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Executive summary

Re-discovering rivers and lakes in cities

In Europe, extensive urbanisation poses a range of significant challenges for the natural resources and ecosystems within and close to urban regions, including the rivers, streams and lakes which are part of the landscape of cities and towns.

In recent decades, and after the gradual improvement of water quality due to wastewater treatment and reduced industrial activities, urban rivers and lakes have become increasingly important in the planning of urban ecology, green infrastructure and green areas in European cities. Especially, river and lake restoration are offering win–win situations: they improve flood control and ecological functions while offering recreational value and raising the quality of life in urban areas. They also mitigate the impacts of the urban heat island effect while providing better visual balance to the cityscape.

Restoration projects offer the chance for a future oriented city planning and development. In recent years more and more people have been recognizing this as an asset for their quality of life. For many years, cities were turning their back to water (harbours, rivers) or were covering rivers to protect themselves from pollution and flood risk. Now rivers and lakes are being re-discovered as valuable spots in the city landscape. Activities on the restoration of urban rivers and lakes are likely to expand further as urban development continues and the demand for safe, sustainable and attractive cities increases. Indeed, much of the impetus for urban restoration efforts has been the recognition of the range of public benefits that river restoration provides. As more and more cities move towards a water-centric urban design, many restoration projects have urban regeneration as part of their primary objectives.

Against this background, many European cities have developed broad visions and strategies to promote a more integrated management of their water bodies, especially in terms of restoring their rivers and lakes. Such strategies provide a broad framework for carrying out a number of restoration projects over a longer planning period. There are also important links between restoration and local/city authority strategies for open space, green infrastructure or green networks.

In the European Union, there are also several policy processes that act as drivers for managing urban rivers and lakes in a more integrated way. This relates to several Directives such as the Urban Wastewater Treatment Directive, the Water Framework Directive, the Floods Directive, the Birds and the Habitats Directives as well as other policies such as the EU strategy on adaptation, Green Infrastructure and more recently the Urban Agenda for the EU. These policy processes and their interplay with one another can contribute to linking water quality improvements with ecosystem protection, climate change adaptation and recently with urban development in urban areas across Europe.

Objectives of this report

This report aims to outline the ways European cities develop strategies and measures to cope with the key challenges they currently face for their inland surface waters (rivers and lakes) and showcase specific measures, strategies and initiatives which can serve as source of inspiration and lessons learned. For this purpose, river and lake restoration strategies and projects in European cities were screened and seventeen case studies were selected for presentation in this report.

Coping with key challenges for urban rivers and lakes

For the purpose of this report, the major challenges that urban rivers and lakes in European cities face are grouped into:

- Water availability and supply challenges
- Water quality issues
- Structural changes, related among others also to flood risk management.

For each of these major challenges, the report provides a brief review of the issues at stake, documents the key approaches followed to deal with the issues and gives case study illustrations.

Water availability and supply: Several European cities depend on surface waters for their drinking water supply, in several cases having to resort to rivers or lakes situated hundreds of km away from the city. The design of urban water supply infrastructure still predominantly rests on a engineering and supply-led approach dating back to the first stage of urban development and industrialisation. However, to prevent urban water crises, water resources should be managed effectively at every stage, involving consumption reductions, new ways of collecting and using water and awareness campaigns.

Water quality: Urban rivers and lakes have also been heavily polluted in the process of urbanization and industrialisation of the last century. Looking back to the past 25 years, clear progress has been made in reducing emissions into urban rivers and lakes due to connections to sewers, the introduction of wastewater treatment and the upgrading of earlier treatment plants. Improvements in the water quality of urban rivers and lakes due to reduced emissions and wastewater improvement have brought about benefits to river and lake ecology. However, some key challenges still remain with water quality impacts related to stormwater management and historical pollution of sediments.

Structural changes: Rapid urbanisation and industrial growth have introduced additional types of stress to urban rivers and lakes, in the form of modifications to their morphology and hydrology (e.g. via river channelization and straightening). This has taken space away from the river to serve flood protection and the creation of living space for growing towns. This report describes the response of cities and towns to impacts of physical modifications and distinguishes between activities that aim at a) hydromorphological restoration mainly of rivers and streams of medium/small size, b) activities of de-culverting covered streams and rivers and c) restoration of urban water bodies with strong links to flood risk management. In practice, all these types of activities are strongly interconnected and often take place simultaneously in the context of the same restoration scheme.

Lessons learned and way forward

The case studies on urban river and lake restoration reviewed for this report reveal that there are several critical aspects to think about when planning and running urban restoration activities. The report draws some key lessons learned from the reviewed case studies and frames some key contextual issues, which are potentially relevant to different urban settings across Europe. These are aspects related to local planning processes, the multi-functionality of urban restoration, availability of space for urban restoration, public participation and the involvement of multiple actors.

Local planning: Restoring the water environment in urban areas has very important links with local planning and with flood risk management. Local authorities can use land use planning processes to deliver improvements to urban rivers and lakes. Strategic development plans and local development plans are produced by planning authorities with input from a wide range of stakeholders. They can identify aspirations and assist delivery of restoration, and offer an important opportunity for interested parties to become involved in the decision making process. In this context, the planning process and financing of restoration measures in urban areas requires strong collaboration of water and city development authorities, authorities responsible for urban and spatial planning and local residents.

Multi-functionality: In designing restoration projects for urban rivers and lakes, it is important to aim for multi-functional schemes. Multi-functional schemes contribute to the achievement of multiple benefits for different sectors, and are thus in a better position to raise different funding sources and enhance cooperation between different actors in the governance setting. Multi-functional urban restoration measures are seen as win-win measures that help deliver synergies, e.g. to implement different policies such as the WFD, Floods Directive and Habitats Directive. Except for the strong links of restoration with flood risk management, it is additionally important to create spaces that allow experiencing nature. Such win-win restoration measures can easier gain public and political acceptance and secure multiple sources of (co-)funding. It also becomes obvious that defining multiple benefits more accurately (both direct and indirect benefits in terms of ecosystem services) often supports decision-making for restoration projects in cities.

Space for restoration: In urban areas, where available space is limited, river restoration projects are frequently restricted. However, there is potential to deliver improvements in physical condition, along with significant environmental and social benefits, by using innovative approaches. For example, there may be opportunities to remove redundant structures and buildings, and restore derelict land alongside rivers in order to improve local amenity and environment. Because of the lack of space in urban areas, some cities have also been developing stepping-stone concepts for restoring the networks of their water bodies. Such stepping-stone approaches involve starting restoration from the outskirts and peri-urban areas and moving step-by-step towards the more central urban areas, which are more difficult to restore.

Public participation: Planning and execution of measures in urban river restoration should not follow a top-down approach. Public consultation and engagement with local communities have emerged as a crucial step in the planning and implementation of restoration measures in cities. Civil society and the private sector are crucial for the development of cities and their hinterlands and will play a major role in coping with the challenges ahead.

Governance framework: Except for engaging with the public and citizens affected by restoration schemes, it proves equally important to establish effective cooperation between the different actors (especially government bodies and organised stakeholder groups) with a stake and influence on urban restoration.

Activities on the restoration of urban rivers and lakes are likely to expand further as urban development continues and demands for a sustainable and enhanced quality of life increase.

1 Introduction

Context

Europe is an urban and increasingly urbanising continent. Roughly three quarters (72.4%) of the total EU28 population lives in cities, towns and suburbs (Eurostat, 2015). Although the speed of urbanisation has slowed down, the share of the urban population continues to grow, and is likely to reach more than 80% by 2050 (European Commission, 2014; EEA, 2015d). This will pose a range of challenges for the natural resources and ecosystems within and close to urban regions, including the rivers, streams and lakes which are part of the landscape of European cities.

In Europe, as in other industrialized parts of the world, the quality of urban rivers and lakes degraded after the 19th century due to the increasing numbers of settlements and industries discharging untreated wastewater. Urban rivers and lakes were also structurally modified to accommodate human uses such as navigation, construction activities and flood protection.

In recent decades, and after the gradual improvement of water quality due to wastewater treatment (this driven in part by the Urban Wastewater Treatment Directive) and reduced industrial activities, urban rivers and lakes have become increasingly important in the planning of urban ecology, green infrastructure and green areas in European cities. Especially, river and lake restoration, often as integral parts of city development projects and urban planning, are now offering win–win situations: they improve flood control and ecological functions while offering recreational value and raising the quality of life in urban areas. Furthermore, integrating green and blue spaces in the design of the urban fabric reduces overheating and pollution, thus mitigating the strength and impacts of the urban heat island effect (EEA, 2012b).

