Constrains and Challenges in Rehabilitation Concepts of the Old Danube and Morava River

Contraintes et défis pour les concepts de réhabilitation du Vieux-Danube et de la Morava

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RÉSUMÉ

La construction et l'exploitation de l'aménagement hydro-électrique de Gabcikovo (1992), en lien avec la dérivation de l'écoulement principal du Danube dans le canal de fuite, ont créé un tronçon fluvial de 43 km du Vieux-Danube dans lequel les conditions hydrauliques et sédimentaires ont significativement changé. En raison de la baisse du niveau d'eau dans le Vieux-Danube, le lit majeur et son système de bras secondaires a été déconnecté du lit mineur. Récemment, quelques concepts pour rétablir la connectivité latérale ont été formulés. Est présenté le concept d'élargissement du chenal, qui prévoit la suppression de la protection de berge pour déclencher de l'érosion latérale. Les résultats de simulation obtenus par l'application d'un modèle 1D (MIKE11) pour la prédiction à long-terme de l'incision du lit sont discutés. La Morava est une rivière de plaine à méandres avec un transport sédimentaire actif. Le cours d'eau a été régularisé principalement pour des objectifs de protection contre les crues et de navigation (qui ne s'est jamais concrétisée). A cause de la rectification de la rivière et de l'enrochement des berges, la connectivité latérale est considérablement limitée. Le lit s'est incisé de 1,5 m et 18 méandres recoupés se sont progressivement dégradés en raison d'une intense sédimentation. Le concept commun slovaco-autrichien pour la réhabilitation des fonctions naturelles de la rivière inclut la réintroduction d'une connectivité latérale, et la restauration de la dynamique hydro-sédimentaire au sein du système de bras morts. Il est présenté en s'attachant aux enjeux spécifiques de la première phase de travaux.

ABSTRACT

Construction and operation of the Gabcikovo hydropower plant (1992) connected with diversion of the main flow of the Danube into the tailrace canal created 43 km river section of the Old Danube where flow and sediment conditions are significantly changed. Due to decrease of water level in the Old Danube the floodplain with side arm system was disconnected from the main channel. Recently a few concepts to re-establish lateral connectivity were formulated. The concept of river channel widening that envisages the removal of the bank protection to trigger lateral erosion is presented. Simulation results obtained by application of 1D model (MIKE11) for long-term prediction of the river bed aggradation are discussed. The Morava is lowland meandering river with active sediment transport. The river was regulated mainly for flood protection and navigation (never materialized) purposes. Due to river straightening and hard bank pavement the lateral connectivity is considerably limited. The river bed incised by 1.5 m and 18 cut-off meanders have successively degraded as a result of intensive sedimentation. The common Slovak – Austrian concept for rehabilitation of the natural river functions including re-introducing of lateral connectivity, restoration of flow and sediment dynamics within the oxbow system is presented focusing specific issues of the first planning phase.

MOTS CLES

Connectivité latérale, hydrodynamique, Morava, réhabilitation fluviale, transport de sédiments, Vieux-Danube.

1 INTRODUCTION

Specific hydro-morphologic conditions of the Danube formed a unique anastomozing area with high morphological diversity, which is characterized by a system of side arms interconnected with the main channel. Since 1992 this 43 km long stretch of the Old Danube by-passed by tailrace canal of Gabcikovo HPP has been affected by residual discharges and infrequent bedload transport (floods). Due to significant decrease of water level (2m–3m) the river floodplain with side arm system is disconnected from the river channel. The Morava in the Slovak-Austrian section is slowly flowing meandering river with active sediment transport. The river crates a unique wetland ecosystem that has been seriously impaired by river regulation. Lateral connectivity was considerably limited and cut-off meanders have been successively degraded due to intensive sedimentation. Thus the main challenge for sustainable rehabilitation of both river systems is the re-introducing of hydrological connectivity between the main river channel and floodplain keeping the flow and sediment dynamics.

