MORPHOLOGICAL SCALE EXPERIMENTS TO LINK RIVER BED STRUCTURE WITH RIVERINE VEGETATION

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ABSTRACT

Most of the rivers in Germany and the EU are still missing the good ecological status (BMU, 2010). Severe reasons are the deviancies in the hydro-morphological status. Generally, this could be improved by the use of vegetation along the river, knowing that it may also affect the flood water table. Vegetation not only has fundamental ecological functions in the fluvial environment, but it also affects the flow pattern, bed-shear stress and hence local sediment deposition, which links back to habitat characteristics. Therefore, a joint research project of university institutes with professional focusing on hydraulic engineering, morphology and hydrobiology, together with administration and engineering consultants in the field of environmental planning, is established with the aim to improve the ecological and flood risk status with simultaneous increase in the level of acceptance by the public when flood risk management is systematically combined with environmental protection goals. The objective of this part of the joint-project is to investigate river bed structures due to the influence of riparian vegetation. This paper reviews the current state and includes investigation of parameters in the morphological scale experiments.

Keywords: Morphodynamics; physical model; riverbed structure; sediment transport; vegetated channel.

1 INTRODUCTION

Most of the rivers in Germany and the EU are still missing the good ecological status (BMU, 2010; EEA, 2012), although the first period of target achievement of the European Water Framework Directive (EU-WFD, 2000) ended in 2015. Furthermore, between 1995 and 2013, several devastating floods occurred in Europe (Kron, 2015) which underlined the urgent need for improved flood risk management and contributed to an inherent conflict potential for suitable measures.

In the joint research project "In_StröHmunG" (Innovative systems solutions for transdisciplinary and regional ecological flood risk management and natural watercourse development), which is funded by the German Ministry of Education and Research, flood prevention and natural watershed management shall be interconnected (Stamm & Müller, 2015). The goal of the joint research project is to develop instruments in order to achieve the goals of both EU directives: The European Water Framework Directive and the European Floods Directive (EU-FD, 2007) on the assessment and management of flood risks.

In total, seven partners are linked in this project. University institutes with professional focusing on hydraulic engineering, morphology and hydrobiology are equally involved as administration and practical partners of an environmental and a planning agency as well as partners with economical background. The aim of this research is to improve the ecological and flood risk status for several reference watercourses and to increase the level of acceptance by the public when flood risk management is systematically combined with environmental protection goals.

The project is subdivided into four sub-projects: (1) morphology, (2) ecology, (3) implementation and (4) the scientific and administrative project management. The findings of the applied research will be transferred and implemented to selected reference rivers in different model regions (Figure 1). These German rivers reflect the challenges which are typical for numerous rivers due to realization and minimization of trade-offs of both EU directives; all of them fail the good ecological status:

- Mortelbach and Eulitzbach (Saxony, cities of Waldheim and Roßwein, Kriebstein),
- Mutzschener Wasser and Launzige (Saxony, cities of Grimma, Trebsen and Colditz),
- Zwönitz river near Chemnitz (Saxony, district of Einsiedel),
- Allerriver near Celle (Saxony-Anhalt).

In the first sub-project, three different morphological flume experiments are used. Whereas the small rivers (second order rivers) are object of investigation in an experiment at the Technical University in Dresden, a bigger river of first order and a branch is modelled in the laboratory of the Magdeburg-Stendal University of Applied Sciences and investigations of depositions along streams, especially as it appears on the waterway Elbe, are conducted at the Technical University of Braunschweig (Branß & Dittrich, 2016; Branß et al., 2016). All experiments pursue the development of fundamental knowledge about the interaction of hydraulic,

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vegetation and sediment to enable suggestions for an ecological but also flood oriented watershed management.

The ecology sub-project deals with the effect of bioengineering and stream restoration measures on the quality components of the WFD and the ecological status of the rivers. The hydro-morphology of rivers and their anthropogenic changes have a direct influence on the constitution of fish zoonosis and macrozoobenthos communities. Up to now, measures to improve the structure of rivers have shown only moderate results (Haase et al., 2013). To expand the knowledge about the impact and the need of measures, an extensive sampling of probes of macrozoobenthos and fish has been conducted in the model regions and is still ongoing. Furthermore, the sampling has been extended to probes of the sediment to validate the morphological experiments for small rivers. In addition, research will be done to assess the potential of new settlement of macrozoobenthos and fish in the downgraded rivers. Finally, predictions about the spatiotemporal effectiveness of hydro-morphological improvements in the rivers shall be enabled.

