and control of water conveyance project. He completed his Bachelor (2004) studies at the Wuhan University (Wuhan, PRC) in Hydraulic Engineering and accomplished his doctorate(2008) at the Tsinghua University (Beijing, PRC). Between 2008 and 2010, Zhang Cheng pursued postdoctoral research at Tsinghua University with Prof. Zhang Jianmin. The emphasis of his postdoctoral research was on the operation and dispatch of the South-to-North Water Diversion Project (PRC). In this Sino-German collaboration project, he will cooperate with Doctor Zhang Jin and Doctor Tang Caihong to study river ecosystem response mechanism based on hydrology connection, field monitoring of water ecology, and collecting high precision landform data. Read more on his institutional profile.

Jin Zhang

Dr.-Ing. Jin Zhang, an associate Professor of Yantai University (personal website https://civilen.ytu.edu.cn/info/1235/8231.htm), major in water ecological environment and rehabilitation. Dr. -Ing. Jin Zhang completed her doctorate at the Department of Hydraulic Engineering and Water Resources Management (LWW) at the IWS, University of Stuttgart, under supervision of Prof. Wieprecht in 2014. Since 2007, Dr. -Ing. Jin Zhang has been studying urban river health and ecological rehabilitation for over ten years, she led NSFC projects on potential of fish habitat rehabilitation in urban rivers in plain/coastal areas, and studied its response to hydrodynamic and water quality enhancement. Since 2019, Dr. -Ing. Jin Zhang widened her research area from urban rivers to large scale watershed, worked on the ecosystem and habitats of the Yellow River estuary which might been influenced by the upper steam artificial water and sediment regulation, which is the research foundation for this project. In this NSFC-DFG project, she will work on the **Ecological Response to Changes of Hydrological Connectivity**.

Shiyang Yin

Dr. Shiyang Yin was graduated from Water conservancy and civil engineering of China Agricultural University in 2006. Then He was accepted for direct admission to the M.S. program at China Agricultural University and gained his M.S. degree in 2008. Between 2008 and 2014, He participated Beijing Water Science and Technology Institute as a Engineer&Senior engineer.He undertook the doctorate research at China University of Geosciences (Beijing) between 2014 and 2018 . Dr. Shiyang Yin joined the NCEPU as a associate professor in September 2018. Prior to this. His research primarily focuses on distributed hydrological model and its application and reclaimed water resused and its impact. He also participated in and took charge of 30 national 863 plans, science and technology support projects, industry public welfare projects, major science and technology projects in Beijing, and Beijing water science and technology projects. He was selected in the 2012 Excellent Talent Project of the Organization Department of Beijing Municipal Committee. In this joint program, He will work on the package of hydrologic model model simulation. Read more on his institutional profile.

Le Wang

Dr. Le Wang was graduated from Beijing Forestry University (China) with B.S. in soil & water conservation engineering in 2007. Then He was accepted for direct admission to the M.S. program at Beijing Normal University and gained his M.S. degree in debris-flow dynamics in 2010. Between 2010 and 2015, He undertook the doctorate research on bed-load sediment transport and morphological changes in unsteady flows at Heriot-Watt University. Dr. Le Wang joined the NCEPU as a Lecturer in September 2019. Prior to this, He participated in a NSFC funded Post-Doctoral Research program in fluvial dynamics at Tsinghua University. His research primarily focuses on sediment transport and bed morpho-dynamics in unsteady flows, especially under a series of flood sequences. He is also keen on the study of non-homogeneous debris-flow formation, mobilisation and deposition. In this joint program, He will work on the package of hydrological connectivity through physical model simulation. Read more on his institutional profile.

