# A COMPREHENSIVE MONITORING CONCEPT FOR A LARGE RIVER RESTORATION PROJECT ON THE AUSTRIAN DANUBE

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**Abstract:** This paper outlines the conceptual framework, the principal structure and integrative approach of a monitoring concept developed for the assessment of the "Integrated River Engineering Project" on the Austrian Danube. As fluvial dynamics proved to be the key factor for structural and biological diversity in large river systems, the ecological aim of this large scale restoration project is the promotion of hydro-morphological processes. The implementation of the project over the entire length of approximately 50 river kilometres will be carried out in five successive phases. A long-term monitoring program accompanies and routes the progress of the enginering measures in a stepwise manner through an application of key- abiotic and biotic- indicators. All biotic and abiotic monitoring results of each project step will be integrated and assessed to adjust the measures of the following phase. Hence, this monitoring concept must not be seen as a final, fixed programme but as a constantly evolving process.

**Keywords:** identifying appropriate conservation and restoration objectives, restoration of water dynamics, environmental policy

## Introduction

River restoration has become a global issue in terms of geomorphology, hydrology and ecology. Consequently river engineers increasingly seek and benefit from a close cooperation with these sciences (Bernhardt et al. 2005, Palmer et al. 2005). Until now, however, there is little agreement on what constitutes a successful river restoration and which criteria are essential for a restoration assessment (Jansson et al. 2005, Palmer et al. 2005).

Former river regulations and river bed degradation are major threats to the last free-flowing stretches of the Austrian Danube River like in most other large river systems world wide. In order to improve this situation, the "Integrated River Engineering Project on the Danube to the East of Vienna" (IREP), a large scale restoration and navigation programme, was launched by the Austrian Ministry for Transport, Innovation and Technology and the waterway operating company via-donau (Reckendorfer et al. 2005). The project aims to combine four major objectives with several river engineering measures (Fig.1): 1.) an improvement of the ecological quality of riverine and riparian habitats by river bank restoration and side arm reconnection; 2.) 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); 3.) 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 of groynes) and ford dredging to adjust the river bed; 4.) a reduction of high water levels at flood periods (by river bank restoration and side arm reconnection).

In order to harmonize these aims, 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 "IREP".

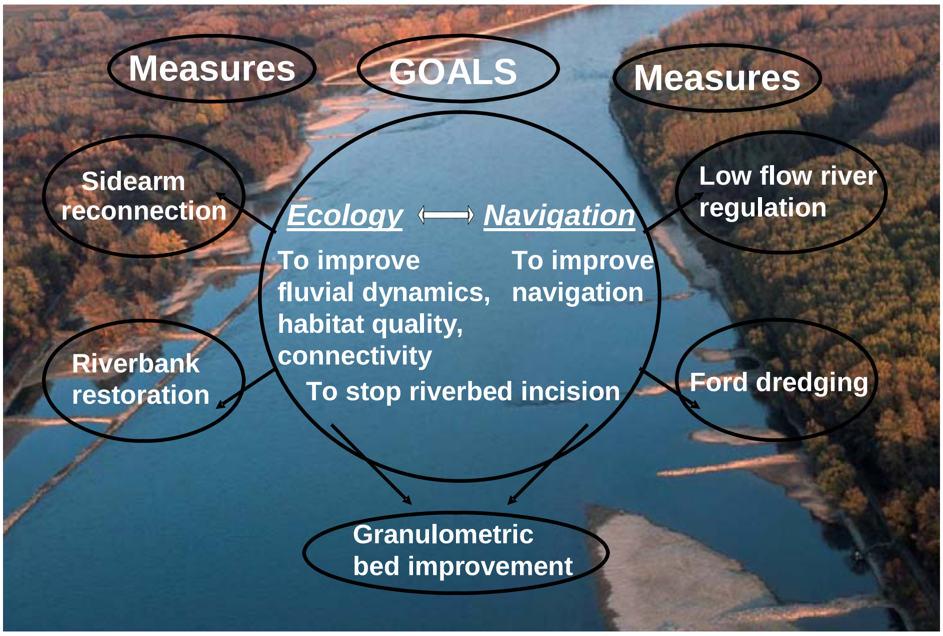


*Figure 1*. Goals and river engineering measures of the "Integrated River Engineering Project" (modified after Reckendorfer et al. 2005).

**Project area**

The various river engineering measures will be applied in the Danube River between Vienna (Freudenau) and the Austrian – Slovak border. The reach, heavily regulated since the 19$^{th}$ 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). Most of the region is part of the Alluvial Zone National Park, which underlines the ecological and socio-economic importance of the area.

**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).
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 a dynamic equilibrium of erosion and deposition.
Hence, our conceptual framework is based on a hierarchical cause-effect chain with a primary focus on the improvement of hydro-gemorphological processes (fluvial dynamics) which in turn define the quality of riparian and alluvial habitats and their characteristic communities.
The monitoring programme evaluates the restoration 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 control 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.

*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 2). The essential issue in this concept is the permanent interaction between these work packages, incorporating primary functional correlations between biotic conditions and abiotic parameters and secondary feedbacks from biotic to abiotic conditions (like the influence of vegetation on shoreline stability).
This enables an optimal synergism crucial for the development of tools (models) to predict the reaction of the ecosystem to the river engineering measures.

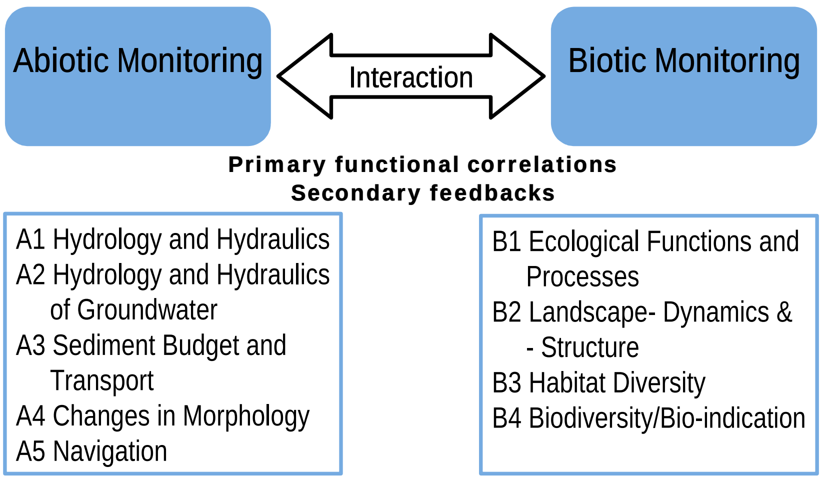


*Figure 2*. Structure and work packages of the monitoring programme

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.
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. 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, a data management scheme with a central, GIS based data bank is essential. This provides a common data format and guarantees a comprehensive consolidation of the various data sets.

*Selection of bioindicators*
In respect to the hierarchical order of the project aims, we focus on indicators for intact discharge-and geomorphological-dynamics (e.g. rheophilic fish).
The indicator set for the monitoring of the "IREP" consists of the following groups: aquatic vegetation (macrophytes), vegetation of riparian and alluvial zones, terrestrial riparian arthropod community (beetles, butterflies, and locusts), macrozoobenthos, dragonflies, molluscs, amphibians, fishes and birds.

*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 order to approve the effectiveness of the engineering 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 2020.

## 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 "IREP" 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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