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INFLUENCE OF CONSTRUCTIONAL ELEMENTS ON SEDIMENT TRANSPORT

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ABSTRACT

Efforts have recently been made to renaturalize the Weißach River which had previously been regulated in a schematic, monotonous manner. During the last flood period an aggradation of sediment occurred, which may provoke an overtopping of the dams. In a hydraulic model with movable bed (scale 1:20) the existing conditions and possible improvements were studied in order to prevent further aggradations. Furthermore, fundamental investigations were made with regard to the influence of constructional measures on sediment transport and water levels.

INTRODUCTION

Recently the attempt has been made to renaturalize rivers which were straightened in former time. The foreshores are often built on with houses or are agriculturally cultivated, so that there is no possibility to lead the river back to its former meanders. Mostly a variation of the course of the river can only be achieved by constructional elements.

Fundamental model investigations into the influence of constructional elements on the sedimentological and hydraulic balance were performed at the Institut für Wasserwesen at the Universität der Bundeswehr in Munich.

BASIC REMARKS ABOUT SEDIMENT TRANSPORT

For the description and calculation of sediment transport processes there are three very important parameters:

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1. Begin of sediment transport
2. Bed forms due to transport
3. Sediment transport balancing

For the description and evaluation of the following model tests it is necessary to give some detailed remarks about the bed forms due to transport and their influence on the roughness of a river.

Bed Forms due to Transport

Sediment transport mostly leads to changes of the river bed and the build-up of so-called bed forms. Basically three types of bed forms may be recognized (Fig. 1a,c,f).

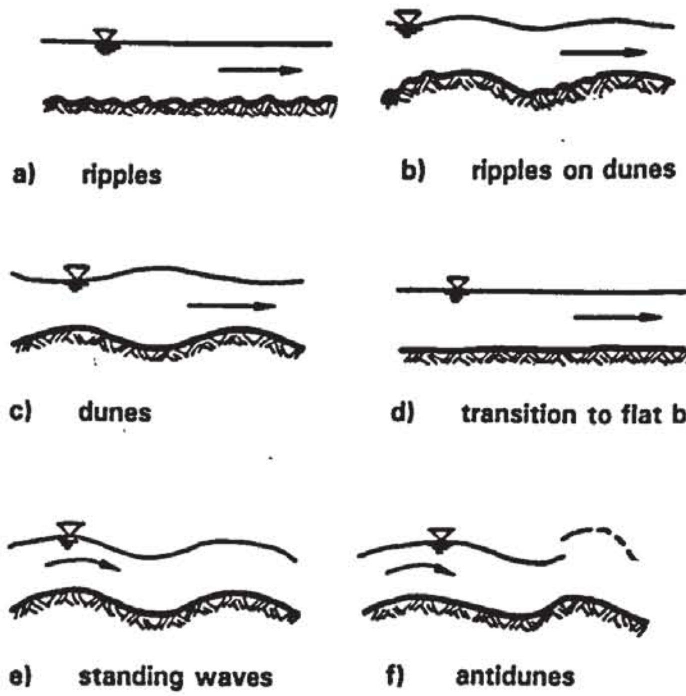

Fig. 1: Types of bed forms

There is no generally accepted explanation for the occurrence of bed forms. Thus most criteria rely on empirical approaches. On the basis of measured and observed results relations were developed in order to define areas, where one or the other bed form will occur. As an example a diagram by Zanke (1982) is shown in Fig. 2.