Activities on the restoration of urban rivers and lakes are likely to expand further as urban development continues and demands for a sustainable and enhanced quality of life increase.

Around the world, there are increasingly more and more examples exploring how people can live with water in their cities in the coming decades. Cities are developing visions for safer and aesthetically more attractive city locations, built on sustainable water management principles and good practices. The OECD recently showcased good practices to promote a strategic vision across sectors, to engage with stakeholders and to foster integrated urban water management in cities and their hinterlands, via rural-urban partnerships and metropolitan governance (OECD, 2016).

In Europe, many examples of restoring rivers and lakes in cities and towns to serve different purposes already exist (EEA 2016a; 2015b; 2015e; RESTORE, 2013; UNISDR, 2012), and are partly (but not only) driven by the objectives of key water policies, such as the EU Water Framework Directive.

In fact, in the European Union, there are several policy processes that act as drivers for managing urban rivers and lakes in a more integrated way. This links up to the implementation of several EU Directives such as the Urban Wastewater Treatment Directive, the Water Framework Directive, the Floods Directive, the Birds and Habitats Directives as well as other policies including the EU strategy on adaptation, Green Infrastructure and more recently the Urban Agenda for the EU. These policy processes and their interplay with one another contribute to linking water quality improvements with ecosystem protection, climate change adaptation and recently with urban development in cities across Europe.

Objectives of this report

The EEA acknowledges the importance of the sustainable use of natural resources in urban areas and has recently issued reports on resource-efficiency in cities (EEA 2015a; 2015b; 2015c) as well as urban adaptation to climate change (EEA 2016a; EEA, 2012b). The EEA has also addressed the various perspectives and perceptions of quality of life in Europe's cities and towns, thereby defining a vision for progress towards a more sustainable well-designed urban future (EEA, 2009, EEA 2015e).

In this context, the current report aims to:

- Outline the ways European cities develop strategies and measures to cope with the key challenges they currently face for their inland surface waters (rivers and lakes).
- Showcase specific measures, strategies and initiatives on river and lake restoration, flood protection, stormwater management and water quality improvements in cities across Europe which can serve as source of inspiration and lessons learned.

The report aims to reach a broad public and citizens across Europe and illustrate that river and lake restoration does not necessarily only take place far away from centres of human activity. On the contrary, river and lake restoration is feasible and even desirable within the towns and cities we live in.

In this sense, the use of the term restoration in this report is not limited to "a management process striving to re-establish the structure and function of ecosystems as closely as possible to the pre-disturbance conditions and functions"(Wagner et al., 2007). The term restoration is used more broadly to refer to activities that aim to improve the status of degraded waters, be it by improving water quality, by changing hydromorphological conditions (see wiki.reformrivers.eu/) and also to serve other needs and preferences of the urban population, i.e. multi-functionality.

This report does not seek to provide guidance on how to carry out urban river and lake restoration. The geographical and socio-economic context as well as the ecosystems potentially targeted by restoration projects in cities and towns may greatly vary. This means that restoration processes and methods cannot usually be implemented in the same way across different locations. Nevertheless, the report draws some key conclusions and lessons learned from good practice examples on river and lake restoration in selected European cities.

Structure & method of report

In order to provide useful examples and lessons learned from real-life cases, a screening of restoration strategies and projects in European cities took place for the purposes of this report. On the basis of this screening, seventeen case studies were selected to cover a range of relevant issues and to ensure geographical spread. The seventeen case studies are presented in separate factsheets in the Annex to this report. These factsheets provide information on the key water management issues, restoration measures and strategies implemented in the case studies, the main results and benefits as well as key lessons learned.

The case studies have served as a source of evidence and illustration for the key issues put forward in the main part of this report, especially in order to reflect on main types of restoration measures and strategies for urban rivers and lakes and to frame some of the key issues that are potentially relevant to different urban settings across Europe. In addition other examples of water management in European cities are mentioned in the report.

The following table gives an overview of the case studies reviewed and illustrated in more detail in the Annex.

Table 1 Case studies of this report

City/Town	Country	River/lake	Title of case study
Aarhus	Denmark	River Aarhus	Reopening the River Aarhus
Bucharest	Romania	River Dâmbovița	Wastewater treatment in Bucharest
Leipzig	Germany	River Luppe	Revitalization project in Leipzig's urban floodplain forest (Living Luppe)
Ljubljana	Slovenia	Podutik reservoir	Multi-functional flood reservoir Podutik
London	United Kingdom	River Mayesbrook	Mayesbrook River and park restoration initiative
Leuven	Belgium	River Dyle	Flood protection / restoration of the River Dyle
Łódź	Poland	River Sokołówka	Restoration of the River Sokołówka
London	United Kingdom	River Quaggy	River Quaggy in Sutcliffe Park
Lyon	France	River Yzeron	Flood protection / restoration in the River Yzeron
Mérida	Spain	River Guadiana	Restoration of the River Guadiana
Munich	Germany	River Isar	Urban river restoration on the River Isar
Nijmegen	The Netherlands	River Waal	Room for the River Waal
Oslo	Norway	Streams & rivers	Water in the City - the Oslo strategy for de-culverting its streams and rivers
Ruhrgebiet	Germany	River Emscher	River Emscher re-conversion
Stockholm	Sweden	Lake Trekanten, Igelbäcken stream	Stockholm Water Programme for improved water quality and recreational value including the cases of the Lake Trekanten and the Igelbäcken Stream
Tallinn	Estonia	Lake Ülemiste	Protection of Tallinn's drinking water resources: The case of Lake Ülemiste
Vienna	Austria	River Liesing, Wienfluss, old Danube	Restoration measures and strategies for Vienna's urban water bodies

Chapter 2 outlines the importance of rivers and lakes as key features of European cityscapes and describes the key impacts of urbanisation on rivers, streams and lakes. It also discusses the way we view urban rivers and lakes, their functions and services to people has changed in recent decades. It also illustrates how European cities have started developing visions and strategies for more sustainable management of their water bodies.

Chapter 3 addresses the major challenges that European cities face for their urban rivers and lakes; these challenges are grouped into water availability and supply challenges, water quality issues and structural changes, related among others also to flood risk management. The chapter provides a brief review of the issues at stake, documents the key approaches to deal with the issues and gives case study illustrations.

Chapter 4 summarises key lessons learned from the reviewed case studies and frames some key contextual issues which are important for planning and running river and lake restoration activities in cities. This section also highlights some significant challenges for the future, and identifies opportunities for more effective restoration of rivers and lakes in an urban setting.

2 Fall and rise of urban rivers and lakes

2.1 Importance of rivers and lakes in European cities

Almost all cities around the world were built along waterways, or along a coast of an ocean, sea or lake. The multifaceted relationships between urban planning and water have structured and influenced the development of metropolitan areas, cities, towns, rural areas, villages, and even neighbourhoods throughout history and will continue to do so (Brandeis et al. (2014)).

Over time, the settling of humans next to rivers and lakes has transformed the natural environment into the towns and cities we see today. Urbanisation has come at a cost to rivers and lakes, as they have been heavily degraded to enable development, carry waste, supply drinking water and facilitate transport and industry.

In Europe, almost all capital cities have at least one major river or lake crossing their urban landscape (see **Error! Reference source not found.**). The largest rivers of Europe such as the Danube, the Rhine and the Elbe are home to a number of cities on their main channels, their tributaries of the wider catchment and on their estuaries.

Table 2. Major rivers and lakes of the capitals of the 33 EEA member countries.

