

River rehabilitation in urban areas – restrictions, possibilities and positive results

Michael Weyand and Ludgerus Rullich

ABSTRACT

Reaching the goal of good ecological status stipulated by the European Water Framework Directive (WFD) is generally difficult in German rivers. Appropriate habitat conditions for multiple and abundant incidence of flora and fauna are still missing. Existing water bodies, particularly in urban areas, are extremely affected by anthropogenic-induced pressures, resulting in reinforced river bottoms and river banks. In such regions, river rehabilitation is a challenging task and often requires a step by step approach to alter the given conditions. Nevertheless, work must be done and may create successful results as in the case of the Sprockhoevel creek. Over recent years this 11-km-long river in the western and industrialised part of the Ruhr River basin has partly been changed in shape to better resemble nature. Such change implies the widening of the river bed, the improvement of the river bottom by inserting natural gravel substrate, the removal of drop structures and the construction of a new river bed. Presently, this part of the river has again become a valuable habitat for aquatic life. Moreover, the area surrounding the rehabilitated Sprockhoevel creek is now also attractive for the neighbourhood community. Rehabilitation projects have the additional effects of reconnecting people to nature, encouraging public interest in near-natural aquatic systems, and catalysing further investments in similar projects.

Key words | rehabilitation measures, river morphology, urban rivers, Water Framework Directive

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INTRODUCTION

The Rhine-Ruhr region is one of the most densely populated and industrialised conurbations in Germany and Europe as a whole. About 10 million people live and work in this metropolitan area, which spans around 7,000 km². The pressure of extreme settlement coupled with commercial and industrial activities affect both terrestrial and aquatic ecosystems. The region's surface waters are particularly marked by anthropogenic uses. Industrial land use and urban development have led to fundamental changes of the aquatic ecosystem. Rivers and creeks were diverted, channelized, and removed from their natural beds and therewith shortened in length. It is known that higher percentages of impervious surfaces promote higher flood waves that must be safely discharged through

straightened and deepened water bodies; some rivers were practically squeezed into a concrete straitjacket. Such change results in both higher flow rates and accelerated sediment transport. Already present in the early days of industrialisation, the surging energy demand encouraged the impoundment of streams to generate hydropower. Today, these weirs or barrages disrupt the water bodies' continuity to a very high degree. Furthermore, surface waters are used to take up and carry away treated waste water, run off from separate sewer systems and combined sewer overflows.

These use-dependent boundary conditions are currently put to the test in order to meet the requirements of the European Water Framework Directive (WFD) which came

into effect in 2000 ([Official Journal of the European Communities 2000](#)). The overriding goal set out therein is to stop any further deterioration of the existing rivers and lakes statuses, which involves all activities in and around the water bodies. Furthermore, the directive states that good ecological and chemical status must additionally be achieved for all natural still surface water bodies. With regard to the category of heavily modified aquatic systems, it defines the objective as achieving ‘good ecological potential’.

Both good ecological status and good ecological potential are determined and classified by the quality of different biological elements; the composition and abundance of aquatic flora and of benthic invertebrate fauna as well as the composition, abundance and age structure of fish fauna. Additionally, hydromorphological elements (hydrological regime, river continuity and morphological conditions) and various chemical and physico-chemical elements have been defined to support the biological elements. All of these parameters must be monitored on the level of delineated water bodies within a period of at least three years. To achieve a good ecological status or potential, the values of such biological quality elements must convey low levels of distortion resulting from human activity, and should deviate only slightly from those normally associated with undisturbed surface water bodies. This requirement is challenging to fulfil in urbanized and industrialized areas, where rivers generally reveal conditions that have been altered by human activity for centuries.

STATUS AND RESTRICTIONS OF THE RIVERS IN THE RHINE-RUHR REGION

The status of most water bodies located in the Rhine-Ruhr region still reflects the above described situation. Historically, the Rhine-Ruhr region has experienced enormous pressure on its water resources due primarily to the high level of urbanisation and industrialisation. Despite fundamental structural change the Ruhr area has undergone since the peak of industrialization, the region continues to be characterised by high population density. Thus, it is no surprise that almost all water bodies, in particular the smaller ones in the urbanised zones, have been heavily regulated, reshaped and confined in concrete channels. Numerous water bodies in this region have been classified at level 5 or higher on the scale from 1 (unchanged) to 7 (completely modified) in the assessment of the hydromorphological water status ([Landesumweltamt 1998](#)). Only to the south of the Ruhr River do some less modified and more natural river stretches still exist. This situation is more or less ongoing, although some efforts to improve river morphology have begun (see [Figure 1](#)).

