A comprehensive concept for an eco-hydrological assessment of large scale restoration programmes of floodplain rivers

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Introduction

Man induced alterations through impoundment, river regulation and channelization represent a major threat to river systems world-wide. These impacts affect important riverine hydro-morphological processes (fluvial dynamics) which define the dynamic equilibrium of habitat distribution with their characteristic biota (Giller 2005, Nilsson et al. 2005, Reckendorfer et al. 2005, Schiemer et al. 1999). Hence, river restoration has become a global issue in terms of geomorphology, hydrology and ecology, and river engineers are seeking the cooperation of these sciences to improve degraded waterways within small to large scale river restoration projects (Palmer et al. 2005). Until now, however, there is little agreement on what constitutes a successful river restoration and which criteria are essential for restoration assessment (Jansson et al. 2005, Palmer et al. 2005).

Like in other large river systems in Europe, former river regulations and the ongoing river bed incision and degradation with its negative impacts for riverine and riparian habitats are major threats to the last free-flowing stretches of the Austrian Danube River (Bretschko 1992, Hary & Nachtnebel 1989). For the approximately 50 km free-flowing stretch of the Austrian Danube in the Alluvial Zone National Park downstream of Vienna the “Integrated River Engineering Project”, a large scale navigation and restoration programme, was launched by the Austrian Ministry for Transport, Innovation and Technology (BMVIT) and the waterway operating company “viadonau” (Reckendorfer et al. 2005). The project aims to combine four major objectives with several river engineering measures (Fig. 1): i) a stop of the ongoing degradation and incision of the river bed by “granulometric bed improvement” (an adaptive input of coarse gravel in deep areas and in those parts of the river which are intensively exposed to the flow); ii) an improvement of the ecological quality of riverine and riparian habitats by river bank restoration and side arm reconnection; iii) an improvement of navigation in critical riffle sections on the Danube River, an international waterway (Pan-European Transport Corridor, class VII), by low flow river regulation (modification and construction of additional groynes) and ford dredging to adjust the river bed; iv) a reduction of high water levels at flood periods (by river bank restoration and side arm reconnection).

In order to harmonize these aims and interests of the different stakeholders (nature conservation, navigation and flood protection), an integrative planning approach with a close cooperation between geomorphologists, hydrologists, ecologists and water engineers was necessary. This paper outlines the conceptual framework, the principal structure and integrative approach of a scientifically based monitoring concept developed for an eco-hydrological assessment of the “Integrated River Engineering Project”.

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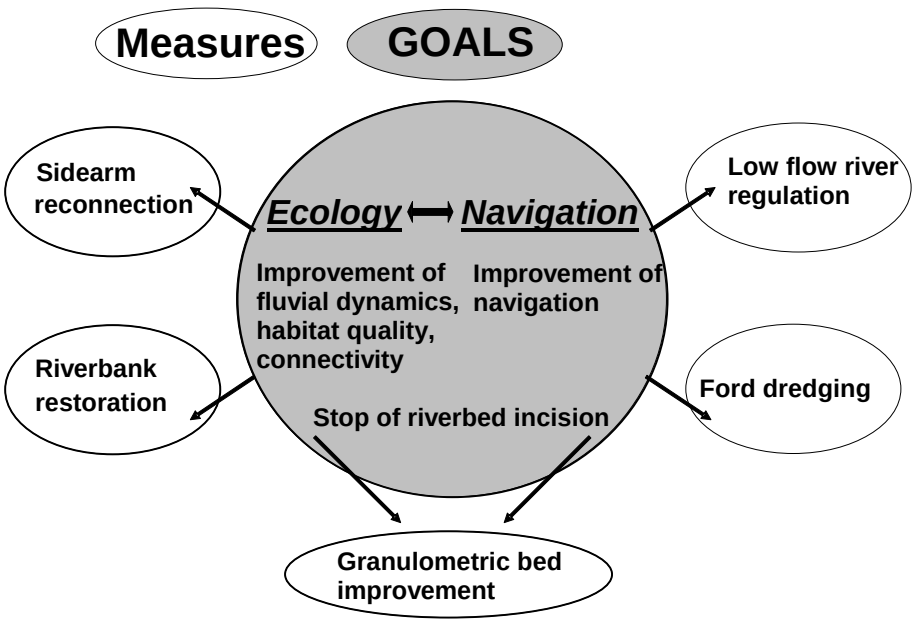

Fig. 1: Goals and river engineering measures of the "Integrated River Engineering Project" (modified after Reckendorfer et al. 2005).