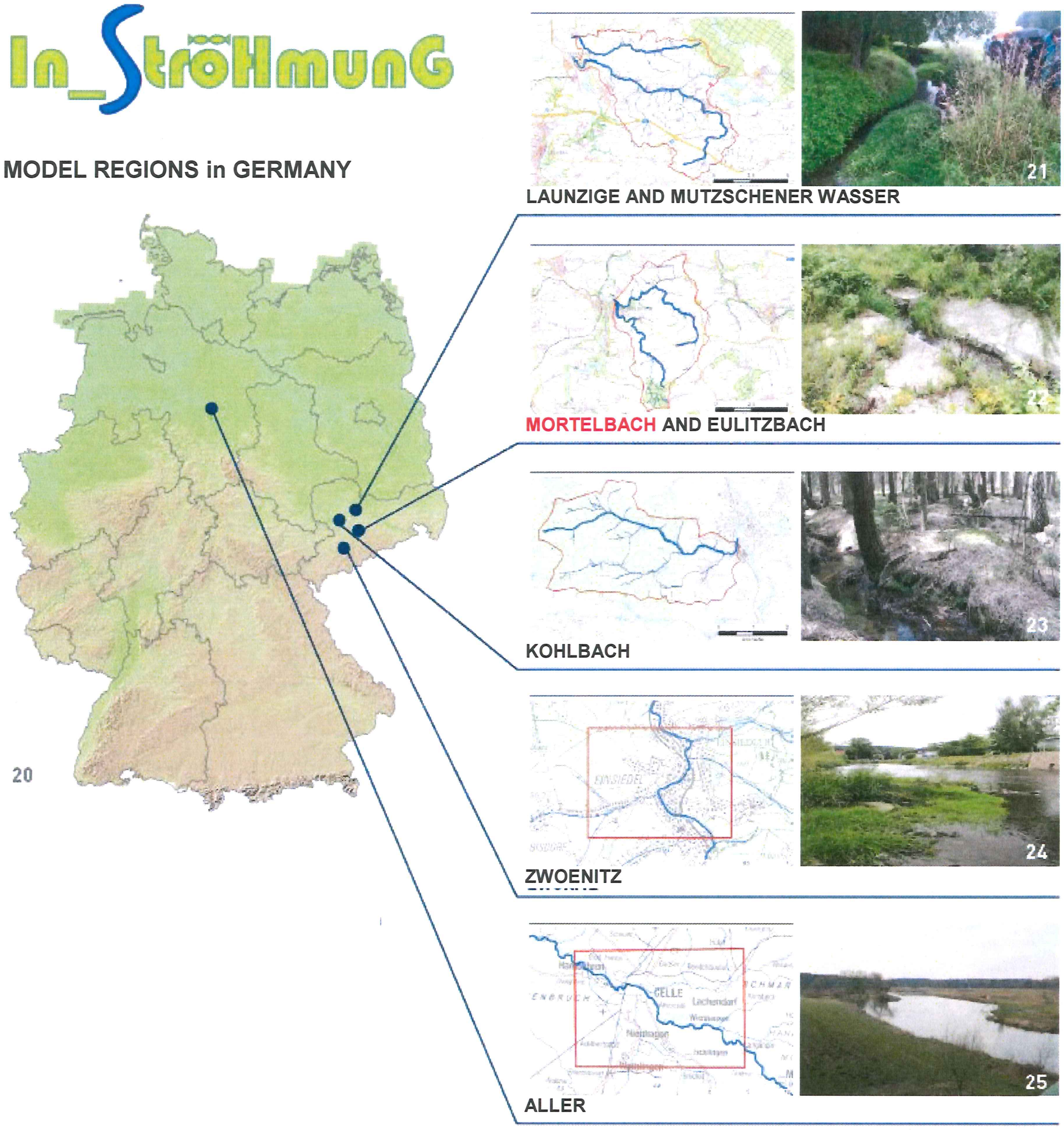


Figure 1. Model regions of the joint research project and location of Mortelbach, which is represented in the laboratory experiment (special base data: © Staatsbetrieb Geobasisinformationen und Vermessung Sachsen (GeoSN), 2016; Bundesamt für Kartographie und Geodäsie (BKG), 2016; Landesamt für Geoinformation und Landesvermessung Niedersachsen (LGLN), 2016; Images: 20 © LfuLG; 21 © M. Stengert, ube; 22, 23 © LfuLG; 24 © N. Müller, IWD; 25 © B. Ettmer, HS MD).