The aforementioned hydromorphological deficits find expression in the poor ecological condition of such rivers as well. Until recently, only 3% of 31 water bodies within the western part of the Ruhr River Basin exhibited good ecological status as demanded by the WFD; 81% were evaluated as poor or bad ([MULNV 2017](#)). As reducing the current pressures and improving the river’s shape is necessary to fulfil the WFD requirements, river rehabilitation becomes a significant topic.

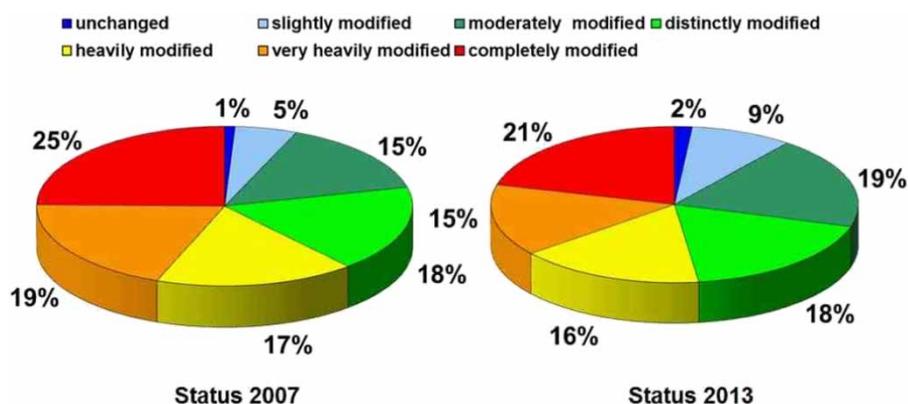


Figure 1 | Percentage of hydromorphological classification of rivers in the western part of the Ruhr River Basin.

However, changing the status of the region's rivers is a challenging task due to some essential limitations. For one, as such rivers were historically used as urban runoff and raw sewage transport media, many rivers flow mostly hidden from public view. Such implies that they may still be piped, covered or located in the background of urbanisation. Furthermore, the rivers are generally constricted in a given shape, lack the needed space, and are disconnected from their original floodplains. There is limited area available for river rehabilitation and enlargement, and when enough area does exist, it is often in competition with other possible uses. This situation could result in the use of suitable river rehabilitation land for commercial anthropogenic purposes. Such are the consequences of missing information and a lack of coordination within one department. In addition to the lack of available space for natural river rehabilitation, another restriction is the lack of needed resources. As river status improvement was historically regarded as strictly a water quality task, efforts were concentrated on improving waste water treatment plants and storm water facilities. Thus, rehabilitation measures such as maintaining natural river stretches and creating suitable habitat conditions for flora and fauna were not prioritized. In turn, only few personnel and small budgets are available to carry out the necessary task of achieving a good ecological status in the region's rivers. The lack of capital and operational experts has thus led to delays in designing, the prolongation of implementation, and late completion of projects.

Although the current system includes renewing the river basin management plans and programmes of measures every six years, it must be recognized that this administrative process alone is inadequate to achieve the desired goal. In order to overcome the most essential limitation, the missing area for river rehabilitation, coordinated agreements between agriculture and water-related authorities are needed in addition to individual negotiations with the affected landowners. Moreover, communal acceptance for river rehabilitation must be cultivated publicly and at the individual level of those using a river for commercial activity. It must be made clear that the investment in establishing a good ecological status is beneficial for sustainable natural resource use as well as for the long-term welfare of society.