Project area

The various river engineering measures within the "Integrated River Engineering Project" will be applied in the Danube River between Vienna (Freudenau) and the Austrian – Slovak border (Fig.2). The reach, heavily regulated since the 19th century, is today a critical spot for navigation, characterised by a steady riverbed erosion of 2 to 3.5 cm per year and an unbalanced sediment budget due to upstream impoundments (ICPDR, 2004, Reckendorfer et al. 2005). The fluvial dynamics are drastically reduced, causing serious ecological problems in the main channel and the alluvial zones. Most of the region is part of the Alluvial Zone National Park, which underlines the ecological and socio-economic importance of the area and hence leads to a high public interest regarding the protection of this river section.

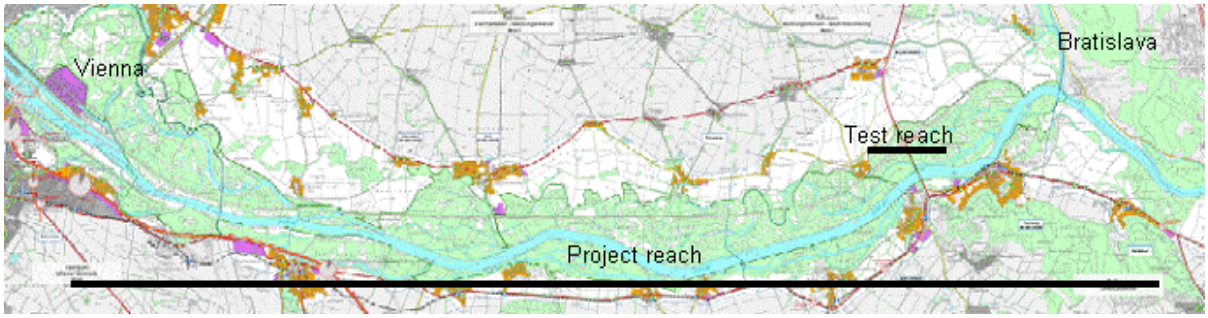

Fig. 2: Project area of the "Integrated River Engineering Project".

Monitoring concept and programme

Conceptual Framework -Hierarchical order of project aims

The size of the project and the lack of international experience with similar restoration projects of large rivers required the development of a comprehensive monitoring concept with an iterative stepwise approach ("adaptive management"). This restoration project is process-(ecosystem-) oriented instead of species-focused and should primarily foster the hydrological

and geomorphological functions of the river. A long-term monitoring of pre-and post-restoration conditions will be applied in order to assess the various complex correlations between engineering measures and their effects on ecology, geomorphology and hydrology (Schiemer 1994, Schiemer et al. 1999, Poole, 2002, Schiemer & Reckendorfer 2004, Habersack et al. 2003).

The ecological target of this project is based on the reference conditions prior to the major regulations in the 19th century. At this time, the Danube was a braided river system characterized by distinctive discharge and sediment dynamics, establishing a dynamic equilibrium of erosion and deposition. These fluvial dynamics are the most important driving forces for the development of long-term, self-sustaining alluvial river landscapes that exhibit high biodiversity (Amoros & Roux 1988, Tockner et al. 1999, Ward et al., 2002). Hence, our conceptual framework is based on a hierarchical cause-effect chain with a primary focus on the improvement of hydro-morphological processes (fluvial dynamics) which in turn define the quality of riparian and alluvial habitats and their characteristic communities. The project aims and success are based on the following hierarchical order ("value system"):

1. Promotion of dynamic geomorphological processes
2. Promotion of habitat-dynamics and quality
3. Promotion of biocoenoses which are characteristic of the reference state

The monitoring programme evaluates the success through an application of appropriate abiotic and biotic indicators and the definition of their absolute or relative thresholds. Thresholds are defined through abiotic measurements (e.g. certain increase of water level, changes in sediment budget) and on habitat and species level through the application of a before after impact (BACI) sampling design (Underwood, 1994). If these thresholds are not reached, certain countermeasures in coordination with the engineering measures will be applied. Conservation issues (red lists, Flora-Fauna-Habitat Directive) are taken in consideration but are also subject to the hierarchical order. The Integrative "River Engineering Project" pursues a holistic, system-orientated approach and the hierarchical "value system" enables the integration of diverging conservation issues (fostering a dynamic process versus the conservation of a static ecological situation) and corresponds with the aims of the management plan for the Alluvial Zone National Park.