EEA member countries	Capitals	Rivers and lakes
Austria	Vienna	River Danube, River Wienfluss, River Liesing
Belgium	Brussels	River Senne
Bulgaria	Sofia	A number of rivers cross the city, including the Vladayska and the Perlovska
Croatia	Zagreb	River Sava, Jarun Lake
Cyprus	Nicosia	River Pedieos
Czech Republic	Prague	River Vltava
Denmark	Copenhagen	Lakes Sortedam, Peblinge, and Sankt Jørgens Lake (originally, there was one long stream which was dammed)
Estonia	Tallinn	Lake Ülemiste, Lake Harku, River Pirita
Finland	Helsinki	River Vantaa
France	Paris	River Seine, Lake Daumesnil
Germany	Berlin	River Spree, River Havel, several lakes (Tegeler See, Großer Wannsee,

		Großer Müggelsee)
Greece	Athens	Historical rivers are the Cephissus river, the Ilisos and the Eridanos stream
Hungary	Budapest	River Danube
Iceland	Reykjavík	River Elliðaá
Ireland	Dublin	River Liffey, River Tolka, River Dodder
Italy	Rome	River Tiber
Latvia	Riga	River Daugava
Liechtenstein	Vaduz	-
Lithuania	Vilnius	River Vilnia, River Neris, numerous lakes
Luxembourg	Luxembourg	River Alzette, River Pétrusse
Malta	Valletta	-
The Netherlands	Amsterdam	River Amstel, River/Lake IJ
Norway	Oslo	River Alna, River Akerselva, Lake Maridalsvannet, Lake Østensjøvannet and many smaller lakes
Poland	Warsaw	River Vistula, several lakes e.g. Czerniaków Lake, the lakes in the Łazienki or Wilanów Parks, Kamionek Lake.
Portugal	Lisbon	River Tagus
Romania	Bucharest	River Dâmbovița, River Colentina, numerous lakes e.g. Lake Herăstrău, Lake Floreasca, Lake Tei, and Lake Colentina,
Slovakia	Bratislava	River Danube, River Morava, several lakes
Slovenia	Ljubljana	Rivers Ljubljanica, Sava, Gradaščica, Mali Graben, Iška and Iščica
Spain	Madrid	River Manzanares
Sweden	Stockholm	Lake Mälaren; River Norrström
Switzerland	Bern	River Aare
Turkey	Ankara	River Ankara Çayı ran through the center of the Roman town; it is now covered and diverted
United Kingdom	London	River Thames, St. James Park Lake, Serpentine Lake

Some of the most popular tourist city destinations in Europe are built on and strongly defined by their rivers, among others Paris on the River Seine, Rome on the Tiber, Budapest and Vienna on the Danube, Prague on the Vltava and London on the Thames. Some European cities, such as Dublin, are characterised by a complex water landscape unknown to most visitors passing through (see box below).

Dublin – A city of three rivers

Dublin is situated at the mouth of the River Liffey, which divides the city in two between the Northside and the Southside. Each of these is further divided by two lesser rivers – the River Tolka running southeast into Dublin Bay, and the River Dodder running northeast to the mouth of the Liffey. Two further water bodies – the Grand Canal on the southside and the Royal Canal on the northside – ring the inner city (Dublin, n.d.).

In addition to the larger better known urban rivers, there are many small rivers and streams which have shaped the landscape of European cities and are frequently subject to recent urban restoration schemes. Several of these smaller rivers and streams feature as case studies in the Annex to this report.

Lakes are not as frequent a feature as rivers in large European cities. However, there are a number of cities, which have partly developed on lake shores, coasts and estuaries, that serve as popular recreational areas and/or sources of drinking freshwater for the city. Some examples of cities with major lakes are Tallinn (Lake Ülemiste), Berlin (lakes Wannsee, Müggelsee, Tegeler), Stockholm (lake Mälaren), Zürich (Lake Zürich) and London (Serpentine Lake). Several other European capitals such as Oslo, Vilnius and Bucharest are connected to a number of smaller and middle-sized lakes.

2.2 Key impacts of urbanisation

In industrialised and developing countries in the 19th and 20th century, most urban rivers were channelled into canals, buried or otherwise confined. Eden and Tunstall (2006) summarise the traditional European approach to urban river management as "…bury them, turn them into canals, line them with concrete and build upon the (now protected) floodplains". This approach was designed both to improve urban hygiene and to protect cities from flooding. In the 1950s, the growing use of cars in cities led to river banks being transformed into high-speed traffic lanes (e.g. the case of the River Manzanares in Madrid and the Seine in Paris). Due to pollution from wastewater and the fact that river banks became increasingly difficult to access, traditional uses of urban rivers (bathing, boating, fishing) disappeared. Cities gradually turned their backs on the rivers that they once relied upon for their prosperity. Only major water shortages and flooding reminded local authorities and residents of the presence (or absence) of water in the city (Bruhn, 2015).

Madrid: Prioritizing people over cars

After a massive highway was built on both sides of the Manzanares River in Madrid in the 1970s, nearby neighbourhoods declined and most city inhabitants avoided the region entirely. In 2003, Mayor Alberto Ruíz-Gallardón implemented his vision to bury the highways and move traffic through tunnels instead. Ultimately, the river banks were freed for pedestrians and more than nine km of the Madrid Río Park were designed with playgrounds, ball fields, bike paths, and a wading pool known fondly as "the beach" (World Watch Institute Blog, 2016).

The negative impact of urbanisation on river and lake systems in European cities is wide-ranging and multi-faceted. The impacts go beyond the historical issue of water pollution and extend to structural changes of the once-more natural rivers and lakes. The ways urbanisation has affected urban rivers and lakes include (based on ECRR, 2015):

- **Water quantity impacts**: Decreased flow and reduced groundwater levels through abstraction as well as increased flow from surface run-off, increased frequency of floods and reduced infiltration affect the quantitative status of rivers and lakes in cities.
- **Water quality impacts**: Wastewater discharges and increased run-off from impervious surfaces such as roads, roofs and gardens, and contamination from household and industrial stormwater overflows degrade water quality.
- **Physical structure impacts**: Artificial walls replace natural river banks, barriers disrupt connectivity or in many cases the river is hidden underground (covered rivers).
- **Geomorphological impacts**: Urban rivers lack the space to erode their banks and deposit sediment or connect to their floodplain, which leads to altered morphology. Bridges, pipes and other infrastructure alter the width and depth of rivers, and their courses are changed by straightening and bypassing.

- **Impacts on the ability to support wildlife**: Natural corridors, riparian zones and in-channel habitats are lost.
- **Removal of riparian vegetation**: This reduces organic input, habitat complexity, increases river temperature and reduces bank stability.
- **Invasive species**: Urban areas often suffer from introduced non-native species that become dominant and cause damage to the environment.

Urbanisation also has a notable impact on channel ecology, made obvious in terms of decrease in biotic richness and increased dominance of pollution- and flow-tolerant species. As urban centres have expanded in size and number, negative impacts on freshwater ecosystems have become more severe and widespread (summarised by Everard & Moggridge (2011)).

The illustrations below show some examples of degraded urban water bodies:

Photos: @E.Kampa (upper left), @Flemish Environment Agency (upper right), @ Syndicat d'Aménagement et de Gestion de l'Yzeron, du Ratier et du Charbonnières (lower left), @ Wasserwirtschaftsamt München (lower right).

2.3 Re-discovering rivers and lakes in our cities

Historically, rivers and lakes offered a popular setting for urban development due to the fact that they could provide food, water, power generation, flat land for development, trade routes and transport. Furthermore, urban rivers and lakes have functioned for centuries as receivers and transporters of household and industrial wastewater, which gradually led to their degradation, making them a source of nuisance to city inhabitants. During the 20th century, many European rivers and lakes were polluted, deteriorated, and they lost their significant roles.

Since the 1970s, substantial investments have been made in sewers, wastewater treatment and stormwater management and led to water quality improvements across Europe. As a result, European rivers and lakes have gained a more positive image in cities and towns. It is now recognised that urban rivers and lakes are called upon to fulfil more roles such as providing space for recreation and an aesthetically pleasing environment for urban regeneration. More and more cities and communities re-discover their rivers, streams and lakes as open spaces in the urban environment, and as meeting points for social and cultural activities.

As cities are changing the way they view their water bodies, there are more opportunities for restoring urban rivers and lakes. Cities rediscover the value of rivers and lakes around which they were originally organised and developed and, in this context, many municipalities launch restoration projects. Especially urban rivers are becoming an important focus for restoration, and this is likely to expand further as urban development continues and demands for a sustainable and enhanced quality of life increase.

Restoration projects offer the chance for a future oriented city planning and development. In recent years more and more people have been recognizing this as an asset for their quality of life. In practice, many restoration projects for urban rivers are initiated not so much with the view to improving aquatic biotic ecosystems but as part of urban (regeneration) projects closely associated with the rivers running through the cities (Bruhn, 2015). Indeed, much of the impetus for urban restoration efforts has been the recognition of the range of public benefits that river restoration provides (Petts et al. 2002).

The type of benefits which can be delivered by improving urban water environments include:

i) reducing flood risk and helping to deliver flood risk management planning,
ii) creating opportunities to access the natural environment, providing new open spaces for amenity and recreation, and green networks for wildlife and people;
iii) reducing the heat island effect;
iv) reducing urban water pollution by incorporating sustainable drainage schemes and remediating contaminated land and
v) improving fish passage and in-stream and riparian habitats.

Delivering these benefits can have wider socio-economic consequences as restored urban water bodies create an attractive environment which encourages recreation, boost physical and mental health, encourage business investment and tourism and enhance property values. This contributes to green infrastructure, local biodiversity action plans, wellbeing and regeneration goals (Natural Scotland – Scottish Government (2015)). In addition, defining benefits more accurately (both direct and indirect benefits in terms of ecosystem services) often supports decision-making for restoration projects in cities.