POTENTIALS OF RIVER RESTORATION MEASURES

Despite the aforementioned limitations, authorities as well as other organisations responsible for river status are searching for ways to improve river continuity and river habitat conditions for flora and fauna. In the Rhine-Ruhr region, water bodies located south of the Ruhr River are generally the focus of river restoration measures. Due to the rural nature of this region, the water bodies have kept their natural appearance to a certain degree. However, several parts have been affected by industrial processes and urban development, resulting in straightened and reinforced river beds.

One of these water bodies is the 11-km-long Sprockhoevel creek located in the south-east part of the Rhine-Ruhr region. It is a tributary to the Paasbach River, which flows into the Ruhr River in the City of Hattingen. For the most part, the upper river reaches of the Sprockhoevel creek flow through smaller woods, wide meadows, pasture and isolated patches of arable land. Consequently, this section of the creek still displays the aesthetics of a relatively natural environment. After, the Sprockhoevel creek passes a flood retention basin with permanent impoundment that was built to serve as flood protection for the surrounding densely developed area. This urban region changed the appearance of the river completely; the river appears constricted, sometimes covered, and hidden for over two kilometres, and is still characterised by vertical concrete walls, drop structures up to 2.10 m high, concrete half-shells and deep cuttings.

Most modifications carried out through the last decades have resulted in an impoverishment of the biocenosis. In response to this unsatisfactory situation, the water board Ruhrverband – in close contact with the concerned cities of Hattingen and Sprockhoevel – has established a concept for morphological improvement (CMI) based on the authority's guideline concerning the development of natural watercourses (MUNLV 2010). A variety of measures have been developed with the aim of achieving the required good ecological status: measures to remove barriers for migratory fish species and to create structures that provide a good basis for other aquatic species (Weyand *et al.* 2009).

Due to the limitations of lack of space, staff and finance, a step by step procedure was agreed upon to improve the status of the Sprockhoevel creek in that section. Commissioned by the City and based on the contents of the

developed CMI, an implementation plan was set up describing rehabilitation measures realistic in perspectives of costs and time. Since 2009, Ruhrverband has been putting this plan into practise in different short sections.

The starting point was an area adjacent to a private garden cut through by the Sprockhoevel creek, which was practically straight jacketed between vertical concrete walls and brickwork sections at this point. At its narrowest point, the creek was just 1.30 m wide. After the demolition of the artificial structure of the bottom and rim, the cross-section of the water body was widened and its course slightly meandered. Where possible, the embankments were carried out with varying inclinations. In addition to the construction of a layer of willow brushwood (live fences of willow seedlings), which also serves as a natural bank protection, a horizontal 'green roof' provides shade. Furthermore, some alder seedlings were planted within the water exchange zone. After completing such measures, the hydromorphological structure of the creek resembled its natural structure.

However, only 150 metres downstream of this 'new' river stretch, a big drop structure with a subsequent long culvert disrupted the continuity of Sprockhoevel creek (see [Figure 2](#)). Thus, the next step of the agreed implementation procedure was the removal of that obstacle. Just

above the drop structure, the course of the water body was heavily narrowed by the adjacent housing on the left side and its bottom was reinforced with placed stones. The first thoughts of re-designing the river course at that section included the use of a nearby un-farmed meadow on the right side of the river suitable for bypassing the large drop structure via a natural little creek. But when discussing that idea with the staff of the city of Sprockhoevel responsible for river maintenance, it was learned that this area had been sold as a building plot to a property developer a few months previously. The new plot boundaries were drawn at the existing embankments and to further complicate matters, additionally raised by one metre. Thus, the only remaining solution was the development of a new structure within the longitudinal axis of the river. Construction of the new river bed was only possible within the limited given space and using the river itself as a construction site. This led to frequent interruptions, especially during flood periods, and an extension of the construction period.

