River Re-naturalization - a Nature-based Solution for Climate Change in Urban Areas

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Abstract. The subject of the article is river management and their reconstruction in connection with the need to adapt urban areas to climate change. The article presents a fragment of a wider research. The aim of the study is to identify and indicate the main directions of activities undertaken in the field of river reconstruction, based on the analysis of documents and literature on the subject. The case study of the Wandle River - one of the tributaries of the Thames, running through heavily urbanized areas in London, is an example of the restoration of the river. In this case, the use of natural solutions improved: flood and drought risk management, stormwater retention, inhabitants’ access to the river and biodiversity of natural habitats associated with the river.

1. Introduction
The blue-green infrastructure in the context of adaptation to climate change is one of the most important challenges of the 21st century. The contemporary spatial policy of each city should aim at the transformation of individual urban systems towards sustainable development and resilience to the phenomena caused by climate change [1].

A modern approach to the management of blue and green infrastructure is often associated with the need to reconstruct it. In the context of rivers, it is about, among other things, abandoning outdated activities that were only to accelerate the drainage of water. Instead, modern methods of flood protection are introduced, which retain and slow down water where it is safe, by: taking into account natural hydrodynamic, habitat and biological conditions, using the retention potential of river beds and valleys, and consequently also improving the ecological status of waters [2].

2. Scope of research
The article presents a fragment of research on blue-green infrastructure, including elements such as: retention ponds, bioretention basins, bioretention ditches, infiltration ditches, rain gardens, green stops, green roofs, green facades, urban greenery rings, ventilation corridors and river restoration. The article focuses on the latter, i.e. the restoration of rivers.

Moreover, the presented scope of research was limited to rivers of London. The Thames itself was omitted during the research, as it was constantly rebuilt over the last century and its riverside areas changed their image. Rather, the tributaries of the Thames, which are an important city-wide issue, require intervention now as they flow through all 33 districts. These rivers are important elements of
the natural system on a city scale, as well as airing corridors, wildlife habitats and places of local recreation. They are also important because they run through densely built-up areas. Projects implemented for these rivers may be examples of good practice that can be implemented under different, but similar conditions.

3. River management system in the context of climate change

River management involves documents at all decision-making levels. The basis for the development of many plans, strategies and policies are the three most important directives:

• The 2000 Water Framework Directive (which established the framework for Community action in the field of sustainable water policy) [3],
• The Floods Directive of 2007 (aimed at reducing the risk of flooding and reducing the effects of floods in EU countries) [4],
• The Habitats Directive of 1992 (dealing with the protection of natural habitats and wild fauna and flora) [5].

River management at the national level refers to, among others:

• Environment Act (1995),
• Wildlife & Countryside Act (1981),
• Countryside & Rights of Way, Land Drainage Act (1991),
• Water Resources Act (1991),
• Planning Policy Statements Working with the Grain of Nature: A Biodiversity Strategy for England.

On the other hand, at the regional level, the issues of London's blue infrastructure are regulated by the provisions in:

• Regional Spatial Strategies, The London Plan - blue ribbon network & biodiversity strategy, The London Plan 2021 - this is the current Greater London spatial development strategy over a period of 25 years [6],
• Environment Agency Wetland Policy,
• Environment Agency Culverting Policy,
• Environment Agency Floodplain Policy.

At the local level, there are, among others: Unitary Development Plans, Environment Agency River Restoration Strategy and Borough's Local Plans.

The analysis of the planning documents also showed the functioning of two strategic documents developed for south and north London, which effectively stimulate the processes of reconstruction and reconstruction of rivers. They are: A Strategy for Restoring Rivers in North London (2006) and River Restoration - a Stepping Stone to Urban Regeneration Highlighting the Opportunities in South London (2002). Additionally, the London Rivers Action Plan [7] is a tool supporting the implementation of the above plans.

