

Functional restoration of a Rhine anastomosing channel: temporal trajectory, initial state, post-restoration monitoring, modelling (Upper Rhine, France, Rohrschollen island)

Restauration fonctionnelle d'une anastomose rhénane : trajectoire temporelle, état initial, suivi post-restauration, modélisation (Rhin Supérieur, France, île du Rohrschollen)

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RÉSUMÉ

Le projet LIFE+ "Restauration de la dynamique des habitats alluviaux rhénans sur l'île du Rohrschollen", a pour objectif de restaurer le fonctionnement hydro-morphologique et écologique de l'hydrosystème : transport sédimentaire grossier, mobilité latérale, échanges nappe-rivière, rajeunissement des successions végétales, renforcement du caractère hygrophile de la végétation. À cet effet, un chenal de connexion amont nouvellement créé et un ouvrage de prise permettent de reconnecter le Rhin au Bauerngrundwasser, principal chenal de l'île. Les débits injectés varient de 2 à 80 m³.s⁻¹ en fonction du débit du Rhin, permettant à l'hydrosystème de recouvrir des inondations dynamiques. Un suivi interdisciplinaire (hydro-géomorphologie, écologie) fondé sur la comparaison des dynamiques pré- et post-restauration permet d'évaluer l'efficacité du projet en tenant compte de la trajectoire temporelle longue de l'hydrosystème. Le suivi des compartiments abiotiques intègre la topographie (lasergrammétrie, photogrammétrie...), la cartographie, le transport sédimentaire (pit-tags, chaînes d'érosion, hydrophone), l'hydrologie, l'hydrogéologie. Des modélisations hydraulique, hydrogéologique, géochimique et morpho-sédimentaire sont également développées. Le suivi écologique porte sur les macrophytes, la végétation rivulaire et le macrobenthos. L'évaluation et l'optimisation du protocole de suivi permettront de formuler des recommandations opérationnelles en termes de gains environnementaux, de durabilité et de transposabilité.

ABSTRACT

The LIFE+ project "Restoring dynamics of Rhine alluvial habitats on the Rohrschollen Island", aims to restore the hydromorphological and ecological functioning of the hydrosystem: bedload dynamics, channel mobility, surface water-groundwater exchanges, renewal of pioneer ecosystems. Thus, the Bauerngrundwasser (anastomosing channel of Rohrschollen Island) was reconnected to the Rhine by a floodgate and a new upstream connection channel. The water input can reach 80 m³.s⁻¹, leading to dynamic overflows. In order to assess the efficiency of the restoration project, an interdisciplinary monitoring is carried out and is based on the comparison of pre- and post-restoration dynamics. The geomorphic monitoring focuses on topographic (lasergrammetry, photogrammetry...), cartographic, sediment transport (pit-tags, erosion chains, hydrophone), hydrological and hydrogeological data. It takes also into account the temporal trajectory of the hydrosystem. Hydraulic, sedimentary, hydrogeologic, geochemical and morphodynamic 3D modelling are also developed. The ecological monitoring focuses on macrophytes, riparian vegetation and macrobenthos. The evaluation and optimization of the monitoring protocol aims to formulate operational recommendations in terms of environmental gains, sustainability and transferability.

KEYWORDS

Functional restoration, anastomosing channel, hydromorphology, interdisciplinary study, modelling

1 INTRODUCTION

The Upper Rhine is one of the most altered hydrosystem in Europe. Ninety percent of its floodplain has been converted to arable and industrial areas (Schneider, 2011). Restoration projects conducted for three decades aims to achieve different objectives: (1) ecological enhancement, (2) flood control, (3) groundwater protection and (4) recreational area.

The Rohrschollen artificial island, which is a Natural Reserve, is located 8 km south-eastern the city of Strasbourg and results of several engineering works that have been implemented since the mid-19th century (fig.1-a) such as correction and canalization. Consequently, the main watercourse of the island, the Bauerngrundwasser, an anastomosing channel, is upstream disconnected (fig.1-b).