Fortunately, the existing culvert was oversized for the given maximum runoff in the river. As the bottom of the culvert could be raised by 0.7 metres, the remaining height to overcome was decreased to 1.4 metres. In the area just before entering the culvert, the existing supporting walls

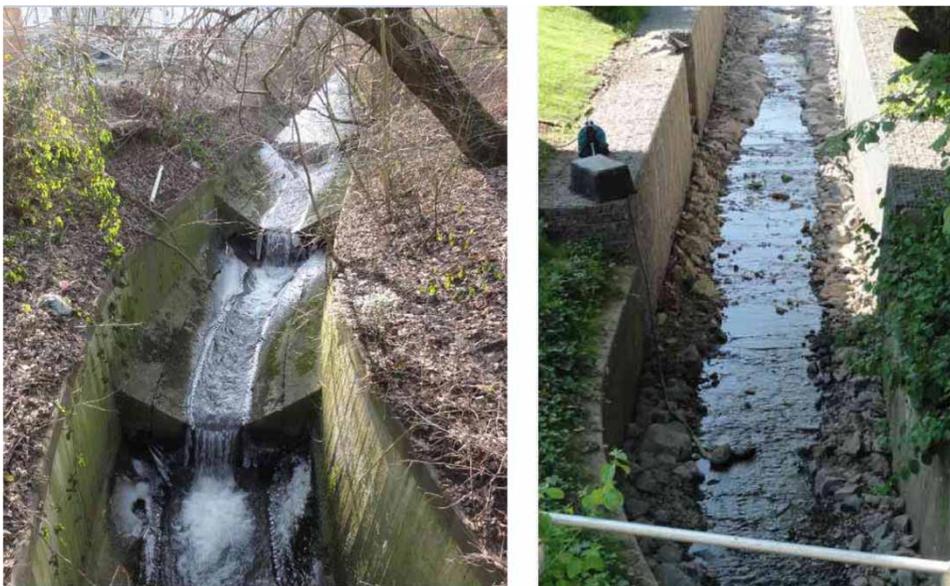


Figure 2 | Existing drop structure (left) and new river course at the former drop structure (right).

made of concrete remained for structural and static reasons. The subsequent banks near the buildings had to be secured with heavy weighted walls in the form of gabions. The original river bottom was removed and replaced by natural substrates. After completion of work, the Sprockhoevel creek consisted of over 200 m of natural river structure, which made it possible for fish to migrate and rest in specially created pools (see [Figure 2](#)).

Further downstream, the creek revealed a straightened course for about 700 m accompanied by a completely artificial bottom and embankment structures. Thus, the third measure consisted of the re-establishment of river continuity and the creation of a bottom status typical for this water body. In order to save costs, it was agreed with the local authorities to only destroy and cut up the existing concrete shells at the river bottom and to use them as substructures for the uplift of the river bed. In general, typical substrates were installed on the bottom of the whole renewed section and various smaller pools were compiled to increase the depth of water in the case of low flow.

Within that river stretch, a special facility – an old sluice gate as a relic of the past mining activities in the Rhine-Ruhr region – that was completely built in the cross section of the creek had to be addressed. This structure could not be removed and demolished because the municipal combined sewer, with a diameter of 700 mm, runs directly behind the existing concrete retaining wall. A realignment of this main collector would be too expensive, as it would be necessary to go into the basin area of the coal wash of the former colliery. For this reason and to preserve the sluice

gate as a historical remembrance for the present generation, the existing total construction was maintained. To create a near natural river bed in that section, the concrete was covered with stone mattresses in a thickness of approx. 30 to 60 cm on the bottom and the embankments.

The last step was the removal of a drop structure two meters in height in the upstream part of the urban section of the Sprockhoevel creek. Due to the limited space, a bypass water course was created to receive all discharges up to the long term statistical flow of 330 days of a year (see [Figure 3](#)). Every drop of water exceeding that value is drained via the old river section, which is controlled by a special dividing structure. The slope of that bypass reaches the upper limit of the typical slope for the given creek and creates flow velocities of up to 1.3 m/s.

The chronological development of these rehabilitation measures and their geographic position within the Sprockhoevel creek is depicted in [Figure 4](#) appended by an additional measure near to the WFD monitoring site.

Ultimately, the project's costs must be mentioned. As the implementation measures have been carried out in an urban area characterised by limitations due to the given surrounding circumstances and difficult construction conditions, it may be no surprise that the costs were relatively high. All in all, an amount of about 775,000 € had to be spent including designing and construction costs. The Sprockhoevel creek was rehabilitated over a distance of 785 m which resulted in specific costs of almost 1,000 €/m at an average. However, these specific costs range from 650 €/m to 1,580 €/m depending on the individual implementation



Figure 3 | Restoration of river continuity at an existing drop structure (left) by bypassing it via a new water course (right).