Many restoration measures taken (e.g. reopening covered rivers, water quality improvements that enable bathing) have resulted in significant changes in the way citizens and visitors experience the blue elements of cities (rivers and lakes). Waterfront amenities are more and more highly appreciated and urban river and lake restorations can be a good way for improving accessibility to water.

The case studies reviewed in the Annex to this report provide evidence of how restoration of rivers and lakes in European cities can contribute to better quality of life and urban regeneration.

2.4 European policy impetus

In the European Union, a number of legislative and policy processes have provided further impetus to manage urban rivers and lakes in a more integrated way, by means of linking water quality improvements with ecosystem protection, climate change adaptation and recently with urban development.

The **Urban Wastewater Treatment Directive (UWWTD)** adopted already in 1991 aims at protecting the environment from the adverse effects of urban wastewater discharges and discharges from certain industrial sectors. Progress has been made in combating water pollution, especially in terms of wastewater effluents.

The **Nitrates Directive** also adopted in 1991 aims to prevent pollution of ground and surface waters from nitrates coming from agricultural sources. Although the Nitrates Directive is mainly relevant to agricultural activities outside urban areas, pollution from agricultural sources greatly impacts water quality in urban areas.

As public policies which exclusively focus on the fight against water pollution soon revealed their limitations, the EU adopted in 2000 the **Water Framework Directive (WFD).** This is the main piece of EU water legislation which reflects a turn from viewing water as a resource to viewing it as part of the environment. The WFD requires the achievement of good ecological and chemical status for all European surface waters including urban rivers and lakes. The 1st River Basin Management Plans implementing the WFD were adopted in 2009 and updated versions of these plans are to be drawn up on the basis of a 6-year cycle (2015, 2021). Despite improved water quality in cities, there is still room for improvement in the ecological status of their rivers and lakes. Many urban rivers are still encased in concrete structures, and along with degraded habitats make environmental objectives on the basis of the WFD challenging to achieve.

Due to changes to their physical structure, urban rivers and lakes are often defined as heavily modified water bodies (HMWB), according to Art. 4 (3) of the WFD, meaning that the important human uses which they serve (e.g. flood protection and transport) should not be undermined by measures taken to improve their status. In the same time, the WFD spells out minimum requirements for the restoration and ecological quality enhancement of HMWB, including those in an urban setting.

Examples of WFD acting as driver for restoration of urban water bodies

In several case studies reviewed for this report, the implementation of the WFD and its strong focus on restoring water bodies to achieve good status have acted as a key driver for urban restoration.

In Oslo, the WFD and its strong drive for restoring water bodies have added to the political will to allocate resources to a de-culverting strategy for urban streams. In particular, for the major streams, defined as water bodies according to the WFD, the de-culverting strategy is considered as a solid city contribution to ensuring good ecological and chemical status in river water bodies. The strategy is included as a measure in the WFD programme of measure for the water area of Oslo.

In Vienna, the projects of the City Administration for restoration of urban water bodies aim at reaching the goals of the WFD, following the national WFD implementation strategy. Restoration projects related to the urban River Liesing, River Wien and the Old Danube are designed to be in line with the WFD requirements and aim to improve "ecological potential".

In Stockholm, the trigger and initial driver for the city Water Programme and Action Plan for good water status has been the WFD and its strong focus upon achieving good ecological and chemical status.

The **Floods Directive** adopted in 2007 gives European countries a common framework to identify, evaluate and address flood risk. The Directive requires developing an integrated approach to managing flood risk using approaches based on the scale of the river basin and working more closely with nature. The 1st Flood Risk Management Plans focused on prevention, protection and preparedness were to be drawn up by 2015. For cities, the Floods Directive points to the development of urban areas which are resilient to changes that would otherwise cause an increasing likelihood of flooding.

The **Birds and the Habitats Directives** are also relevant to urban restoration as specific restoration measures may be taken to achieve biodiversity protection objectives in urban nature reserves including freshwater habitats.

The 2013 Commission **Communication on green infrastructure** (European Commission, 2013b) called upon planners to use natural measures or a combination of engineered structures and natural solutions more proactively to achieve the objectives of water and adaptation policy (see **EU Strategy on adaptation to climate change of 2013** (European Commission, 2013c)**)**. River restoration in and close to urban areas is particularly relevant to green infrastructures for reducing flood risk, especially in terms of floodplain restoration measures aiming to increase natural water retention.

Further, in 2015, the Commission published the "Towards an EU Research and Innovation" **policy agenda for Nature-Based Solutions & Re-Naturing Cities[1]**. This agenda has provided strong impetus for a strengthened research and innovation focus and deployment of many city water-related nature-based solutions such as de-culverting of previously piped

[1] https://ec.europa.eu/research/environment/index.cfm?pg=nbs

streams and the re-creation or restoration of small city lakes and ponds. These activities aim to serve a diversity of purposes of which climate adaptation is one important aspect.

Last but not least, an **Urban Agenda for the EU** is now in place as a joint effort of the European Commission, Member States and European Cities Networks to strengthen the recognition of the urban dimension by European and national policy actors. The European Urban Agenda recognises that to fully exploit the potential of urban areas the urban dimension should be stronger embedded within the EU policies. To this aim, a better working method, focused on cooperation between the EU, Member States and cities is needed. Part of this new approach includes the development of a range of European partnerships (Urban Agenda for the EU, Pact of Amsterdam, 2016).

At the time of writing this report, a draft **Urban Water Agenda 2030** was prepared by European cities which convened at the Cities & Water Conference (February 2016, Leeuwarden) to discuss urban priorities in relation to water. There is growing understanding among decision-makers in European cities and regions that water is as important for cities as energy or climate, and there are risks and opportunities related to water that will affect the economic development and prosperity of European cities in the future. The Urban Water Agenda 2030 calls for city leadership and coordination to address water challenges and exploit opportunities for smart and sustainable urban water management. The agenda identifies important water issues for cities, sets objectives for 2030 and proposes concrete actions to achieve these objectives around five core areas (Urban Water Agenda 2030):

- Water efficiency – to reduce water abstraction to the level of sustainable use and good ecological status of water bodies
- Energy and resource efficiency of urban water systems
- Water quality – to ensure the quality of water for urban use, prevent pollution of water by cities thereby reaching good ecological status of water bodies
- Sustainability of urban water infrastructure
- Flood prevention and nature based solutions

2.5 City visions and strategies for water

Upscaling the new perspective on the urban water environment to enhance results

The multiplicity of aspects in which urban planning and water come together shapes the evolution of the city and its surrounding areas. While this relationship has led to the deterioration and neglect of urban water bodies in the past, more recent examples from around Europe show that the adoption of new vantage points towards city planning has the capability of changing the dynamic. In many cases this change in perspective has either arisen from or been developed into a city’s strategic vision. This can allow local officials and city planners to identify synergies across sectors and increase the level of ambition of the measures being considered. Furthermore, such city visions can help optimize actions on short term goals while keeping mid- and long term objectives in focus.

Many European cities have developed broad visions and strategies to promote a more integrated management of their water bodies, especially in terms of restoration of their rivers and lakes. Such strategies provide a broad framework for carrying out a number of restoration projects over a longer planning period. There are also important links between restoration and local/city authority strategies for open space, green infrastructure or green networks. These strategies often require a proportion of open space in developments. If well designed, this open space can create green networks for morphological restoration, wildlife and people (Natural Scotland – Scottish Government, 2015). In this context, there are opportunities to give more priority to space for the river in urban areas.

Some examples of such city strategies are the London Rivers Action Plan, the river de-culverting strategy for the City of Oslo and the Stockholm City Water Programme(see the case studies in the Annex to this report).

London Rivers Action Plan

The London Rivers Action Plan was adopted in 2009 (Thames River Trust, 2016). The main aim of this Plan is to provide a forum for identifying stretches of river that can be brought back to life, by improving river channel or riparian habitats, by removing or modifying flood defence structures, or by reclaiming 'lost' rivers currently buried under the surface (LRAP Partnership, 2009). In 2011, the broader city strategy “Securing London’s Water Future” was adopted, which is the first water strategy for London to provide a complete picture of the city’s water needs. The strategy promotes increasing water efficiency and reducing water wastage to balance supply and demand for water, safeguard the environment and help tackle water affordability problems. It also sets out how London’s Mayor will help communities at risk of flooding to increase their resilience to flooding (Greater London Authority, 2011).

The restoration of the River Quaggy and the River Mayesbrook reviewed for this report are part of the London Rivers Action Plan.