LRAP (with a website functioning in parallel) identifies river sections requiring:
• improving flood management through the use of natural processes, i.e. by rebuilding the river bed, including restoration and recovery of buried rivers,
• activities related to reducing the negative effects of climate change,
• reconstruction of riverside areas, i.e. such revitalization of riverside urban areas that will help to reconnect people with the natural environment, facilitate access to recreation in riverside areas, improve the microclimate, and thus improve the quality of life of local residents in the context of a changing climate,
• modification or removal of inoperative flood defenses,
• improving biodiversity and wildlife habitats.

LRAP's task is also to provide practical information on ongoing projects. These "lessons" are important for all partners in river transformation processes, including: Environment Agency, local authorities, developers, individual landowners, non-governmental organizations (NGOs), local nature conservation funds, anglers, canal authorities, businesses water, individual interest groups, residents, etc. LRAP has prepared around 100 large-scale projects mainly in the rivers Crane, Lee, Ravensbourne, Roding and Wandle. [7].

4. River re-naturalization
Greater London's rivers and canals make up the Blue Ribbon Network. Not including the River Thames, they are over 600 km long in total. Over the years, the rivers in London have changed significantly from their natural state. Pollution, the development of industry, communication and buildings, and subsequent reconstructions resulted in the loss of the original values of the rivers. The changes aimed at the maximum subjugation and control of rivers had already begun during the Industrial Revolution. The primacy of human interests in the vicinity of the river over its state and natural environment resulted, above all, in enormous urban pressure, over-regulation of rivers, housing, and even burying rivers in canals beneath the city's surface. Ultimately, this led to the complete loss of some rivers (such as Fleet, Tyburn and Effra) that are now part of the city's sewage network.

From the point of view of the environment and adaptation to climate change, these phenomena are very unfavorable, especially in densely built-up areas, i.e. such as we deal with in London. Accordingly, efforts are now being made to identify those sections of the Blue Ribbon Network for which previous unsustainable changes need to be reversed. Despite similar problems and conditions, they require an individual approach to the issue of their reconstruction in terms of adaptation to climate change.

One example of such an approach is the reconstruction of the Wandle River. It is a tributary of the Thames approximately 14 kilometers in length, flowing through the southern boroughs of Croydon, Lambeth, Merton, Sutton and Wandsworth. The present character of Wandle was influenced by strong industrialization in the 18th and 19th centuries, when textile and tobacco plants, paper mills and printing houses developed on its shores. In total, 68 water wheels operated along its entire length, driving industrial machines (some of them have survived to this day, e.g. at Merton Abbey Mills). Before the cleansing, the Wandle was infamous to be one of the most polluted rivers in England.

During the reconstruction of Wandle, the idea of river management was applied, based on an in-depth diagnosis of existing problems, and then on their permanent and effective solution. Eight different stretches (8 projects) were selected for intervention, including a 120-meter stretch at Carshalton, in a heavily built-up area (Figure 1) where the river is heavily limited by: a housing estate,
a road and a brick wall. Before the reconstruction, the river's course here was straight, shallow and wide, and its deep, silty bottom sediments constituted a poor habitat structure [8].

Figure 1. Intensive development around the reconstructed section of the Wandle River (source: own study based on google maps [9])

South East Rivers Trust (SERT) worked with volunteers from the Wandle Trust to develop and implement the project. The purpose of rebuilding the Wandle River in Carshalton was to improve: flood risk management, biodiversity and habitat quality, hydromorphology and water quality, fish flow, as well as river availability, and last but not least, to improve the quality of the urbanized environment.