Changqing Meng

Dr. Changqing Meng is a lecturer at the School of Water Resources and Hydropower Engineering at North China Electric Power University. Her research focuses on hydrological models, climate change and downscaling analysis. Dr. Changqing Meng completed her doctorate at the School of Hydropower & Information Engineering, Huazhong University of Science and Technology. Between 2017 and 2019, Dr. Changqing Meng pursued her postdoctoral research at the Tsinghua University. Her recent research focuses on the evolution process of basin water cycle factors under future climate change. She has been working with the National Natural Science Foundation of China Youth Science Fund Project (2019) and the General Fund for Basic Research Projects of Central Universities (2020). She has published more than ten academic papers and 5 academic papers have been included in SCI and she is mainly engaged in regional hydrological simulation and climate diagnosis, flood risk map compilation, mountain torrent disaster evaluation and other research work. In recent years, she has participated in national key research and development projects, key projects of the National Natural Science Foundation of China, and undertaken projects of the National Natural Science Foundation of China. Read more on her institutional profile.

Wei Miao

Dr. Wei Miao is lecturer in school of Water Conservancy and Hydropower Engineering (NCEPU, North China Electric Power University). Her research focuses on flume experiment, image technique, sediment transport, and flow coherent structure. She completed his Bachelor (2012) study at Beijing Forestry University (Beijing, China) in soil and water conservation, and accomplished her doctorate (2018) at Tsinghua University (Beijing, China). Between 2018 and 2020, she pursued postdoctoral research at Tsinghua University with Prof. Danxun Li. In her postdoctoral research she focused on the Characteristics of Rainstorm, Flood and Sediment Yield in the Upper Changjiang River. In this project, she will participate in designing the physical model of lateral river connectivity and mechanism experiments about diffusion of water, sediment and organic mater on micro topography. And she will take part in remote sensing interpretation at yellow river.

Caihong Tang

Dr. Caihong Tang is an assistant professor in North China Electric Power University (NCEPU). She completed the Bachelor in Hydrology and Water Resources Research from NCEPU in 2013, and got the Ph. D. in Environmental Science from Beijing Normal University in 2020. She worked in Massachusetts Institute of Technology as a visiting scholar and joined NCEPU since 2020. Now she collaborates with Prof. Shanghong Zhang for postdoctoral research. Her research focuses on the water environment simulation, effects of vegetation on sediment resuspension, and lake ecological response to water transfer. In this joint project, she would like to explore the lateral connectivity of the Yellow River under flood stress by studying the ecological response of riparian vegetation system to the human activities and climate changes. Specific work mainly includes three parts: numerical modeling of water and sediment for the local reach of the Yellow River, dynamic simulation of vegetation growth and diffusion, and resilience analysis of riparian vegetation system.

6.2.2 Methods

Eco-morphological Connectivity

Lateral and vertical connectivity (University of Stuttgart)

More coming soon

Hydrological Connectivity

Longitudinal connectivity (NCEPU/YTU)

More coming soon

6.2.3 Code Documentation

This section will be filled with codes products.

6.2.4 Data

Small Datasets (<100MB)

Smaller and test datasets for application examples will be provided on GitHub repositories with instructions on how to use the data with algorithms from this project.

Large Datasets (>100MB)

Large datasets will be hosted on the independent educational, and state-funded bwSync&Share platform. To get read and write access to the large file repository, email Sebastian.

6.2.5 Instructions

Create new Code

A code example

The Python script `example_solver.py` lives in the host repository of this website in `ROOT/codes/`. The left column shows this Python script in its original form with docstrings (the `"""This is a docstring"""`). For writing new code, please read this entire page first, follow the instructions below, and visit hydro-informatics.github.io. All contributors, please respect the *Zen of Python* (`import this`). Thank you!

```python
"""This is the example_solver.py script for solving 1D hydraulics."""
import math as m


def calc_discharge(b, h, m_bank, S, k_st=None, n_m=None, D_90=None):
    """
    Calulate discharge in SI units. Provide one of the optional parameters k_st, n_m,
↪or D_90.

    Arguments:
        b (float): width (m)
        h (float): depth (m)
        m_bank (float): bank slope (-)
        S (float): slope (-)
        k_st (float): Strickler roughness (optional)
        n_m (float): Manning roughness (optional)
        D_90 (float): D90 for roughness (optional)
```

(continues on next page)

(continued from previous page)

```

    Returns:
        ``float`` of discharge in CMS
    """
```

How to add new package or library imports:

- Add it to the global import management file (*ROOT/import_mgmt.py*) within an *try-except-ImportError* statement (read more).
- If you need to import a library or package that is not yet listed in the *ROOT/environments.yml* and *ROOT/requirements.txt* files, please make sure to add the new library or package in both files.
- Add the new library or package to the `autodoc_mock_imports` *list* in *ROOT/docs/conf.py*.
- Update the version number according to the CONTRIBUTING standards.