Third part of the project focuses on the development of innovative system solutions and concepts for the administrative watershed management as a key element of sustainable regional water resources management. A transdisciplinary approach linked with intensive public relations will help to reach that aim. The main issue is the planning and realization of innovative concepts and measures which integrate flood protection and an enhancement of the ecological status in the model regions (Niemand et al., 2016). To facilitate the maintenance of small rivers in consideration of an ecological orientated flood water prevention, a software will be developed for the cities and municipalities which are responsible for their preservation. In addition, the software will help to inform and get feedback from the citizens (Stowasser et al., 2016).

The main objective of this study is to present the laboratory experiment of the Institute of Hydraulic Engineering and Technical Hydrodynamics (IWD) at the Technical University Dresden, where the riverbed structure is investigated due to the influence of riparian vegetation.

2 PROJECT SITE

In order to simulate the results of the laboratory experiment with the natural river condition, a model river needs to be developed. Therefore, several parameters based on channel geometry, hydrology, morphology, grain size curves (Figure 2) etc. were investigated.

One of the selected river sections of the joint research project – the Mortelbach, which is a small river in the middle of Saxony became the examination subject and was schematically modelled in the laboratory. The Mortelbach belongs to the German stream type 5, which means it is rich of coarse material and a silica based low mountain range stream. The stream is rising in Grünlichtenberg and flows 9.5 km later in Waldheim into stream Gebersbach, which itself waters into the Zschopau.

The Mortelbach has a mean channel-width of 3÷7 m, a mean discharge of MQ = 0.14 m³/s and a flood water flow of HQ100 = 12.5 m³/s. The catchment area is 10.3 km².

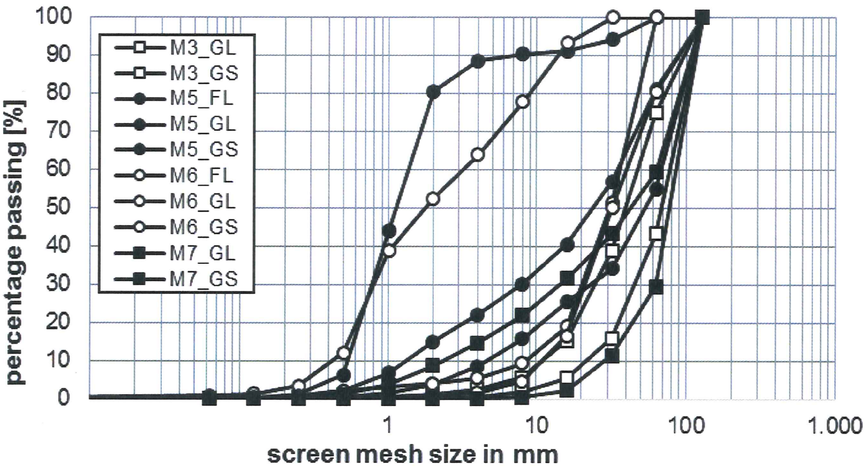


Figure 2. Grain size curves on several sampling positions (M3, M5, M6, M7) and mineral substrate types (mineral substrate: G-coarse and F-fine; velocity: L-slow and S-fast in relation to the corresponding patch).

Figure 3. Sampling Position M6, Mortelbach (© N. Müller, IWD).

3 LABORATORY EXPERIMENT

The aim of the flume experiments was to ascertain the influence of riverine vegetation on the bottom structure of rivers, especially small rivers. Small rivers play an important role in the total ecological status, because on one hand the sum of the total length is relevant and on the other they significantly affect the biological status of the larger rivers they are flowing into.

In the Hubert-Engels hydraulic laboratory of the IWDat Technical University of Dresden, Germany, scale experiments with mobile bed and vegetation roughness were in progress. The straight channel used for the morphological experiment was made of concrete angular retaining elements with overall measurements of 30.0 m in length, 2.0 m in width and a height of 0.64 m. Bed width was 1.4 m within embankments with a gradient 1:1 on both sides. The bottom of the flume was covered with mobile sediment with a mean thickness of 0.2 m (Figure 4). The longitudinal slope of the channel was 2.0 ‰. Discharge was conducted through two valves from an underground-tank. The water entered the flume first through a stilling basin and second a set of parallel rectifiers for directing the flow. Downstream at the end of the channel, a sediment trap was constructed, followed by an adjustable overflow weir, which was used to adjust the desired flow depth to reach normal flow conditions. A fixed set of three flow depths (0.2, 0.25, 0.3 m) was adopted for the study. This led to flow capacities up to 0.45 m³/s.