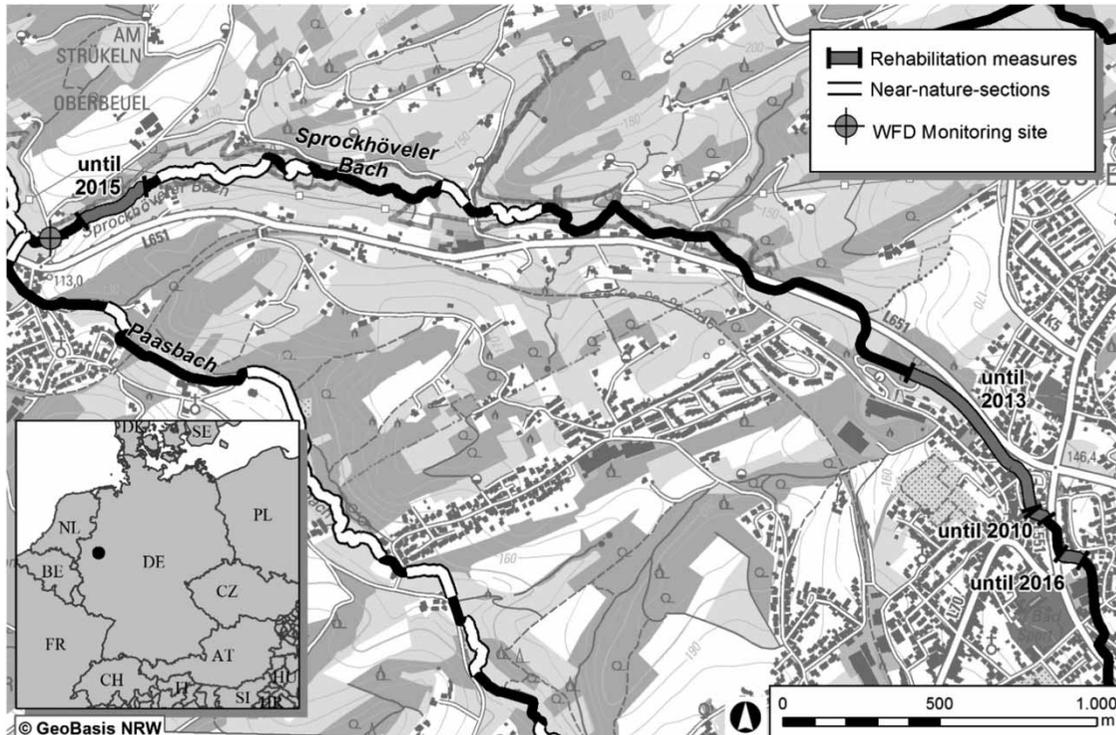


Figure 4 | Topographical map of the lower part of the Sprockhoevel creek showing the position of the rehabilitation measures and of the WFD monitoring site.

step. In comparison to an actual cost evaluation derived from a collection of 766 restoration projects across Europe, these specific costs seem to be very high. Ayres *et al.* (2014) determined mean costs of 151 €/m for a bed and bank fixation removal and 231 €/m for a re-meandering of a watercourse. Unfortunately, in that project report, costs for a weir removal or upstream longitudinal connectivity improvements are given in the unit €/m height only. However, such measures are included in the given specific costs of the work carried out at the Sprockhoevel creek. Moreover, it should be considered that the circumstances found there are more complex than in rural areas due to the given urbanised surrounding. Such situations may result in higher implementation costs as well.

RESULTS OF RIVER RESTORATION AT THE SPROCKHOEVEL CREEK

One year after finishing the first restoration measure, a small random test series was carried out in the rehabilitated section in spring 2011, which provided the first evidence of

the measure's success. The total abundance of the species found was a sum of 22. Several important species had increased in abundance and new taxa were registered after such a short period of time. The saprobic index found corresponded to a good saprobic status according to the standards of the WFD. Additionally, the terrestrial animals benefitted as well, as many birds like dippers and even kingfishers chose the rehabilitated site as their new habitat.