The immediate measure of the result is, of course, the running meters of the renaturalized river. However, the number of indicator species - wild trout in its upper reaches was adopted as the most important natural measure of the river's recovery. £ 76,000 was spent on the project (including £ 31,000 for the reconstruction of the weir and fish pass). The reconstruction project, after approval by the Environment Agency (checking if the river would meet the necessary flood protection conditions), was carried out in the following stages [8]:

1. reconstruction of Butter Hill Mill weir and fish pass, which in principle never functioned due to improper length and steep angle. After conducting construction tests and finding the lack of integrity of the weir with the neighboring building, the weir was lowered by 1 meter, and then the fish pass was modified and its slope was reduced to 15 °;

2. reconstruction of the straight section of the river so that it has a meandering course. The calculations and hydraulic models showed that meanders should be made at a distance of 10-14 river
widths from each other. The width of the river itself was reduced from about 5 meters to 2-3 meters. The new, winding shorelines were secured with wooden piles, coconut geotextile, bundles of branches and silt selected from the bottom;

3. covering the new bottom with gravel (110 tons, grain size 40 mm), creating natural depressions and unevenness as well as a smooth transition between the bottom and the bank. Scouring the river bottom with gravel has a positive effect on the hydrodynamic balance of the river. This is called river bed paving;

4. distribution of tree limbs at the bottom, which play a habitat-forming role;

5. planting 2000 seedlings of marginal plants by volunteers on new embankments in order to stabilize them and start plant colonization. Natural plant succession was found to be difficult because there was no good source of plants in the upper bank of the river. Among other things, Carex riparia, Carex acutiformis, Lythrum salicaria, Juncus effusus, Myosotis palustris and Mentha aquatica were used.

5. Results and discussions
Monitoring the effects after completion of the work led to the following conclusions [8][10]:

• the river responds correctly to freshets caused by severe storms and flash floods, without causing a flood risk to the residential areas surrounding the reconstructed fragment, as well as those located in the lower reaches of the river,

• the hydromorphology assumptions were correct in terms of: flow variation, water depth and the amount of gravel displacement downstream,

• although the river is now more resistant to water level fluctuations than before the reconstruction, it is still susceptible to periodic drying, which in the long term may pose a significant threat to its ecosystems,

• plant colonization occurs very quickly,

• the fish pass functions properly - in the first spawning season, 5 trouts made it upstream for the first time in 80 years, and the next year 67 trouts aged 0+ floated downstream,

• the Wandle river is characterized by low dynamics, therefore it does not generate a sufficient number of natural depressions in the bottom. Therefore, in the gravel bed of the river it was necessary to introduce greater variability in the depth of the riverbed for a greater variety of fish habitats,

• in rivers with similar characteristics, more tree limbs can be placed at the bottom of the river. These branches play an important role in creating a habitat. Along with changes in the river level, these boughs tend to scrub the bottom, which additionally shapes them.

6. Conclusions
The issues related to the management of rivers and their reconstruction presented in the article are part of the trend of adaptation to climate change by: improving the risk management of floods and droughts, retention of rainwater in urban riverside areas, restoring and developing natural habitats and animal corridors, as well as restoring city dwellers access to the river. All this indirectly also contributes to the improvement of the quality of life of the inhabitants of the riverside areas.
The analyzed plans and cases showed that the modifications of the morphology of the riverbed and the use of the natural dynamics of the river make the river and its ecosystem resistant to hydrological extremes resulting, inter alia, from climate change, i.e. high water levels as a result of heavy rains, and low water levels during droughts.

The process of river restoration is a very beneficial activity in urbanized areas. The elongation and increase in the tortuosity of the river extinguishes its energy. This phenomenon is beneficial both from the flood and drought management point of view. The meandering of the river and, at the same time, its variable depth make it possible to trough retention and the formation of natural, potential floodplains in the river bends. However, it should be remembered that the river aims at "dynamic stabilization", that is, the state in which its course changes with time, but remains within certain limits.

An in-depth diagnosis of the condition of rivers, cooperation at various levels and areas, the development of appropriate plans and their implementation at various levels, and then constant monitoring of the effects achieved and drawing conclusions from these "lessons" in the form of examples of good practices can significantly contribute to reducing negative the effects of climate change on people living near rivers and on nature, whose habitats are based on the river ecosystem.

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