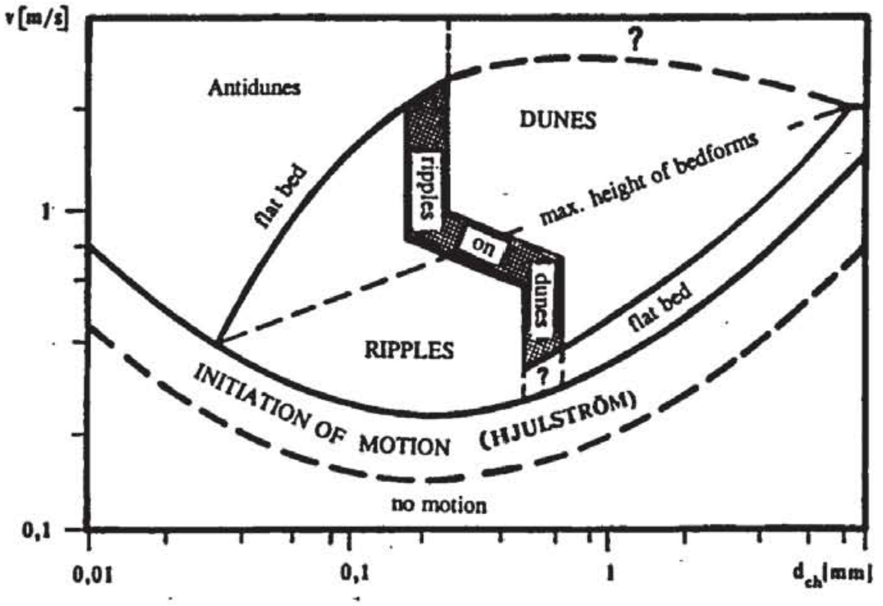

Fig. 2: Bed forms, Zanke (1982)

Roughness of a River

Up to now the Manning-Strickler equation is the best known and most applied formula for the calculation of the river roughness resp. discharge. The essential assumption of this formula is, that the roughness and water depth do not depend on each other. But in natural rivers, especially with vegetation on the embankments or "obstacles" such as big stones on the ground, the roughness is very different for certain parts of the channel. In Fig. 3 the composition of the different resistances of a river is shown.