Unfortunately, these developments find only little expression in the results of the monitoring investigations according to the standards of the WFD (see Table 1). The measuring site, reflecting the effects of finished restoration measures, is located about 4 km downstream of the restoration area and is thus influenced by pressures occurring in between the sites as well. Moreover, the time period of two monitoring cycles is three years, as pre-set by Annex V, chapter 1.3.4 of the WFD. The monitoring done in spring 2010 – implying just in the starting phase of river restoration of the Sprockhoevel creek – revealed 28 different discovered taxa with a total amount of 449 individuals per square metre, amongst them Ephemeroptera and Gammari-dea – both genera representing good habitat conditions of a

Table 1 | Results of water body monitoring in the Sprockhoevel creek for some basic water quality parameters and benthic invertebrate fauna of three different years including taxa list in excerpts and determined ecological status

Date of sampling	14.04.2010	11.03.2013	23.03.2016
Water temperature [°C]	9.8	11.7	7.6
pH value [–]	8.2	8.0	8.2
Total nitrogen [mg/l]	1.5	1.7	1.4
NH ₄ -N [mg/l]	0.10	0.05	0.05
Total phosphorus [mg/l]	0.04	0.02	0.04
Oxygen [mg/l]	11.3	10.9	11.6
Total organic carbon [mg/l]	1.5	1.7	2.8
Amount of taxa	28	23	29
Individuals per square metre	449	556	1,826
Amongst them			
Family of Ephemera	18	1	20
<i>Ephemera</i> sp.	–	–	12
<i>Ephemera danica</i>	18	1	8
Family of Gammaridea	180	355	952
<i>Gammarus</i> sp.	–	–	204
<i>Gammarus fossarum</i>	71	300	632
<i>Gammarus roeselii</i>	109	55	116
Family of Chironomidae	86	64	576
Chironomidae	71	60	–
Chironominae	–	2	–
Chironomini	15	2	576
Ecological status determined for benthic invertebrate fauna	good	good	moderate

river. These findings indicate that there existed a good ecological status of the water body at the monitoring site for benthic invertebrate fauna at the time; however, this site may not directly represent the conditions of the Sprockhoevel creek within the urbanised area. The following investigation repeated in spring 2013 shows more or less the same result. However, the amount of Ephemeroptera and Gammaridea almost doubled to 355 individuals per square metre. By that, an improved ecological assessment set in which may be influenced by the restoration measures having been implemented in the meantime. The status evaluation for benthic invertebrate fauna according to the WFD confirmed the good ecological status already ascertained in 2010.

Three years later, in spring 2016, the newest monitoring at that water body site took place. Regarding the discovered amount of 29 different taxa, a similar result to that in 2010

was found. However, the abundance showed an explosive growth up to 1,826 individuals per square metre. On the one hand that was mainly caused by the increase of Ephemeroptera and Gammaridea, but on the other hand, the family of Chironomidae also increased in abundance. Chironomidae mainly feed on fine organic material, which is normally a rare substrate in such a creek. As such, the increased abundance of this family indicates a disturbance in the ecosystem. Triggered by the mass incidence of Chironomidae, the determined ecological status for benthic invertebrate fauna deteriorated to only a moderate status. That unsatisfactory development is caused by five small river rehabilitation measures in the river section just covering 500 m upstream of the monitoring site which were finished only two months before the date of taking the monitoring samples. These measures included the release of large amounts of soil and fine suspended solids due to the re-enforcing of bottom and embankments. Transported downstream by the water, the material could settle down with decreasing flow velocities and create unnatural habitat conditions until it was washed out by the next bigger flood event. Thus, these circumstances are the main cause for the only moderate status result. As well, it becomes clear that a longer time lapse between the end of restoration work and the taking of samples is essential when aiming for a reliable evaluation of the ecological effects of such measures.