Please use *PEP 8* for any code (read more on hydro-informatics.github.io/hypy_pystyle) and try to keep the number of lines per script below 150 (it's hard or even apparently impossible sometimes - just try please).

To learn more about Python coding in general, visit the teaching website from the hydro-morphodynamics research group of the IWS: hydro-informatics.github.io.

Download and Upload Project Code

Start with downloading (i.e., **pull** or **clone**) the project repository to your local computer.

Windows Users

Download and install Git Bash. Linux users will most likely not need to install git because it is inherently part of the system tools.

Then open `Git Bash` (on Windows) or `Terminal` (on Linux or MacOS) and tap (replace capital letters with your target directory):

```
cd TARGET/DIRECTORY/
git clone https://github.com/sschwindt/econnect.git
cd econnect
```

Now, the source code for this website and the above shown `example-solver.py` script are copied to your local computer. To make changes in the code or to modify any existing file, you will need to become a contributor of this repository and you will need to email Sebastian to get the required read & write rights. Once you are a contributor, edit, add, or remove scripts and files in your local `TARGET/DIRECTORY/econnect/` (corresponds to `ROOT`) folder. Consider to create a new subfolder in `ROOT/codes/` and save your code there locally (basically in any programming language). Then, upload, or **push** new code:

```
git add .
git commit -m "ADD AN ACTIVE-VOICED MESSAGE IN SIMPLE PAST"
git pull --rebase
git push
```

If you encounter an error or warning after running `git pull --rebase`, that means someone else has been editing the file at the same time. No worry about that, git will guide you through troubleshooting: Just open the concerned file and manually fix the indicated code blocks (indicator: <<< and >>> signs). Then follow the commands that *GitBash* or *Terminal* suggest you to use. To read more about git, visit *https://hydro-informatics.github.io/hy_git.html*.

Important: Only push debugged code - Thank you!

What is the goal of this approach?

Using git enables version control and collaborative development of algorithms. Following coding standards (e.g., PEP8 styles), and with the help of git, the project results will be transparent, re-usable, safely stored, and accessible for anyone interested. Eventually, we want to provide the project results as a pip-hosted Python package to leverage universal use of the project achievements along with coherent and understandable documentation.

How the Code Docs work

The automated code documentation of Sphinx ReadTheDocs automatically parses functions and classes for docstrings and implements them in the documentation. Python code docs are implemented via google style of docstrings in scripts. Please familiarize with the style format and strictly apply in all commits.

To implement code documentations:

1. Save the file in `ROOT/codes/` (example: `ROOT/codes/example_solver.py`).
2. Add a new section (create a new ~~~ header for single scripts/modules and a === header for new packages).
3. In the new header add the following:

```
.. automodule:: script-name (without.py at the end)
    :members:
```

Example

This is the example_solver.py script for solving 1D hydraulics.

`example_solver.`**`calc_discharge`**(*b*, *h*, *m_bank*, *S*, *k_st=None*, *n_m=None*, *D_90=None*)

Calulate discharge in SI units. Provide one of the optional parameters k_st, n_m, or D_90.