A changing paradigm for the rivers and streams in Oslo

One of the key water management issues dealt with in the city of Oslo is the set of negative consequences caused by culverted streams passing through the city. The de-culverting strategy for the City of Oslo, *Water in the City*, addresses all the streams and rivers that originate in the surrounding forests and eventually cross through the city down to the Oslo Fjord. *Water in the City* became part of a more comprehensive Strategy for Urban Storm Water Management, whose objectives include meeting the challenges posed by climate change, enhancing water quality and using stormwater as a resource in cityscapes. Within this strategy, the de-culverting programme works as an inter-agency programme coordinated by the Agency for Water and Sewerage Works, but with involvement of three other city agencies. Focus is placed on the major streams, but the strategy also covers the smaller tributaries (Oslo Kommune, 2015). The stream de-culverting initiative is also linked to two major strategic city policy programs, namely the City Ecological Program approved by the City Council in 2009, and the new Municipal Master Plan 2015 - Oslo 2030 “Smart - safe and green” adopted in 2015.

Beyond developing action plans for restoring urban water bodies, several European cities (e.g. Copenhagen and Rotterdam) are developing a more water-centric overall urban design and are transiting towards a Blue-Green city model. This entails integrating water management with urban green space provision to garner the added value associated with the connection and interaction between the blue and green assets of a city (see table below).

Blue-Green Cities may be key to future resilience and sustainability of urban environments and processes (Blue-Green Cities Research Project, n.d.). They aim to recreate a naturally oriented water cycle while contributing to the amenity of the city by bringing water management and green infrastructure together.

Table 3. Blue and green assets and features in the urban realm

Urban Blue	Urban Green
Wastewater reuse and recycling Rain water harvesting and recycling Stormwater management as a new resource	Green Roofs Green parks, streets, squares, parking lots, etc. Living Walls Systems Urban Agriculture

Source: Based on Blue Green Dream, 2012.

There are also initiatives to establish so-called urban green and blue networks. The goal of urban green networks is to link natural habitats together, enabling animals and plants to move along ecological corridors connected to the city's surroundings. Urban blue networks, consisting of rivers, streams and other bodies of water in the city, can complete the green networks. The Brussels Capital Region, for instance, is strengthening the ecological corridor in the region through the development of such an urban green and blue network. To ensure a more even distribution of green nature areas and to strengthen the ecological corridor between these areas, a Regional Development Plan was drawn to gradually develop a green and blue network around Brussels. The green network connects the green areas as a ring around the urban area, and the blue network aims to improve the ecological conditions of the rivers and associated wetlands (Bruxelles Environnement – IBGE/Leefmilieu Brussel BIM, 2006). The Green and Blue Network programme was laid out in 1995 and taken up in the Brussels Regional Development Plan. New green spaces were created with “new” objectives for the urban area: preservation of natural vegetation, restoration of pond banks, recuperation of water and improvement of soil quality. Simultaneously, efforts have been made to reconnect green spaces by reopening formerly covered rivers (Chevalier, 2013).

What drives the move towards more integrated city strategies for water?

As the citizens' perception of urban rivers and lakes returns to one that acknowledges them as key historic elements of local identity and associates them with accessible refuge from the high pace of modern life in urban centres, the political narrative around urban water bodies is necessarily following course. The recognition of the multiple benefits that revitalising our urban water environments and reconnecting with them can bring to society has in numerous cases fuelled the political will necessary to transit from small scale, isolated actions to more integrated strategies based on long-term visions of better organized, more resilient cities. For instance, in the aforementioned case of Oslo, the political determination to back the city’s de-culverting strategy emerged as public and political awareness of the value of natural streams in the cityscape arose. This perception of value that was increasingly associated with the urban water ecosystems stemmed not only from recognizing that they could be used for recreational purposes, but, in the face of climate change, they also provided an increased sense of safety and resilience related to stormwater retention and cleansing capacity.

In addition to changes in local public and political awareness, policy and regulation at higher administrative scales can also be responsible for the transition towards more integrated urban development strategies, as outlined in the previous section in terms of European policy impetus (section 2.4). At the European level there is an explicit agreement on the principles upon which an ideal European city should be based as part of an EU Urban Agenda (Urban Agenda for the EU, Pact of Amsterdam, 2016). One of the characteristics put forward for the European city of tomorrow is to be “a place of green, ecological or environmental regeneration”. At EU level, it is also argued that urban territorial development should “enjoy a high level of environmental protection and quality in and around cities” (European Commission, 2011).

Finally, the environmental objectives and requirements set in place by pieces of legislation like the EU Water Framework Directive have locked in further support for integrated action, both in terms of funding and acceptability. In this specific case, the WFD’s aim for incorporating externalities by reconnecting the urban water cycle to the natural water cycle has a strong influence on policy- and decision-making at the local level. Furthermore, the Directive has provided a strategic frame that allows linking individual restoration efforts within River Basin Management Plans, facilitating communication and buy-in of stakeholders. The case of the Stockholm City Water Programme is a good portrayal of how the intrinsic relationship of a city with its water environment can converge with policy frameworks at higher scales to result in enduring commitment to water protection.

Stockholm City Water Programme and the Action Plan for good water status

In Stockholm, ‘the Venice of The North’, ten per cent of the city’s area is covered by water, and the many lakes are highly valued for recreational purposes. The city’s affinity and intrinsic aquatic character resonated with the EU Water Framework Directive and its strong focus upon achieving good ecological and chemical status, leading to the adoption in 2006 of an ambitious Water Protection Programme (2006 -2015) which set objectives for cleaner water and outlined methods to achieve this. The objective of improving water quality in the city was to be achieved in a way that preserved the recreational value of the lakes and streams. Until the end of the programme progress has been made both concerning water quality and increasing recreational value of many water bodies.

Ongoing political ambition to reinforce local efforts towards improved water quality led to the adoption in 2015 of an Action Plan for good water status as a follow up of the late Water Protection Programme (Stockholms stad, 2015). Within this new plan separate local programmes of measures (PoM) are planned for each water body.

The Stockholm City Water Programme and the Action Plan for good water status are considered good practice examples of what can be achieved if there is strong political will to allocate funding for a major and long term water improvement program benefiting both aquatic ecosystems and the urban population in enjoying the water bodies and their ecosystems.

Lastly, increased pressures on urban water ecosystems are expected to result from climate change and its interaction with socio-economic factors like geopolitics, economic trends, demographic change, further urbanisation and urban sprawl, among others (EEA, 2016a). This also calls for the preparation of appropriate water management strategies in the urban context to cope with impacts and increase resilience. Such strategies should take careful consideration of the state of the environment, society and the economy at the local level (Anthonj et al., 2014) to ensure their objectives can be efficiently achieved. Furthermore, the actions planned within these strategies should go beyond addressing the direct impacts of climate change to consider the broader knock-on effects that could follow (EEA, 2016a). A good example of a city strategy taking several of these factors carefully into account is the case of the Water Plan for Rotterdam.

A Water Plan for Rotterdam

Rotterdam is Europe's largest port and also a bustling city with a strong economy and an intrinsic water character. The connection with the rivers Maas, Schie and Rotte, and the multitude of canals and lakes gives Rotterdam its identity as a water city.

On the other hand, such a close and intertwined relationship with the water environment sets Rotterdam directly against the challenges of climate change, as are rising water levels, increased rainfall and increasing pressures on water quality. To confront these future challenges, Rotterdam has developed Waterplan 2 Rotterdam, a plan for a sustainable development towards 2030 based on an adaptive approach that aims for multiple objectives, among which the following can be highlighted: to cope with the increasing amounts of water that will be reaching the city and putting its infrastructure to the test, and to ensure the attractiveness of the city through carefully thought and versatile urban design. Waterplan 2 Rotterdam is understood as the framework to achieve the city's long-term vision, and a forum for consultation and discussion between the multiple actors that will allow for future ideas and solutions to emerge and develop (Municipality of Rotterdam et al. 2007).

3 Coping with key challenges for urban rivers and lakes

For the purpose of this report, the major challenges that urban rivers and lakes in European cities face are grouped into:

- Water availability and supply challenges
- Water quality issues
- Structural changes, related among others also to flood risk management.

For each of these major challenges, the following sections provide a brief review of the issues at stake, document the key approaches followed to deal with the issues and give case study illustrations.