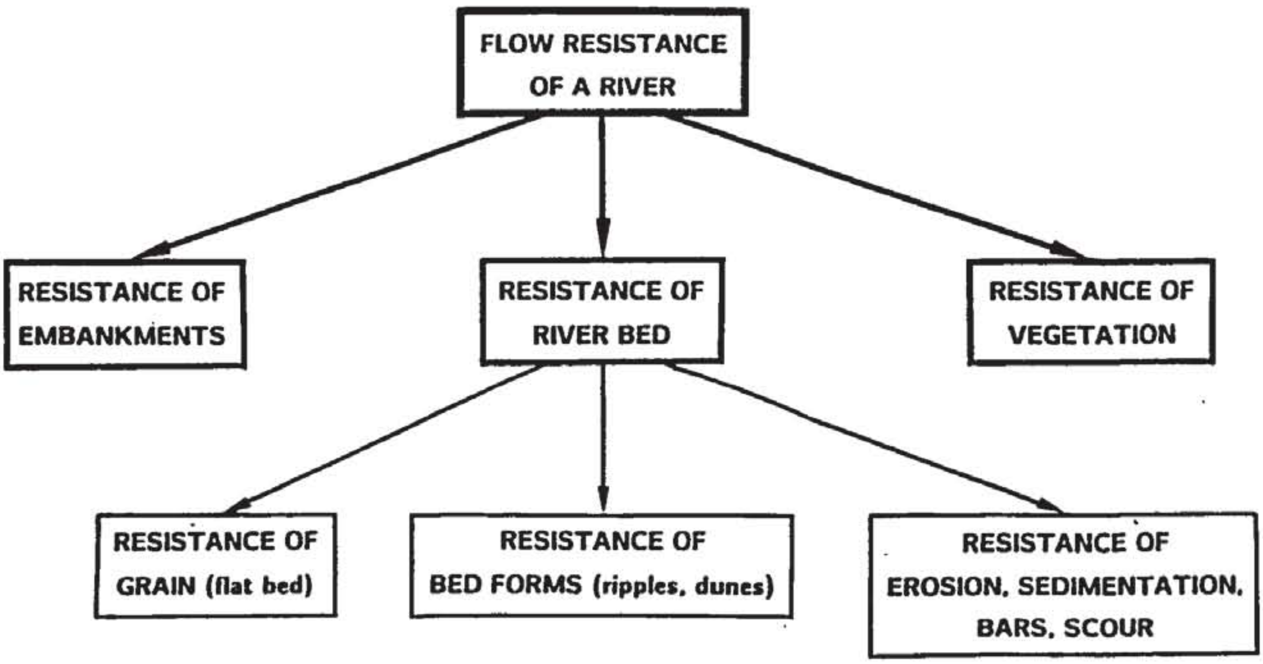

Fig. 3: Flow resistance of a river

MODEL DESCRIPTION

The model consists of two equally long sections that are connected by a hinge. It is supported by two I-shaped steel girders, the elevation of which can be adjusted to any slope desired, up to 1%, for the different investigations. River cross-section simplified by a trapezoidal model cross-section. The lateral embankments are made of sheet iron. Roughness is simulated by coarse sands glued on the surface. A bed material ground layer of 10 cm thickness avoids the ground plate to be washed free in erosion ranges and the flume roughness to be changed. Two circular metal rods serve as guide rails for the measuring carriage. Fig. 4 shows the model cross-section and plan view.

As measuring installations serve an inductive flowmeter for discharge regulation, point gauges for the control of water depths and a profile follower for the assessment of river bottom changes. The sediment input comes as a sand-water-mixture out of a plexiglass tube having a vertical slot, which is opened at a constant predefined speed and thus provides a constant inflow of material per time unit.