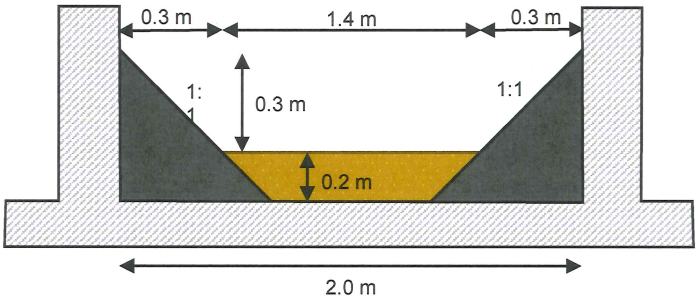


Figure 4. Experimental Setup, flume cross-section.

In order to get diverse bottom structures and observe separation of the soil, a specific grain-size curve was used. The material adapted to the conditions of the chosen project site, which was mentioned in chapter 2, with a scale of 1:4 (Figure 5). In order to fit flume experiments to Mortelbach, specifically stream type 5, a method to distinguish the grain-size curve was developed. The sampling method for the WFD had been extended in order to represent the ecological relevant conditions: After determining the substrate type at the sampling position (bedrock type) in 5-percent-steps, one substrate pattern per substrate type had been taken with a cylinder or a Van-Veen-gripper. In the laboratory, the substrate pattern had been dried and sieved in order to get a grain-size curve. If the probes had a not negligible content of fine material, a laser-analysis had been done additionally. Afterwards, the grain-size curve had been scaled and matched with curves of quartz sand and gravel to make it suitable for measurements with the use of three-dimensional photogrammetry system. Sampling Position M6 with a scale of 1:4 was chosen for representation in the laboratory experiments (Fig. 5). For safety reasons due to pump-protection finer sediments, suspension load was neglected.

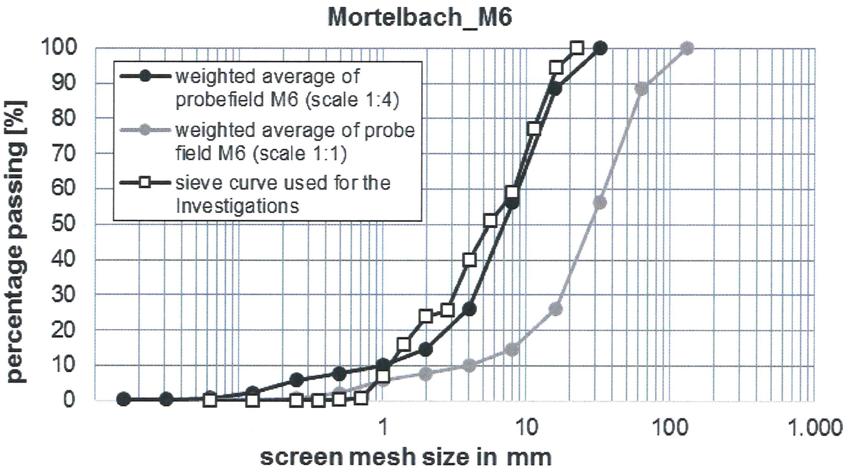


Figure 5. Grain size curves on several sampling positions (M3, M5, M6, M7) and mineral substrate types (mineral substrate: G-coarse and F-fine; velocity: L-slow and S-fast in relation to the corresponding patch).

To investigate the impact of vegetation at the beginning, experiments without any vegetation (variant 0-A) were conducted. Experimental setups including grass-covered slopes were also executed (variant 0-B). For the mentioned experimental setups, discharges near the beginning of transport were conducted in order to see how the vegetation influenced the bottom structures. Previous analytical calculations for cases of obstacle-free cross-sections showed, that nearly 50.0 % of the sediment-particles were below the critical threshold for particles to move in all stages.

Experiment with diverse vegetation patterns was also carried out (variant 1, 2 etc.). Rigid as well as flexible vegetation will be installed.

4 DATA COLLECTION

Bottom structures were measured contact free by using a special photogrammetry system based on correlation measurements, containing three cameras, which were fixed at a movable traverse system. After calibrating the cameras by finding information according to camera-orientation, the system was moved to the area of interest. Reflecting encoded markers, which were fixed along the flume and had predefined positions identified the regions, where the camera system was recording. By means of a software which calculates the bottom height, the structures can be analyzed (Fig. 6 left). To verify the results and increase the data density, additional laser measurements were taken with a movable traverse, which covered an area of 1.4 m × 4.6 m. Laser measurements were taken with a solution of 8 mm × 1 mm (Fig. 6 right).