Parameters

- **b** (*float*) – width (m)
- **h** (*float*) – depth (m)
- **m_bank** (*float*) – bank slope (-)
- **S** (*float*) – slope (-)
- **k_st** (*float*) – Strickler roughness (optional)
- **n_m** (*float*) – Manning roughness (optional)
- **D_90** (*float*) – D90 for roughness (optional)

Returns `float` of discharge in CMS

`example_solver.`**`interpolate_h`**(*Q*, *b*, *S0*, *m_bank=1.0*, *n_m=0.04*, *prec=0.001*, ***kwargs*)

Inverse calculation of normal water depth for a given discharge and channel geometry uses Raphson-Newton Algorithm

Parameters

- **Q** (*float*) – of target discharge in (m3/s)

- **b** (*float*) – of channel base width in (m)
- **S0** (*float*) – of channel (energy) slope is (m/m)
- **m_bank** (*float*) – of channel bank inclination (dimensionless), default=1.0
- **n_m** (*float*) – of Manning's n, default=0.04
- **prec** (*float*) – of result precision (don't be too picky)
- **kst** (*float*) – of Strickler value supersedes n_m
- **d90** (*float*) – of surface grain size supersedes n_m

Returns `float` of flow depth in M

More about Sphinx & ReadTheDocs

This page uses *Sphinx* readthedocs and the documentation regenerates automatically after pushing changes to the repositories `main` branch.

To set styles, configure or add extensions to the documentation use `ROOT/.readthedocs.yml` and `ROOT/docs/conf.py`.

To modify this documentation file, edit `ROOT/docs/index.rst` (uses reStructuredText format).

For local builds of the documentation, the following packages are required:

```
sudo apt install build-essential
sudo apt install python-dev python-pip python-setuptools
sudo apt install libxml2-dev libxslt1-dev zlib1g-dev
apt-cache search libffi
sudo apt install -y libffi-dev
sudo apt install python3-dev default-libmysqlclient-dev
sudo apt install python3-dev
sudo apt install redis-server
```

To generate a local html version of the documentation, `cd` into the `docs` directory and type:

```
make html
```

Learn more about *Sphinx* documentation and the automatic generation of *Python* code docs through docstrings in the tutorial provided at github.com/sschwindt/docs-with-sphinx.

6.2.6 List of Project publications

Conference Contributions

Coming soon

Peer-reviewed Papers

Coming soon

Reports

Data Management Plan

The Data Management Plan (DMP) outlines how research data, including codes and models, collected, created, or generated in the eConnect project will be handled during and after the project. The DMP describes standards and methods for data storage and sharing among project collaborators, with the scientific community, the general public, and potential stakeholders. The DMP is expected to evolve with the project and its implementation is required for all partners of the eConnect project, also when data is reused after the end of the project. Download the latest version of the eConnect-DMP here.

Software and Other

Coming soon

6.2.7 Internal (Admin)

Register on trello.com and contact Sebastian Schwindt with your request to join the project team. Include if you also aim at contributing to the web-docs (below) that are managed on GitHub.

6.2.8 Disclaimer and License

Disclaimer (general)

No warranty is expressed or implied regarding the usefulness or completeness of the information provided on these pages and its documentation. References to commercial products do not imply endorsement by the Authors. The concepts, materials, and methods used in the codes and described in the docs are for informational purposes only. The Authors have made substantial effort to ensure the accuracy of the code and the documentation and the Authors shall not be held liable, nor their employers or funding sponsors, for calculations and/or decisions made on the basis of application of the information provided on these pages. The information is provided "as is" and anyone who chooses to use the information is responsible for her or his own choices as to what to do with the descriptions, code, documentation, data, and other information and the individual is responsible for the results that follow from their decisions.

BSD 3-Clause License

CHAPTER

SEVEN

REFERENCES

[1] D. J. Allan and M. M. Castillo, Stream Ecology - Structure and Function of Running Waters, Second. Dordrecht, The Netherlands: Springer, 2007.

[2] J. Kalff, Limnology: inland water ecosystems. Upper Saddle River, N.J.: Prentice Hall, 2002.

[3] B. Yu, J. Z. Zhang, and Y. O. Liu, "Influence of water sediment regulation in Xiaolangdi reservoir on plankton in the Yellow River," Hebei fisheries, vol. 1, pp. 15–20, 2013.

[4] J. G. Tulla, Die Grundsätze, nach welchen die Rheinbauarbeiten künftig zu führen seyn möchten [The principle according to which the future construction works at the Rhine need to be managed]. 1812.