3.1 Water availability and supply

3.1.1 Tapping water from rivers and lakes for European cities

Public water supply accounts for 32% of the total water use in Europe (EEA, 2016b). This is, roughly a third of the total freshwater abstracted in Europe is directed to households, small businesses, hotels, offices, hospitals, schools and some industries. Some of the main challenges faced by urban water supply include droughts, water scarcity, seasonal or geographical mismatches between water availability and water demand, and low efficiency of water distribution networks (including leakage). In some European countries these challenges have led to overexploitation and pollution of groundwater resources, as falls in the piezometric level of aquifers can give way to higher pollutant concentrations and salt water intrusion (the latter in coastal aquifers). This has subsequently resulted in the implementation of measures ranging from the softer – like awareness-raising campaigns – to the more drastic – like abstraction restrictions (De Paoli et al., 2016) and water transfers between different river basins.

To secure a reliable and safe water supply, cities have typically developed centralised systems to abstract, transfer and distribute water. Urban uses of water, including the necessary hydraulic interventions to secure a regular supply, are transforming considerably the natural ecosystems within and close to cities and are in competition with other water uses (e.g. recreation, irrigation etc). In turn, these other uses affect the availability of the resource for urban use by impacting on its quality (Kallis & Coccossis, 2001).

With growing populations and increasing demand for water, Europe's larger cities have generally relied on the surrounding regions for drinking water supply, mostly supplied by groundwater but sometimes by surface waters. For example, Athens, Istanbul and Paris are all cities which have developed wide networks for transporting water, often over more than 100-200 km, to their water-hungry densely-populated cities. Even in Germany, which is a relatively water-rich country, water is being transported over long distances to supply urban centres. This is the case for the city of Stuttgart which receives its drinking water from Lake Constance, located at a distance of 160 km.

Athens tapping water from 150 km away

Athens is located on the Attica peninsula in the central-southern part of Greece. Most of Attica's water resources are not available for potable use. Surface sources are buried under concrete and groundwater aquifers are polluted (under the city) or salinised (those on the coast).

To obtain its water supply, Athens has resorted to a number of surface hydraulic works and transfers. The main water source for the city is the artificial reservoir at the Mornos river (built in 1980) which is supplemented by a regulating reservoir at the Evinos river (2002). The older branch of the hydrosystem consists of the pumping station drawing at Lake Yliki (installed in 1958) and a number of boreholes in its vicinity and along the conveyance aqueduct. The first artificial reservoir for the city, the Marathon reservoir (built in 1928), now serves for storage and regulation of network supply (Kallis & Coccossis, 2002).

The rivers and lakes from which water is extracted to supply Athens are situated at fairly long distances. The Marathon Reservoir lies approximately 42 km away from the centre of Athens, while the Mornos Reservoir (main current water supply source) is at 150 km northwest of the city.

There are also other European cities that depend on lake surface waters for their drinking water supply such as the city of Tallinn. The city of Tallinn uses Lake Ülemiste as its main drinking water reservoir and has been applying several measures to protect and improve water quality in the lake.

Securing the supply of drinking water for Tallinn

Lake Ülemiste is a shallow eutrophic lake which has been the main reservoir of drinking water for Tallinn since the 14th century. The water level is controlled by a Water Treatment Plant which supplies over 90% of the inhabitants of Tallinn with drinking water (the rest of the population is supplied from bore wells (Tallinn Environmental Strategy to 2030). The catchment area of the lake has been enlarged from 70 km² to 1865 km² and a complex interlinkage of reservoirs and canals has been built on the Pirita, Jägala and Soodla rivers in order to direct water into the lake (Panksep et al. 2009).

Lake Ülemiste is affected by water quality problems, the main of which include its high phytoplankton biomass, which results in costly treatment for human consumption, an accumulation of thick sediment at the bottom of the lake that can release particulate matter during windy periods; and contamination from the city’s airport which is located on the eastern shore of the lake.

The main measures taken so far by the city to protect Tallinn’s drinking water reservoir and improve water quality have included:

- The renewal and expansion of a sanitary protection zone of Lake Ülemiste, completed in 2009. Considering the importance of the surface water intake of the lake as a source of drinking water, expanding the sanitary protection zone by more than was required under the Water Act (i.e. 90 metres) was deemed as necessary. The sanitary protection zone covers Lake Ülemiste, its water intake facilities, its shore protection facilities and the close surroundings of the lake, which must be preserved in their natural status and where the movement of people must be restricted. The sanitary protection zone is surrounded with a fence and is not in public use.
- The reconstruction and extension of the shore protection dam of Lake Ülemiste, completed between 2011 and 2012. Its goal was to increase the adjustable volume of the shallow lake, reduce the eutrophication of the water, stop the shore erosion caused by waves and guarantee a service path for the management and inspection of the lake.
- A biomanipulation project in order to control phytoplankton biomass and therefore improve the water quality in the lake (see detailed description in section 3.2.2).

3.1.2 Towards a more sustainable water supply in cities

Considering that water around large cities is often polluted and cannot be used as potable water, a number of factors should be taken into account when seeking to reduce the vulnerability of large cities to water stress. These factors may include growing urban populations, improving lifestyles, reduced water availability due to climate change and the introduction of drinking water quality standards (EEA 2010).

The design of urban water supply infrastructure rests on a dominant engineering and supply-led approach in managing water dating back to the first stage of urban development and industrialisation. This is now considered outdated in an era of regional and global inter-dependence, technological development, economic restructuring and unprecedented flow of people, goods and resources (Kallis & Coccossis, 2001).

While centralized water systems have, in general, ensured adequate water supply, sanitation and drainage services in cities around the world (Sitzenfrei et al., 2013), several factors such as climate change, increasing water supply and consumption, as well as ageing water and wastewater infrastructures increasingly pose maintenance challenges to the cities.

To prevent urban water crises, water resources should be managed effectively at every stage: from the supply of clean water to its different uses by the consumers. This could involve reducing consumption (e.g. by means of technological improvements, water pricing schemes and non-pricing approaches to manage water demand) as well as finding new ways of collecting and using water (e.g. re-using rain and grey water) and reuse treated wastewater. Water management should also be better integrated within wider urban management while taking into account characteristics of the local environment (EEA, 2012c).

For instance, only a minor fraction of the high quality potable water provided by the centralized systems is currently used for potable purpose and most of the potable water is used for applications with low water quality requirements such as toilet flushing and garden irrigation. Under such conditions, the centralized water service model with the bulk transfer of freshwater and the bulk disposal of wastewater is not always the most sustainable solution for urban development (van Roon 2007). Decentralized water management is a concept in which water is managed, collected, treated and disposed/reused near or at the point of generation (Crites and Tchobanoglous 1998). Decentralized systems are increasingly considered to be implemented for two purposes; (1) to reduce flows to centralized wastewater treatment systems and (2) to provide opportunities for the wastewater reuse and recycling at the local level (Diaper et al., 2007).

One of the non-technological, non-pricing measures to manage water demand in large cities are awareness-raising campaigns. This approach has been used in Europe as a prevention measure as well as an emergency measure in the context of severe drought (e.g. during the severe drought that hit Barcelona in 2007-2008 (Martin-Orega and Markandya, 2009)). Given that this type of measures commonly aim at influencing household behaviour, their actual effectiveness is difficult to assess. Nonetheless, there have been interesting cases where the measures implemented could be directly associated to large scale shifts in water demand. Furthermore, when used in combination with other water demand measures, the overall effect can be stronger. For example, accompanying the promotion of water-saving technologies with educational campaigns that highlight their functionality and the appropriate way to use them can enhance the effect of the former (Cominola et al., 2015). The case of the project *Zaragoza: Water Saving City* is one that has resonated throughout Europe, evidencing the potential of a carefully structured awareness-raising campaign with clearly defined, concrete targets.

Zaragoza: Water Saving City

The awareness-raising campaign in Zaragoza, which started in 1997 and developed into a wider water-saving programme in later years, is directly associated with a 5.6% reduction in the city's annual water consumption solely in 1998. This is, a total of 1,176 million litres of water were saved during the project's second year (Saurí and Cantó, 2008). The campaign was also successful in promoting significant increases in local sales of domestic appliances with built-in water savers, water-saving taps and individual water meters (EC, n.d.). Within the first 15 years after the start of the project, Zaragoza reduced its water consumption level by roughly 30% (CLIMATE-ADAPT, 2014). Some of the factors quoted as being key to the success of the campaign include the ability of the project leaders to align efforts by linking the issue they were addressing with other related topics; the identification and exploitation of opportunities to push their agenda forward; and gathering broad support from a wide set of local actors (Rouillard, Vidaurre et al., 2015).

3.2 Water quality

3.2.1 Main issues

Until the end of the 19th century, water quality in rivers and lakes was generally satisfactory in most parts of Europe. Gradual deterioration was experienced around 1900 with the industrial revolution, the concentration of inhabitants in cities and the development of industrial production. Great volumes of sewage and industrial wastewater were discharged into rivers and lakes from towns and the self-purifying processes of recipient water bodies were not sufficient to assimilate the pollution impacts. In the decades to come, the volumes of sewage drained into rivers and lakes without any treatment were rising as a result of the increasing percentage of inhabitants living in houses connected to sewerage. At the same time, industrial water pollution was also increasing as the construction of industrial plants was not accompanied by the construction of wastewater treatment plants.