Selection of appropriate bioindicators

The success of any monitoring programme depends, apart from the survey of physiographic conditions, on the selection of appropriate bioindicators. The autecological requirements of these indicators provide essential information about their abiotic and biotic environment. Experiences from other restoration programmes on the Danube River have shown that only a sufficient set of indicators is able to comprehend the various effects of engineering measures on large river systems (Reckendorfer et al. 2004). In our monitoring programme we prefer the appliance of organism groups (e.g. fishes, birds, amphibians, shoreline vegetation, etc.) as indicators to the investigation of single species. The acquisition of indicator groups does not require significant additional efforts when compared to the selective investigation of single species and furthermore provides important supplemental community parameters like diversity, proportion of specialists/generalists, etc. (Reckendorfer et al. 1998). The functions, populations, status and interdependencies of these indicator groups can be used to determine biodiversity, ecosystem level and environmental integrity. In respect to the hierarchical order of the project aims we especially employ indicators for intact discharge-and geomorphological-dynamics. The indicator set for the monitoring of the "Integrated River Engineering Project" consists of the following groups: aquatic vegetation (macrophytes),

vegetation of riparian and alluvial zones, terrestrial riparian community (beetles, butterflies, and locusts), macrozoobenthos, dragonflies, molluscs, amphibians fishes and birds.

Structure and integrative approach of the monitoring programme.

The monitoring programme has a modular structure and consists of various abiotic and biotic work packages (Figure 3). The essential issue in this concept is the permanent interaction between these work packages. This enables, through intensive spatial-temporal coordination and data exchange between the individual investigations, optimal synergism crucial for the development of tools (models) to predict the reaction of the ecosystem to river engineering measures. Such a monitoring concept is considerably more innovative and cost effective than a monitoring programme split into many independent, single "before – after" investigations. The integrative approach is symbolized in Figure 3 by two arrows: the black arrow indicates that biotic conditions are dependent on abiotic parameters like hydrology, sediment transport and geomorphology. The grey arrow indicates feedbacks from biotic to abiotic conditions (like the influence of vegetation on shoreline stability) that have to be thoroughly investigated.

Abiotic Monitoring	**Integrative Adaptation**	**Biotic Monitoring**
A1: Hydrology/Hydraulics		**B1: Ecological Functions and Processes**
A2: Hydrology/Hydraulics Groundwater	**Primary functional correlations**	**B2: Landscape Dynamics**
A3: Sediment Budget and Transport	**Secondary feedbacks**	**B3: Habitat Diversity**
A4: Changes in Morphology		**B4: Biodiversity / Bioindication**
A5: Navigation		

Fig. 3: Structure and work packages of the monitoring programme.

In order to extrapolate from single, selective investigations to large scale effects, "upscaling" methods like interdisciplinary models have to be evolved. These models allow to comprehend complex abiotic and biotic connections like the interrelation between riparian geomorphological structures and flow velocities that define the habitat requirements of species (e.g. rheophilic fishes).

The first step of upscaling is the implementation of a grid with cells of various size from a 50x50 m basic-grid over the whole project area to 1x1 m sub-grids in selected areas like certain riparian zones and groyne fields. Data and results from the different work packages are incorporated in this grid leading to a permanent information exchange and providing the basis for further interdisciplinary modelling approaches like a 3D hydrodynamic model and habitat models for the biological indicator groups. For the development of these models, next to a constant calibration through measurements and investigations, a data management scheme with a central, GIS based data bank under a reliable quality control is essential, providing a coordinated, common data format and guaranteeing a comprehensive consolidation of the various data sets.

Time schedule for the implementation of engineering measures and monitoring programme

In a first step the river engineering measures will be applied to a 3 km test reach in the region of Hainburg (see Fig. 2) in order to approve the effectiveness of the measures and the accompanying monitoring programme. The implementation of the project measures over the entire length of approximately 50 km will be carried out in five successive steps and involves an adaptive approach with feedback loops between the eco-hydrological monitoring and the planning and execution of engineering measures. Hence, this monitoring concept must not be seen as a final, fixed programme but a constantly evolving process, which incorporates the experiences of each previous project phase in the planning and monitoring activities of the following step. This scientifically based monitoring programme will accompany the construction process through a succession of micro to macro scale monitoring activities of pre-and post-restoration conditions, presumably until the year 2019.

Conclusions

In respect to the world-wide increasing importance of river restoration programmes the development of well conceived, comprehensive monitoring schemes for the eco-hydrological assessment of river engineering measures is essential. Large restoration programmes like the "Integrated River Engineering Project" offer the opportunity for large scale experiments to test and evaluate overall monitoring concepts and hypotheses and will gain essential experiences for other, future restoration projects.

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