[5] D. Blackbourn, The Conquest of Nature: Water, Landscape and the Making of Modern Germany. London, United Kingdom: Pimlico, 2006.

[6] K. Ochs, G. Egger, I. Kopecki, and T. Ferreira, "Model-based reconstruction of the succession dynamics of a large river floodplain," River Res. Appl., vol. 35, no. 7, pp. 944–954, 2019, doi: 10.1002/rra.3502.

[7] B. O. L. Demars, G. Wiegleb, D. M. Harper, U. Bröring, H. Brux, and W. Herr, "Aquatic Plant Dynamics in Lowland River Networks: Connectivity, Management and Climate Change," Water, vol. 6, no. 4, pp. 868–911, 2014, doi: doi:10.3390/w6040868.

[8] K. E. Trenberth, "The Impact of Climate Change and Variability on Heavy Precipitation, Floods, and Droughts," in Encyclopedia of Hydrological Sciences, American Cancer Society, 2008.

[9] M. Acreman et al., "Environmental flows for natural, hybrid, and novel riverine ecosystems in a changing world," Front. Ecol. Environ., vol. 12, no. 8, pp. 466–473, 2014, doi: 10.1890/130134.

[10] S. Schwindt, G. B. Pasternack, P. M. Bratovich, G. Rabone, and D. Simodynes, "Hydro-morphological parameters generate lifespan maps for stream restoration management," J. Environ. Manage., vol. 232, pp. 475–489, 2019, doi: 10.1016/j.jenvman.2018.11.010.

[11] S. Chen, B. Chen, and B. D. Fath, "Assessing the cumulative environmental impact of hydropower construction on river systems based on energy network model," Renew. Sustain. Energy Rev., vol. 42, pp. 78–92, Feb. 2015, doi: 10.1016/j.rser.2014.10.017.

[12] H. Wang, Z. Yang, Y. Saito, J. P. Liu, and X. Sun, "Interannual and seasonal variation of the Huanghe (Yellow River) water discharge over the past 50 years: Connections to impacts from ENSO events and dams," Glob. Planet. Change, vol. 50, no. 3, pp. 212–225, Apr. 2006, doi: 10.1016/j.gloplacha.2006.01.005.

[13] Q. Tian, "Impacts of climate change and human activity on the water and sediment flux of the Yellow, Yangtze and Pearl River basins over the past 60 years," East China Normal University, Shanghai, China, 2016.

[14] A. McCormick, K. Fisher, and G. Brierley, "Quantitative assessment of the relationships among ecological, morphological and aesthetic values in a river rehabilitation initiative," J. Environ. Manage., vol. 153, pp. 60–67, 2015, doi: 10.1016/j.jenvman.2014.11.025.

[15] W. Gostner, M. Alp, A. J. Schleiss, and C. C. Robinson, "The hydro-morphological index of diversity: a tool for describing habitat heterogeneity in river engineering projects," Hydrobiologia, vol. 712, no. 1, pp. 43–60, 2013, doi: 10.1007/s10750-012-1288-5.

[16] L. Seitz, C. Haas, M. Noack, and S. Wieprecht, "From picture to porosity of river bed material using Structure-from-Motion with Multi-View-Stereo," Geomorphology, vol. 306, pp. 80–89, Apr. 2018, doi: 10.1016/j.geomorph.2018.01.014.

[17] M. Noack, J. Ortlepp, and S. Wieprecht, "An Approach to Simulate Interstitial Habitat Conditions During the Incubation Phase of Gravel-Spawning Fish," River Res. Appl., vol. 33, no. 2, pp. 192–201, 2017, doi: 10.1002/rra.3012.

[18] S. Schwindt, K. Larrieu, G. B. Pasternack, and G. Rabone, "River Architect," Softw. X, 2020.

[19] A. Schaefer Rodrigues Silva, M. Noack, D. Schlabing, and S. Wieprecht, "A data-driven fuzzy approach to simulate the critical shear stress of cohesive sediments," in River sedimentation, Stuttgart, Germany, 2016, pp. 387–393.