By the 1970s, some European rivers such as the Thames in London were declared biologically dead due to the disposal of untreated effluents, industrial chemicals and low oxygen levels. Also in southern Europe, uncontrolled water pollution severely impacted the quality of urban rivers such as the Tiber in Rome and the Lambro in the Milan metropolitan area.

River pollution in the metropolitan area of Milan

The River Lambro drains a very densely populated and heavily industrialized zone, including a significant portion of the Milan metropolitan area with a population of more than three million. Before the construction of a treatment plant in 2002, almost all of the sewage from the city of Milan, as well as industrial sewages flowed untreated into the river. The Lambro is considered to be one of the most polluted rivers in Italy: its basin was declared at high environmental risk area in 1987. Many fish species which used to live in the river have, as a result, disappeared, including for example the bleak (*Alburnus alburnas*), the eel (*Anguilla anguilla*), and the European perch (*Perca fluviatilis*). The situation was even worse after an environmental disaster in 2010, when a huge quantity of oil was criminally dumped into the river, causing unprecedented damage to fauna in particular (Salvini, 2011).

After periods of heavy rain, water quality degradation in urban rivers and lakes can also rise significantly due to overflows from the sewage network. In many European cities, the sewer systems are designed to receive both foul sewage and surface water following rainfall. These so-called combined sewer overflows (CSOs) are there to prevent overloading of sewers and wastewater treatment plants. After heavy rain a mixture of surface water and sewage can be discharged to the water environment via the CSOs. Discharges from CSOs may impact on water quality, including hygienic elements such as pathogens and viruses that influence bathing waters and in turn affect human health. For this reason, there are frequent public warnings to avoid bathing in urban rivers, lakes and coastal waters after heavy rain. There is need to properly protect CSOs by upstream measures (e.g. nature-based retention basins) and manage them to prevent flooding and minimise adverse impacts on the environment and public health.

Across the EU, a diverse set of data is available on stormwater overflows. Although several EU Member States have an advanced understanding on stormwater overflows, a comprehensive overview of overflows at Member State (or regional) level is still not available for a large number of countries (Cools et al,. 2016).

Another persistent problem of concern to citizens is chemical pollution of river and lake sediments in cities. For instance, the constant need for dredging sediment in the River Elbe and the harbour of Hamburg to allow inland water transport has, next to concerns about the impact of the hydrological changes to the ecosystem, faced the city authorities with the problem of how to dispose of polluted sediments (Leal et al., 2006). Another example is sediment pollution of Lake Rummelsburg, an oxbow lake of the river Spree, in a densely populated area of Berlin. The high contamination of the lake sediments with chemicals due to industrial activity on the river banks in the early 20th century is made responsible for the low biological diversity of the lake. Nowadays, the area around the lake progressively develops to a residential area and is popular for local recreation use. Recent remediation measures by the city authorities, such as partial sludge removal, have not improved the ecological situation significantly so far (Dumm et al., 2015; Reifferscheid et al., 2013). The city of Stockholm is also taking measures to deal with sediment pollution in its lakes, e.g. of Lake Trekanten which is a popular recreational spot close to central Stockholm.

Treatment of polluted sediments in Lake Trekanten, Stockholm

Lake Trekanten (Lake Triangle) is a small but important recreational lake (13,5 ha) located in a very densely populated area close to central Stockholm. Although suffering from eutrophication and pollution with heavy metals and hazardous substances, the lake is extensively used for swimming and fishing by local residents. Fish restocking with rainbow trout is done regularly and crayfishing is a popular activity. A large number of measures have been implemented as a response to the water quality problems of the lake. Several measures have been analytical in character, some have focused on monitoring to support analyses, while some measures have been of remedial character such as the aluminum treatment of sediments to bind phosphorous and the implementation of a solution for the treatment of stormwater emanating from the major highway.

Photo: @ Juha Salonsaari, Stockholm Municipality

3.2.2 Response of cities to water quality degradation

In 2011/2012, only 14 of the 28 capitals[2] of EU Member States could be considered to be in full compliance with the EU Urban Wastewater Treatment Directive (UWWTD): Vienna, Copenhagen, Tallin, Helsinki, Paris, Berlin, Athens, Budapest, Vilnius, Amsterdam, Lisbon, Madrid, Stockholm and London. A large number of European capitals are still not fully compliant with the requirements of the UWWTD: Brussels, Sofia, Nicosia, Prague, Dublin, Rome, Riga, Luxembourg, La Valetta, Bucharest, Bratislava and Ljubljana (European Commission, 2016).

Nevertheless, looking back to the past 25 years, clear progress has been made in reducing emissions into urban rivers and lakes due to connections to sewers, the introduction of wastewater treatment and the upgrading of earlier treatment plants. Implementation of the UWWTD, together with national legislation, has led to improvements in wastewater treatment across much of the European continent (EEA 2012a). For instance, Brussels' River Zenne, has been notorious for being one of Belgium's most polluted rivers. All effluents from the Brussels Capital Region were discharged into the Zenne without treatment until 2007, when the completion of new sewage treatment plants began to remediate this problem (Zenne, n.d.).

In some cities of Eastern Europe, the recent construction and operation of wastewater treatment plants has achieved reduced emissions and water quality improvements, linked to

[2] This assessment did not include Zagreb (still without compliance obligations) and Warsaw (not possible to be assessed due to lack of data).

the implementation of the UWWTD during and after their accession to the EU (see the example of Bucharest below).

In other parts of eastern and southern Europe, still much progress needs to be made. For instance, in Serbia only 16% of the population is connected to wastewater treatment plants and the largest cities, including Belgrade, Niš and Novi Sad release their wastewater untreated into the passing rivers (Vujovic´ & Kolakovic´, 2015), the Danube and the Nišava (Sava river).

Wastewater treatment in Bucharest

Bucharest is situated on the banks of the Dâmbovița River, which flows into the Argeș River, a tributary of the Danube. Bucharest is supplied with water by three drinking water plants, located outside the city perimeter. The Argeș river is the main source of raw water for two of the drinking water plants, while the Dambovita river supplies the third water plant.

Until 2011, Bucharest discharged wastewater from more than 2 million inhabitants without treatment into the river. These wastewaters (from both domestic and industrial use) had seriously deteriorated both the Dâmbovita and Arges Rivers and made Bucharest the largest polluter of the Danube in the region. The construction of a wastewater treatment plant in Bucharest began in 1985 but was abandoned in 1996 because of lack of funds. By 2000, the need for an operational wastewater treatment plant became increasingly obvious. Furthermore, Romania declared its whole territory a sensitive area according to the Urban Wastewater Treatment Directive, which requires all agglomerations of more than 10,000 population equivalents to have wastewater treatment plants with the highest degree of treatment, the removal of nitrogen and phosphorus.

In 2011, a wastewater treatment plant, Glina WWTP, started to operate in Bucharest and it will be further developed until 2017. After its completion, the plant will ensure the treatment of the entire wastewater flow of the Bucharest urban area and will discharge an effluent which will meet the requirements of national and European legislation, thus eliminating one of the major pollution hotspots in the Danube River basin (http://www.icpdr.org/main/publications/hotspot-no-more-wastewater-treatment-plant-bucharest).

The operation of the wastewater treatment plant can significantly reduce the impact of Bucharest's urban wastewater on surface water resources. Since the operation of the plant started in 2011, the total pollution removal from the wastewater by the treatment plant has steadily increasedfrom 242 t/day to 340 t/day (Apa Nova Bucureşti S.A., see factsheet in Annex to this report). Since 2014, the total pollution removal is even higher than the design level of the Glina WWTP.

According to the WFD compliant monitoring results at the level of water bodies located on the Dambovita River (downstream of the Glina WWTP discharge) and on the Arges River (the last water body before discharging into the Danube River), the concentrations of organic and nutrient pollution indicators have significantly decreased in the last 5 years, leading to improvement of river water quality. It should be highlighted that in the receiving Dambovita water bodies, approximately 50 % reduction in the concentrations of organic substances (COD and BOD) have been registered, while total nitrogen and total phosphorous concentrations have decreased by approximately 30% and 60% respectively (Source: National Administration ”Romanian Waters”).

The project has also contributed to increasing public’s awareness of the pollution effects of wastewater and the responsibility to protect river ecosystems.