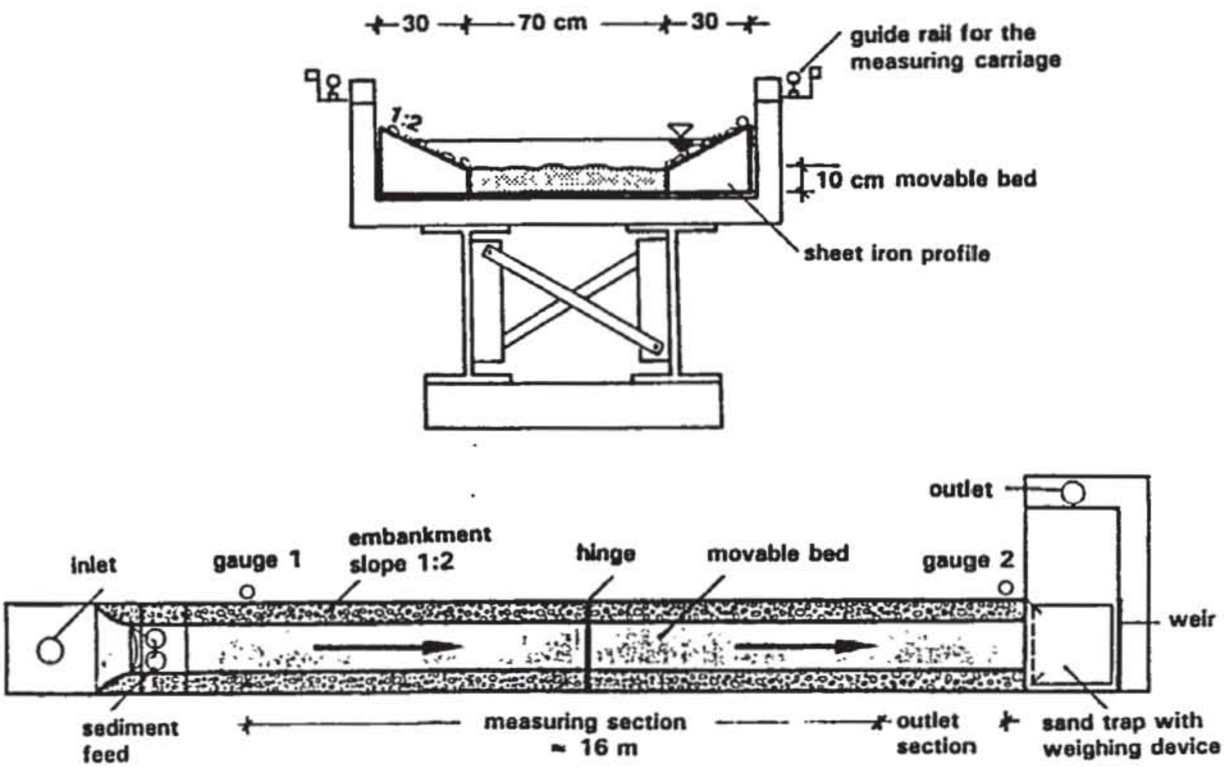

Fig. 4: Cross-section and plan view of the model

MODEL TESTS

In renaturalisation and bed protection works of smaller rivers, whose course had been straightened in previous years, often constructional elements are used to force meandering of the flow from one bank to the other at low discharges. The systematic investigations test the influence of constructional elements on the sediment transport behaviour of rivers. The subsequently described tests intended to obtain general conclusions for the river renaturalisation works. These tests were conducted with varying slopes, grain sizes, discharges and constructional elements.

First tests without constructional elements were made. They served as a basis of comparison with the others. At the beginning tests with constant discharges provided a transport-discharge relation. They were executed for three different slopes (S = 0.002, 0.004 and 0.006), and for three different characteristic grain diameters (d_{ch}). Table 1 shows the test program.

Table 1: Test program

S \ d_{ch}	0.65 mm	0.85 mm	2.00 mm
0.002	Q = 10 l/s 20 l/s 40 l/s	Q = 10 l/s 20 l/s 40 l/s	—
0.004	Q = 10 l/s 20 l/s 40 l/s	Q = 10 l/s 20 l/s 40 l/s	Q = 10 l/s 20 l/s 40 l/s
0.006	—	Q = 10 l/s 20 l/s 40 l/s	Q = 10 l/s 20 l/s 40 l/s

The choice of model sand was guided by the idea to keep the part of the suspended material as low as possible, because a geometrical reduction would have contradicted natural conditions. Therefore almost uniform sands were selected.

The test program comprises investigations of three series of different arrangements of constructional elements, each of which was to be tested for three grain sizes, three discharges and three slopes. The three constructional elements made by stones are groins on both sides, alternating groins (length about 20 cm) and ground sills (height about 6 cm) with a distance of 1 m. They are modelled using stones of 5 to 6 cm diameter. The obstacles are placed on the fixed solid ground plate, which lies 10 cm lower.

The execution of the test is similar with and without arranging constructional elements. Bed profiles were registered before the test after levelling the flume bed, and after test execution. Comparing both registrations allows the assessment of bottom changes. Their differences show where in the 16 m measuring range there were regions with erosion or sedimentation.

TEST RESULTS

The comparison of test series results was made possible by introducing a number characterizing the degree of obstruction caused by the constructional elements. The degree of obstruction was calculated to be a ratio of obstructed volume to unobstructed volume. Reference length is one meter.

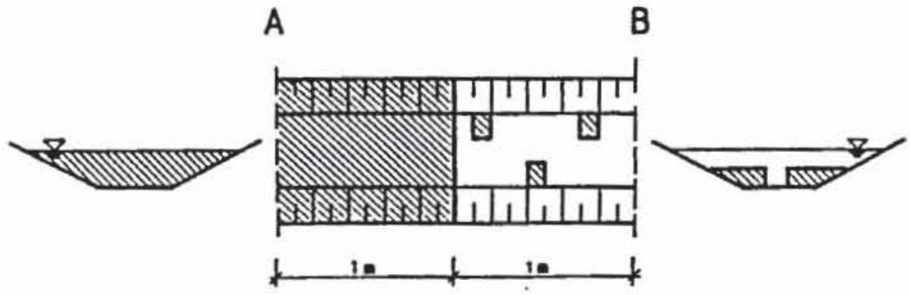

Fig. 5: Obstructed and unobstructed volumes

Hydraulic Conditions

For all tests the same tendency, as expected, could be recognized: with an increasing obstruction degree the water level and the roughness are increasing, while the FROUDE-numbers and the velocities are decreasing.