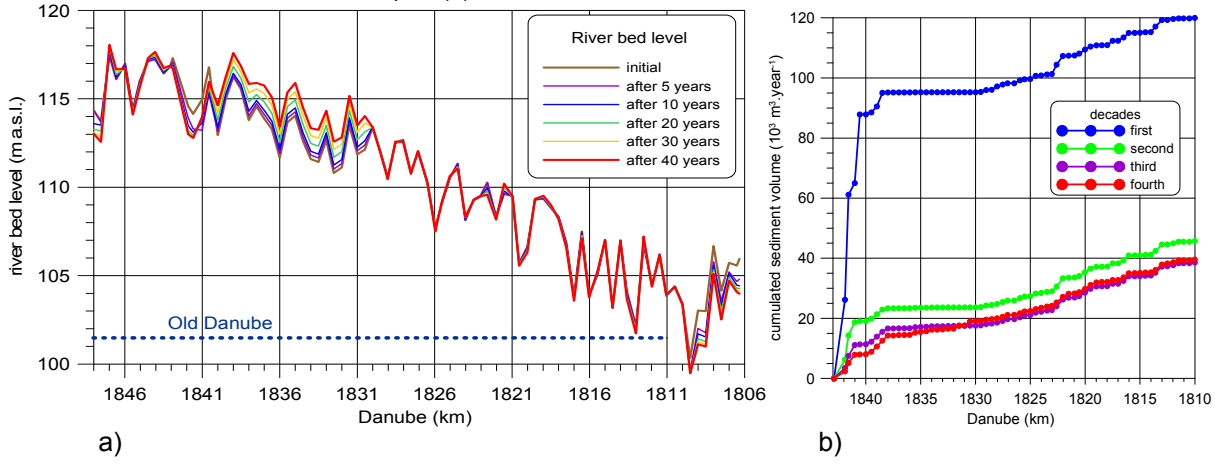
2 OLD DANUBE - CONCEPT OF THE RIVER CHANNEL WIDENING

The idea of the river channel widening is based on the premise of natural bank erosion triggered by bank pavement removal and transport and deposition of eroded sediments along the river bed. Successive aggradation of the river bed over a certain period could provide reconnection of the main channel with side arm system. Bank erosion processes were not analysed because the main aim is to demonstrate whether eroded material could create sufficient deposits in the river bed to restore the former hydrological connectivity between. Numerical morphological model 1D (MIKE 11) was used to test this concept within 10 km stretch of the Old Danube.

2.1 Assumptions for 1D morphological model application

As the bank erosion processes are omitted in this test some further assumption, simplifications and input data modification were done for 1D model application. Total width of widening was 100 m. Channel geometry was modified by moving the steeper bank by 100 m outwards. Widened river channel was used for simulation from the beginning with no further changes during simulations. The transport capacity of the widened section was used for the whole simulation process. Hydrological data from the period 1995 - 2005 were used and repeated to achieve 40-years simulation period. Assumption for volumes of eroded material: 6 m deep gravel depth, represents widening by 100 m along 10 km section, i.e. a total volume of 6 million m^3. If evenly distributed over the simulation period (40 years), this represents a total sediment input of 150 000 m^3/a along 10 km long widened stretch. Sediment input distributed for each of the 10 sections was 15 000 m^3/a. This corresponds to a lateral erosion rate of 2.5 m/a on one river bank. This relatively small value was justified by the actual flow regime and the rather low flood frequency in the Old Danube. In 1D model rain size distribution is represented by D_{50} = 10 mm and sorting coefficient σ. For bank material, D_{50} = 8 mm was used.

Fig.1 Old Danube, simulations of the river bed aggradation (final time - 40 years), longitudinal profile (a), cumulative volumes of bedload transport (b)



2.2 Gradual deposition of the river bed

Simulations of bedload transport for the period of 40 years show gradual deposition of the river bed in tested section (Fig.1a). The highest river bed elevation 1.8 m on average can be achieved in 40 years (+45 cm/10years). Widening concept in terms of geomorphic perspective represents some degree of

the river bed destabilization. However the results of cumulative sediment transport indicate that river bed stability in this case could be achieved during the third decade (Fig.1b). Application of 1D proved realistic basis of the widening concept. Next detail study should include analyses of bank erosin particulary flood hydrographs, evolution of tension crack with basal erosion, bank material saturation prior to bank erosion and time period to wash away failed materials, which belong to the main factors influencing bank erosion (Thorne,1998). Due to complicated bank erosion processes and interaction with sediment transport an application of 2D and 3D numerical models is required.