[20] S. Wieprecht, H. G. Tolossa, and C. T. Yang, "A neuro-fuzzy-based modelling approach for sediment transport computation," Hydrol. Sci. J., vol. 58, no. 3, pp. 587–599, Apr. 2013, doi: 10.1080/02626667.2012.755264.

[21] S. Schwindt, G. B. Pasternack, P. M. Bratovich, G. Rabone, and D. Simodynes, "Lifespan map creation enhances stream restoration design," MethodsX, vol. 6, pp. 756–759, 2019, doi: 10.1016/j.mex.2019.04.004.

[22] M. Noack, "Modelling Approach for Interstitial Sediment Dynamics and Reproduction of Gravel-Spawning Fish," Dissertation No. 214, Institute for Modelling Hydraulic and Environmental Systems, University of Stuttgart, 2012.

[23] V. Chardon et al., "Geomorphic effects of gravel augmentation on the Old Rhine River downstream from the Kembs dam (France, Germany)," E3S Web Conf., vol. 40, p. 02028, 2018, doi: 10.1051/e3sconf/20184002028.

[24] M. Weyand and L. Rullich, "River rehabilitation in urban areas – restrictions, possibilities and positive results," Water Supply, vol. 19, no. 3, pp. 944–952, Aug. 2018, doi: 10.2166/ws.2018.145.

[25] F. Arnaud, L. Schmitt, K. Johnstone, A.-J. Rollet, and H. Piégay, "Engineering impacts on the Upper Rhine channel and floodplain over two centuries," Geomorphology, vol. 330, pp. 13–27, Apr. 2019, doi: 10.1016/j.geomorph.2019.01.004.

[26] A. Schäfer-Rodrigues Silva, G. Schmid, M. Noack, and S. Wieprecht, "Erosionsmessungen an Sedimentkernen aus dem Oberwasser der Wehranlagen Marckolsheim und Rhinau," University of Stuttgart, Stuttgart, Germany, 03/2017, 2017.

[27] M. Noack, G. Hillebrand, U. Seidenkranz, and S. Wieprecht, "Investigation on the erosion stability of cohesive sediment deposits in the weir channel of the barrage Iffezheim, River Rhine," Hydrol. Wasserbewirtsch., vol. 60, no. 3, pp. 164–175, 2016, doi: 10.5675/HyWa_2016,3_1.

[28] M. Noack, G. Schmid, F. Beckers, S. Haun, and S. Wieprecht, "PHOTOSED-PHOTOgrammetric Sediment Erosion Detection," Geosciences, vol. 8, no. 7, p. 243, Jul. 2018, doi: 10.3390/geosciences8070243.

[29] A. Barriga-Morachimo, "Verifizierung und Optimierung eines optischen Messsystems," Bachelor Thesis, University of Stuttgart, Stuttgart, Germany, 2014.

[30] M. Körner, "Anthropogene Einflussnahmen auf den Rhein von Basel bis Emmerich und ihre Auswirkungen auf die Fließtiefen," Bachelor Thesis, University of Stuttgart, Stuttgart, Germany.

[31] R. A. Brown, G. B. Pasternack, and W. W. Wallender, "Synthetic river valleys: Creating prescribed topography for form-process inquiry and river rehabilitation design," Geomorphology, vol. 240, pp. 40–55, 2014, doi: 10.1016/j.geomorph.2014.02.025.

[32] M. W. Straatsma and M. G. Kleinhans, "Flood hazard reduction from automatically applied landscaping measures in RiverScape, a Python package coupled to a two-dimensional flow model," Environ. Model. Softw., vol. 101, pp. 102–116, 2018, doi: 10.1016/j.envsoft.2017.12.010.

[33] G. I. Barenblatt, Scaling, self-similarity and intermediate asymptotics. Dimensional Analysis and Intermediate Asymptotics. Cambridge University Press, 1996.

PYTHON MODULE INDEX

e

INDEX