On the old-Rhine, an agricultural dam was built to raise groundwater level and allow flood mitigation during high flows. Therefore, water level is relatively stable on the Bauerngrundwasser and discharge is very low (less than $0.1 \text{ m}^3 \cdot \text{s}^{-1}$), inducing deposition of fine sediment. In this context, aquatic and riparian habitats were drastically impacted and alluvial species of the island are declining.

The LIFE+ project “Restauration de la dynamique des habitats alluviaux rhénans sur l’île du Rohrschollen”, which is managed by the city of Strasbourg, aims to restore hydromorphological and ecological processes like bedload transport, channel mobility, surface water-groundwater exchanges and renewal of pioneer ecosystems. In order to reach these objectives, the anastomosing channel has been reconnected to the Rhine by a floodgate and a new upstream channel. Water inputs, depending on the discharge of the Rhine (tab.2), varied from 2 to $80 \text{ m}^3 \cdot \text{s}^{-1}$. A scientific monitoring based on hydraulic, hydrologic, morphologic, hydrogeology and hydroecology has been implemented to assess the effectiveness and the sustainability of the restoration project.

This study aims to present: (i) the long term temporal trajectory of the hydrosystem, which is useful for an *a priori* evaluation of the post-restoration evolution; (ii) the initial state based on a two-years pre-restoration monitoring; (iii) the first post-restoration interdisciplinary results; (iiii) the first results and scientific perspectives concerning the modelling of several compartments of the hydrosystem (hydraulic, hydrogeologic, sediment transport and morphodynamics).