Not only do the creatures in and around the Sprockhoevel creek benefit from the restored natural state of the water body, but the people as well. The Sprockhoevel community additionally profits, as their living environment is visibly improved. Moreover, the interest in the changes that took place at the Sprockhoevel creek is shown in the request of teachers at a nearby primary school for pupil field trips concerning the subject of environmental protection. That task was fulfilled by the Ruhrverband with pleasure. A lot of young keen researchers equipped with a sieve, magnifying glass, and readout pan discovered the rehabilitated water body under expert guidance (see Figure 5). After only a short time, the children saw success. The pans were full of freshwater shrimp, an important keystone species of such rivers. Also, certain juvenile fish, a grass frog and various invertebrates were caught and released after extensive investigation. Becoming familiar with nature in front of your own home, gaining insights into the ecosystem, and



Figure 5 | Field trip of a primary school on river ecology.

understanding the technical context was a valuable experience for the girls and boys, revealing the infectious enthusiasm of a third-grade primary school class.

POSSIBLE IMPROVEMENTS IN THE APPLICATION OF THE WFD

Regarding the given delay in fulfilling the WFD requirements, it becomes necessary to set up better communication policy on a more local level between authorities, engineers and the public. Such information transparency concerning the possible future design of a river and its effect on the surrounding ecosystem should be provided by the planning and implementing organization and, in turn, will increase the affected population's approval of the project. On a more regional level, periodical meetings and consultations between all parties involved in the usage of the river basin is needed. Through such consultations, different opinions regarding the development of the river can be discussed and future thoughts regarding the use of the river and its riparian zones may be introduced. Such a procedure may result in the deliberation of potential locations for measures, the early involvement of all affected parties and, thus, a shortening of the necessary administrative processes. However, in order to bring all these ideas into action, it is also necessary to increase the amount of well-educated and qualified staff both in designing and construction institutions as well as in authority institutions.

First and foremost, it is necessary to understand that the WFD is not a directive for water management only. Many human activities such as energy production, global trade or agricultural cultivation are not in the category of water management but have a direct effect on water quality. Thus, on a political level, it must be recognized that the WFD affects other areas of political action in the same way that it affects water management. Factually, that is already laid down in No. 16 of the Recitals of the WFD: *'Further integration of protection and sustainable management of water into other Community policy areas such as energy, transport, agriculture, fisheries, regional policy and tourism is necessary'* (Official Journal of the European Communities 2000). However, up until now, that note appears to be seldom considered in political decisions.

With respect to the upcoming review of the WFD performed by the European Commission in 2019, according to Article 19, this multidimensional political aspect of the directive should be particularly focused on. A stronger integrative consideration and harmonization of the existing European regulations with the WFD may offer great opportunities for improving water protection. That demand is also included in the content of the position paper on the review of the WFD published by the DWA (DWA 2017), one of various publications of German stakeholders with respect to the review process. However, Germany is only one member state of the European Union and other states may publish similar statements on that review process. Thus, it

remains to be seen what decision the European Commission will reach at the end of 2019.

CONCLUSIONS

In urban areas, rehabilitation measures, as exemplarily described above at the Sprockhoevel creek, are not easy to implement but nevertheless are key elements in improving hydromorphological conditions and the ecological status of a water body. Moreover, they have a positive effect on the environmental awareness of the population and can catalyse a change in perception of rivers as a part of nature. In heavily anthropogenically used regions however, local constraints like lack of space or difficult construction conditions often exist. Actual realisation requires good supervisory control of the on-site work, and generally makes the implementation more expensive than in more rural areas and prolongs the completion time due to lengthy construction process.

Thus, good coordination during the design phase of such measures is necessary between all involved parties in order to minimize conflicts and to solve upcoming differences of opinion. The involved parties include the cities as the responsible party for river rehabilitation, the authorities permitting and granting the planned measures, and the designer. In spite of the fact that the above-mentioned project observed strong coordination between parties, its practical realisation has already lasted eight years and is still ongoing. The slow pace is mainly caused by limited financial funds available to the City of Sprockhoevel for river maintenance and river restoration.

Nevertheless, the city promotes such restoration measures wherever possible and is lucky that those implemented up until now have been very successful. The appearing development of the Sprockhoevel creek clearly reveals that river rehabilitation is feasible in urban areas as well and represents an important contribution for reaching the objectives of the WFD, even if projects last longer than the given 15 years. It is a significant step in the right direction to improve river ecology and encourage public interest in near-natural aquatic systems.

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