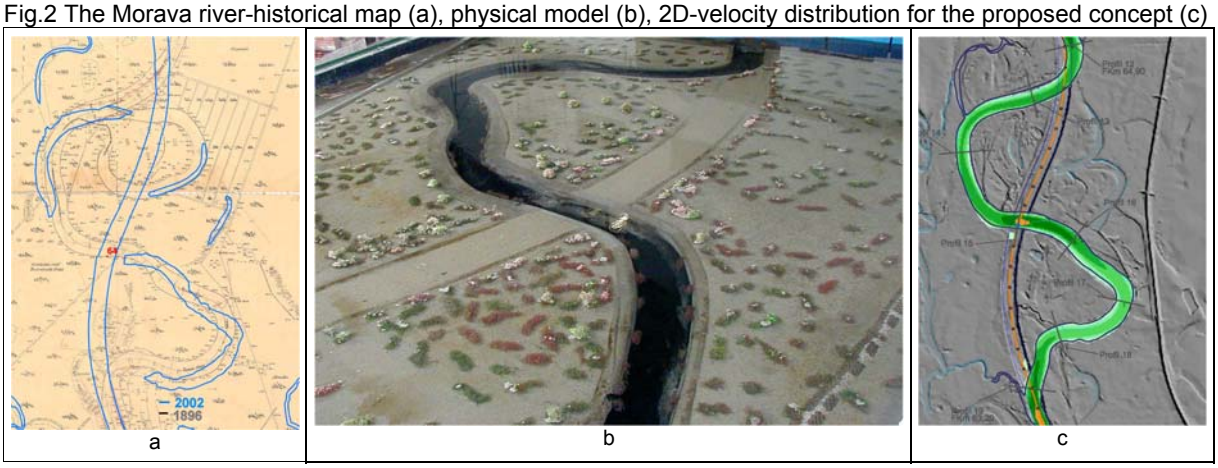
3 MORAVA RIVER -CUT-OFF MEANDERS INTEGRATION

The isolation of meander bends following channel straightening has resulted in the loss of key river habitats and altered the hydrological connectivity between the river and its floodplain. Cut-off meanders that were recently re-opened as well as those still closed have been deposited. In order to restore lateral connectivity and preserve the river ecosystem against successive degradation the rehabilitation concept was based on re-introducing of flow dynamics and sediment transport.

3.1 Flow dynamics and sediment transport as a key issue

Morphological analyses of the historical maps (reference conditions) in relation to flood event and sediment transport were used to define restoration objectives. Long-term monitoring of the river, coupled with physical (Fig.2b) and 1D, 2D numerical modelling (Fig.2c), were undertaken in order to develop effective sustainable measures to improve flow dynamics and minimize sedimentation in reconnected meanders (Holubova, Lisický, 2001). Results form numerical models and hydraulic model indicated that any kind of discharge distribution between the main channel and re-opened meanders is leading to massive sedimentation due to sudden decrease in stream power and shear stress. It was also confirmed by some practical experiences from the Morava. Integration of separated meanders back to the river system represents effective way to restore natural river functions on lowland meandering rivers that actively transport bedload. This arrangement can prevent progressive aggradation and provide long term sustainability.

Fig.2 The Morava river-historical map (a), physical model (b), 2D-velocity distribution for the proposed concept (c)



a b c

3.2 Rehabilitation concept and ongoing planning phase

Meanders integration is the key element of the rehabilitation concept enhanced by further restoration measures: bank pavement removal, lowering of natural levee along the meander relicts and barrier removal on the tributaries. Combined effect of all these measures can bring not only significant ecological improvement but it also can eliminate some of the negative impacts of the river regulation (river bed incision, decrease of ground water, etc.). Detailed plan of restoration measures that is the subject of the ongoing Slovak-Austrian project (MoRe) will be prepared for 16 km river section. From the implementation perspective the moving international border in the main river channel can be one of the most challenging issue as well as the approach some of very traditional engineers.

LIST OF REFERENCES

Holubová, K. & Lisický, M. (2001): River and environmental processes in the wetland restoaration of the Morva River. In: Falconer, R.A. & Blain, W.R.: *River Basin Management 2001,* WIT press, Cardiff, UK, pp. 179-188.

Thorne, C.R. (1998): Processes and Mechanisms of river bank erosion. Gravel-bed Rivers, R. D. Hey, and C. Thorne, eds., Wiley, Chichester, U.K. pp. 227-272.