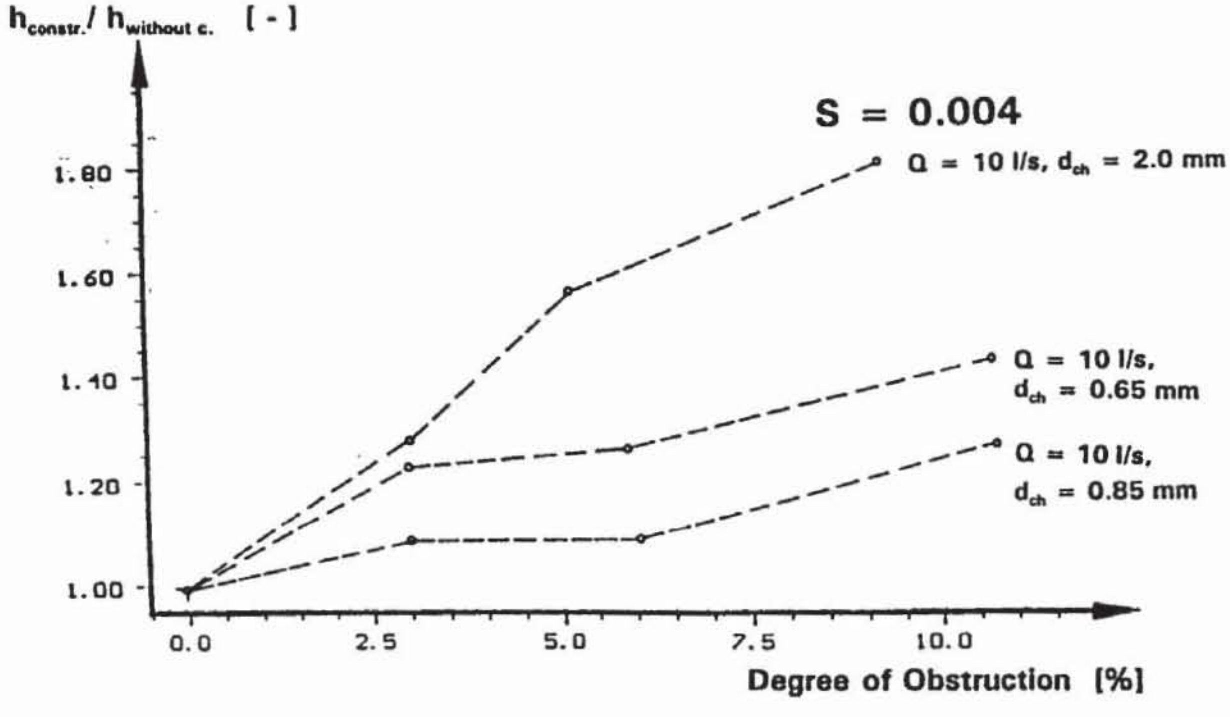

Fig. 6: Relation between the degree of obstruction and the ratio of water depths with and without constructional elements, S = 0.004

The dimension of the increase of the water depth is strongly dependent on grain size. Fig. 6 shows the relation between the degree of obstruction and the ratio of water depths with and without obstructions. The tendency is the same for all tests. With an increasing obstruction degree the ratio of water depths is increasing. Comparing the results of the tests having a discharge of 10 l/s the same systematic can always be recognized. The biggest rise of water depth occurs for sands with d_{ch} = 2.00 mm, second in order are sands with d_{ch} = 0.65 mm and third are sands with d_{ch} = 0.85 mm. The reason for this order lies in the roughness of the flume caused by the different bed forms. The highest bed forms could be recognized for sands with d_{ch} = 0.85 mm and the smallest or even no bed forms for the sand with 2.00 mm. That means the biggest change of roughness due to introducing the obstacles happens in the case of the coarse material. At the same time the roughness caused by the bed forms is at its lowest.

Sedimentological Conditions

For all tests the transport rate is decreasing with an increasing degree of obstruction (Fig. 7).