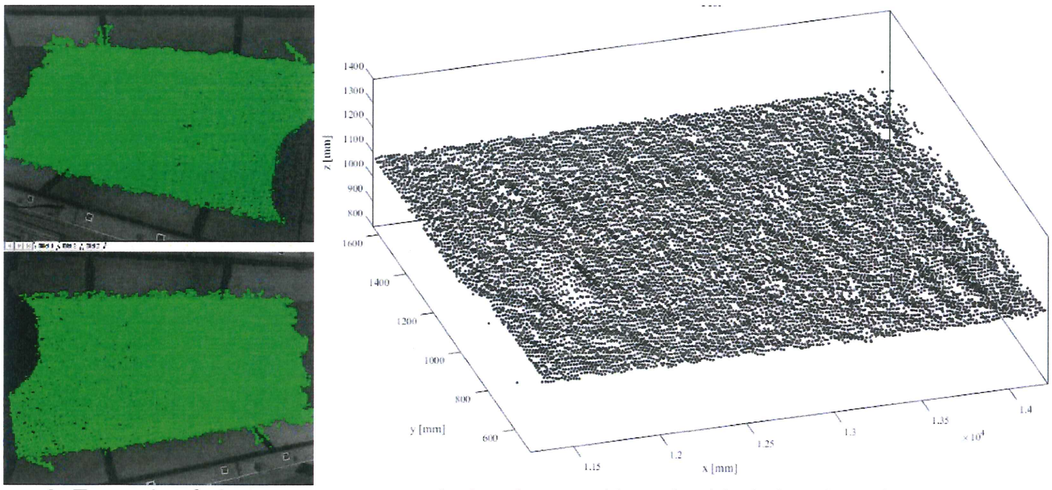
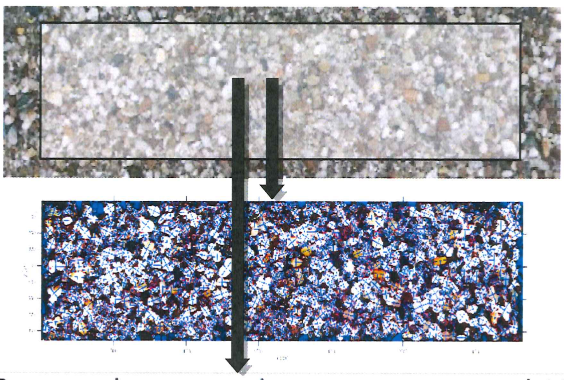


Figure 6. Example of photogrammetry analysis, photos with embedded signals (left) and result (right).

Furthermore, grain size distribution on channel bed surface was analyzed using orthogonal photos. The software BASEGRAIN©, developed at ETH Zurich (Detert, 2013), was able to detect the size and position of grains out of photos (Figure 6). The distribution of grains and the sizing induced by the interaction of flow and vegetation were described. The sizing in connection with the three-dimensional bed structure allowed conclusions for the improvement of bed structure and therefore as habitat for macrozoobenthos.



ID [-]	a [mm]	b [mm]	a [px]	b [px]	area [px]	x [px]	y [px]	orientation [deg]
1	19,841	14,513	19,841	14,513	218	8,404	106,881	79,901
2	18,020	15,791	18,020	15,791	212	11,585	395,571	35,791
3	16,862	12,804	16,862	12,804	164	16,677	367,122	27,029
4	14,713	11,209	14,713	11,209	125	15,312	287,368	-67,070
5	46,425	41,062	46,425	41,062	1447	29,351	793,143	-84,023

Figure 7. Digital grain size analysis by using ortho photos and software BASEGRAIN©.

To determine spatial water surface and surface velocity, the photogrammetry system can be used by the principle of partice tracking within a series of images and using tracer particles at water surface. Continuous as well as temporal but local measurements of water level with ultrasound, proofed by needle gauge measurements, were conducted in addition.

A down-looking Acoustic Doppler Velocimeter (ADV), developed by NORTEK, was used to measure the instantaneous three-dimensional velocity components (Figure 8). Errors in the prediction of mean velocities were less than ±2.5 mm/s (or ±1%) (Nortek, 1998). Velocities had been recorded at each point of measurement with a sampling frequency of 200 Hz and sampling duration of 200 seconds for each measurement. WinADV (Wahl, 2000) was used to filter and process velocity and turbulence data. Data with average correlation lower or equal to 70 % and average signal-noise ratio lower or equal to 15 dB were filtered out.

Figure 8. Impression of the experimental flume with bare concrete slopes.

5 OUTLOOK

Recently, experiments with bare concrete slopes are running to collect basic values for the latter comparative evaluation of the influence of different bank vegetation structures upon the river bed morphology. Investigations including grass covered banks are ongoing. In summer 2017, preliminary results of vegetated banks will be presented.

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