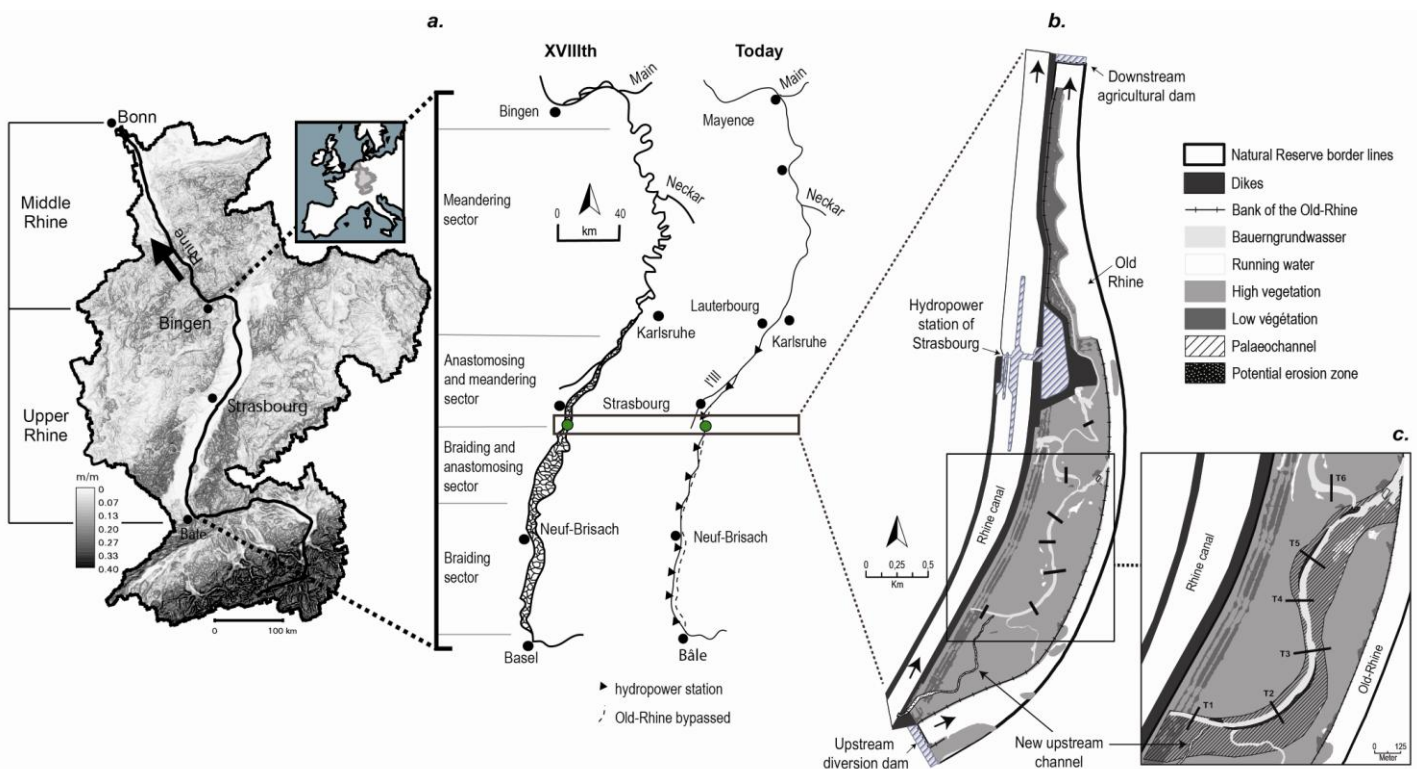


Fig.1 a- Localization of the Upper Rhine basin, sectorization based on its channel pattern (Carbiener and Trémoières, 2003; Schmitt *et al.* 2009), river course evolution from the 18th century to nowadays and localization of the study site. b- Rohrschollen Island. c- Lateral extension of the Rhine's palaeochannel and spatial extend of the potential lateral erosion areas (cf. results).

Tab.2. Protocol of water inputs in the new channel in terms of discharge and mean duration, depending on the Rhine hydrological regime.

Q Rhine (m ³ .s ⁻¹)	Q new channel (m ³ .s ⁻¹)	Days / year
Q<1550 or Q>2800	Q = 2	314
1565<Q<1650 or 2760<Q<2800	2<Q<20	11
1650<Q<1725 or 2725<Q<2760	20<Q<40	7
1725<Q<1755 or 2675<Q<2725	40<Q<60	4
1755<Q<1800 or 2650<Q<2675	60<Q<80	4
1800<Q<2650	Q=80	25

2 METHODS

Historical analysis was based on old maps, aerial photos and sedimentological investigations (granulometry, thickness and deposition process). Monitoring of pre- and post-restoration took into account geomorphic evolutions including both bedload transport (pit-tags, erosion chains, hydrophone) and morphological evolutions (lasergrammetry, photogrammetry, topographical and bathymetrical surveys); hydrological variations (limnometry, piezometry, gauging, infrared thermography) and ecological changes (macrobenthos, riparian and aquatic vegetation, water, plant and sediment chemistry).

3 RESULTS - CONCLUSION

The cartographic overlaying (1828 – 2010) showed that the upstream of Bauerngrundwasser corresponded to the main talweg of the Rhine. The palaeochannel was partly filled by sand and silt deposition. Therefore, the current watercourse was integrated into recent fine sediments which can be partly remobilized by dynamics floods (fig.1-c).

The hydraulic monitoring showed that the low level of energy, during both low and high water flows, was due to the agricultural dam backwater effect. The surface water-groundwater exchanges were also limited channel clogging. Therefore, pre-restoration ecological surveys highlighted that the hydrosystem hosted typical lentic water communities.

Post-restoration monitoring aimed to show the effect of dynamic floods. Diachronic 3D modelling and topographical surveys indicated that the morphodynamic was active in the new upstream channel, in contrast to the former channel. Hydraulic, sedimentary, hydrogeologic and geochemical models may allow long term estimation of flood effects on unclogging, improvement of surface water-groundwater exchanges, bedload transport and risk of remobilization of historical pollutants in the hydrosystem. Coarse grain size and active morphodynamics should allow the re-establishment of running water biological assemblages.

In association with pre-restoration state and temporal trajectory, the post-restoration monitoring was optimized to guide future management decisions taking into account efficiency and sustainability.

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