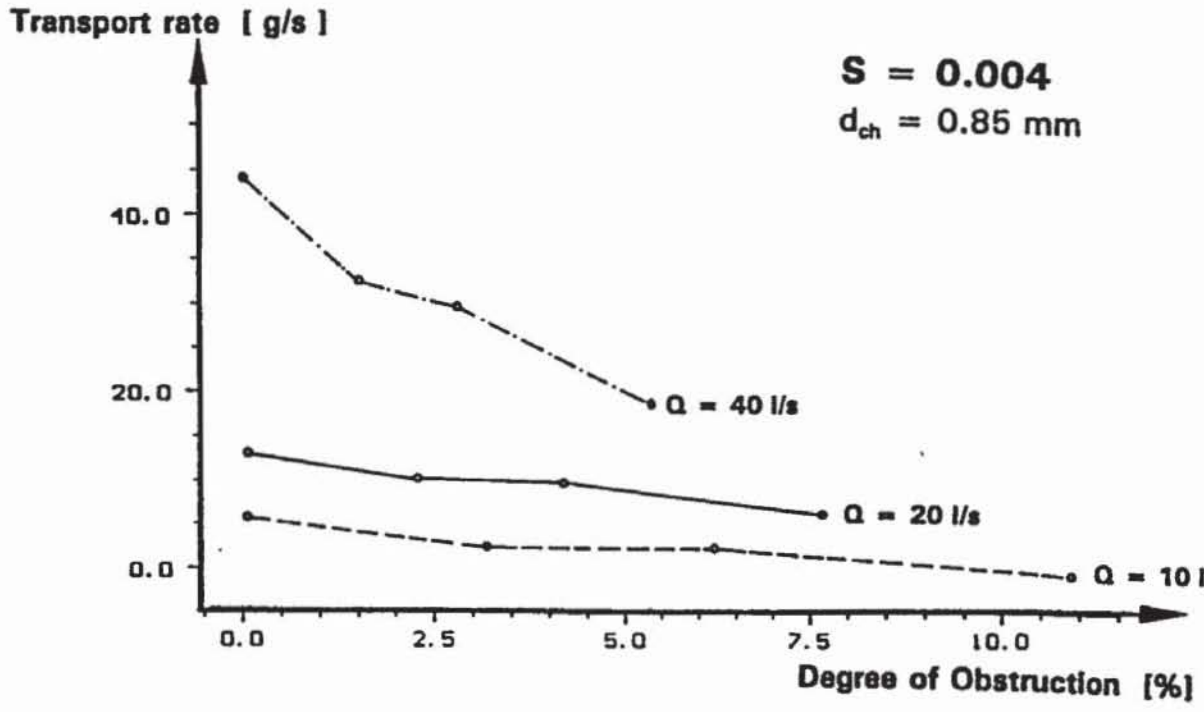

Fig. 7: Relation between transport rate and degree of obstruction

The first "step" from the situation without constructional elements to alternating groins has a relatively big influence on the transport behaviour. The next step to groins on both sides is not so significant as the last step to the ground sills. The reason may be, that in case of groins, even when they are on both sides, there always remains a part of the flume where the material can be transported without disturbance. But in case of sills, the transport is restrained over the whole cross-section.

CONCLUSION

Renaturalisation works have consequences on the hydraulic and morphologic equilibrium of a river, which can hardly be foreseen. It is therefore necessary to rely on simulations with physical models to predict possible effects of constructional measures.

There are already calculation procedures available that deal with overgrown cross-sections. The influence of constructional elements, however, still cannot be described exactly. First investigations on changes of hydraulic conditions and transport capacity have been performed, but are yet to be generalized.

REFERENCES

Bechteler, W., Vollmers, H.-J. and Wieprecht, S., (1994) Model Investigations into the Influence of Renaturalisation on Sediment Transport, Dynamics and Geomorphology of Mountain Rivers, Springer Verlag

DVWK, (1980) Hydraulic Modelling, Bulletin No. 7, Ed. H. Kobus, Verlag Paul Parey

DVWK, (1991) Hydraulische Berechnung von Fließgewässern, Merkblatt 220/1991, Verlag Paul Parey (in German)

Vollmers, H.-J., (1989) "The State of the Art of Physical Modelling of Sediment Transport", Sediment Transport Modelling, Proc. International Symposium, New Orleans

Zanke, U., (1982) Grundlagen der Sedimentbewegung, Springer-Verlag, Berlin Heidelberg (in German)