A special restoration tool used to combat eutrophication in lakes with high nutrient concentration is biomanipulation. It is often used as a means additional to efforts to reduce external nutrient loading via improved wastewater treatment or diversion of nutrient-rich inflows. A biomanipulation project has, for example, been implemented for the Lake Ülemiste, which is the main source of drinking water of Tallinn, Estonia.

Biomanipulation in Lake Ülemiste, Tallinn

A biomanipulation project was one of the main measures taken to protect Tallinn’s drinking water reservoir (Lake Ülemiste) and improve water quality. The aim of the project was to increase the abundance and size of herbivorous zooplankton in order to control phytoplankton biomass and therefore improve the water quality in the lake. Improved water quality helps to reduce the chemical and energy costs of treatment caused by high phytoplankton biomass in the water (Panksep et al. 2009; Panksep, 2009).

Improvements in the water quality of urban rivers and lakes due to reduced emissions and wastewater improvement have brought about benefits to river and lake ecology. In many European capitals, the flagship species salmon has returned to their rivers. In Paris, the wild salmon returned to the Seine after an absence of nearly a century. Salmon is not the only fish in the Seine making a comeback. The number of fish species in the Seine has increased significantly since 1995 due to the improvement of water quality made possible by a new water purification plant (The Telegraph, 2009). In London, there has been significant improvement in water quality in the last 40 years and more than 100 species of fish have been found in the Thames Estuary in recent years, many of them within the city of London (McCarthy, 2010). Other examples include the return of the salmon to the once heavily polluted River Tolka in Dublin after an absence of 100 years as well as to the rivers of Oslo (see box below). In Sweden, it has been made possible to resume the recreational salmon fishery in downtown Stockholm, where salmon fishing had to be stopped in the 1960s as fish had become inedible due to heavy pollution.

Return of the salmon to the rivers of Oslo

Most rivers and streams in the city of Oslo have had a long history of poor water quality until the early 1980s. This was reflected in low benthic diversity and the absence of fish. At the end of the 1970s, considerable efforts were made to limit industrial discharges, pollution episodes, and urban runoff, resulting in a substantial improvement in water quality. This improvement in water quality resulted in major changes to the benthic fauna and fish populations of the rivers, especially the River Akerselva, which runs through the city centre. The Atlantic salmon, which became extinct in Oslo in the mid-1800s, returned to the Akerselva in 1983. Atlantic salmon and sea trout now spawn in the lower reaches of the River Akerselva, and the river supports juvenile populations of these salmonids (Saltveit, 2013).

Jumping salmon in the River Akerselva, city of Oslo (Photo: @Dan P. Neegaard)

Many cities across Europe have also been taking specific measures to reduce wastewater discharges from combined sewer overflows after heavy rainfall. In the city of Copenhagen, the improvement of water quality from similar measures has even enabled recreational bathing in its harbour.

Copenhagen: From sewer to harbour bath

In Copenhagen, Denmark, many years of investments in the sewerage system have revitalised the harbour. For decades, the discharge of wastewater from sewers and industrial companies had a major impact on the water quality in the city harbour. The water was heavily polluted. In 1995, 93 overflow channels fed wastewater into the Copenhagen harbour and the adjacent coastlines. Since then, the municipality has built rainwater reservoirs and reservoir conduits, which can store wastewater until there is space again in the sewage system. This has resulted in the closing of 55 overflow channels. Today, wastewater is only discharged into the harbour during very heavy rainfall (http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/water/copenhagen-from-sewer-to-harbour-bath/).

Municipal investments in modernising the sewerage system and expanding the city's wastewater treatment plants have revitalised the harbour of Copenhagen. In 2002, the first public harbour bath opened and today there are four harbour baths. An established on-line warning system calculates and monitors the water quality in the harbour (http://www.dhigroup.com/upload/publications/scribd/105175057-Copenhagen-Harbour-Bath-DHI-Case-Story-DK.pdf). If the water quality is poor, the swimming facilities are immediately closed.

In the city of Aarhus, Denmark, in order to reduce discharges from combined sewer overflows, new rainwater retention basins were created and an integrated real time control system set up to allow for coordinated operation of the sewer systems and wastewater treatment plants. These actions are part of a large urban restoration project, including uncovering the River Aarhus to reconnect it to the city landscape. Similarly, in the city of Lódz, Poland, measures to counteract stormwater overflows and quality degradation in the urban stream Sokołówka have been combined with a restoration programme for the river and its valley. In London, the Lee Tunnel has been constructed to capture and prevent 16 million tonnes of sewage mixed with rainwater from overflowing into the River Lee each year. The tunnel is the deepest ever constructed under London and forms a key part of the biggest expansion of London's sewerage network since the 1860s (Thames Water, 2016).

Aarhus - Rainwater management against combined sewerage overflow events

The River Aarhus serves as a natural structure connecting the centre of Aarhus, Denmark's second largest city, with the port. To respond to the severe pollution of the river and to promote infrastructure development, the River Aarhus was converted into a covered concrete channel in the 1930s. In 2010, still about half of the water in the river consisted of treated wastewater and around 55 combined sewage overflow (CSO) systems discharged into the river (Basso, 2010).

The city authorities have implemented a series of measures to uncover the river, with the purpose to enhance the aesthetics of the city, to promote recreation, to enhance climate adaptation and flood protection and to reduce the frequency of sewage overflows during extreme rainfall events. These measures included the establishment of two upstream lakes to reduce nitrogen and phosphorus flows into the Bay of Aarhus, the construction of new rainwater retention basins and the implementation of an integrated real time control system to allow for coordinated operation of the sewer systems and wastewater treatment plants. Additionally, a water quality early warning system was installed in Lake Brabrand, River Aarhus and the harbor (Stahl Olafsson et al. 2015). So far, these measures have resulted in a significant change in the way citizens and visitors experience the river, which now forms a blue corridor lined with new waterfront amenities and the harbour where bathing has now become safe (Hvilsoj & Klee, 2013; Aarhus Municipality, 2008).

Łódź: Stormwater retention and ecological quality improvement

The River Sokołówka is a small, urban stream running through the northern part of the city of Łódź, the third largest city in Poland. The catchment spans urban, as well as agricultural and natural areas. In the early 1930s, the upper reaches of the river were straightened, deepened and partially canalized. The main channel of the urban stream was converted into a collector for 50 stormwater outlets. These developments resulted in adverse effects on the urban and surrounding ecosystems, and the Sokołówka and adjacent rivers were polluted with discharge from combined sewage and stormwater overflows several times per year.

Most of Łódź rivers work as a part of a combined sewerage system of the city. During heavy rains, rivers intercept waters from overflows and rain water. Shortage of stormwater retention reservoirs is one of the reasons for pollution of the biggest river of the city, the River Ner, which receives combined sewage from the entire city.

The repeating problems related to pollution, overflows and ecological degradation made the city look for possibilities of stormwater retention, and for improving the ecological quality of the rivers, thus creating friendlier and healthier public space.

The city of Łódź has implemented a comprehensive urban development programme on water and river restoration, part of which has been the restoration of the River Sokołówka . For the River Sokołówka, a sequential stormwater sedimentation-biofiltration system was implemented, which prevents the influx of pollutants into the river during high flows (Zalewski et al. 2012). Five retention reservoirs were constructed in order to increase river retention and pollution absorption capacity. These measures went hand in hand with development plans for a further rehabilitation of the river valley (Wagner and Breil, 2013).

As a result of the measures taken, the river and its valley have turned into an attractive residential and recreational area which has contributed to the positive economic development in the wider area (Wagner et al. 2007). The creation of new green areas as part of the restoration activities has had positive influence on the quality of the inhabitants' life and their health.The restoration of the Sokołówka River has been used as a demonstration case to gather experience that can then be used for further replication on other streams and rivers crossing the city. The demonstration projects implemented by the city of Łódź have played an important role in creating visibility, interest and cooperation, and as such have been vital in the scaling-up strategy of the project.

Zgierska pond in the urban catchment of the Sokolowka River after restoration. (Photo: ©Anita Waack-Zając)

3.3 Structural changes

3.3.1 Key impacts of physical modifications

On top of increasing demand for water and increased water pollution, rapid urbanisation and industrial growth have introduced additional types of stress to urban rivers, in the form of modifications to their morphology and hydrology.

In the last 150 years, riverside areas have been subject to structural changes such as channelization and straightening. These have taken space away from the river to serve flood protection and the creation of living space for growing towns. As a consequence they led to the deterioration of water quality and loss of recreation and amenity uses.

In many towns and cities, rivers and streams have been covered with concrete and rerouted into sewers, drains and culverts as urban areas have grown. In some European capitals, several man-made canals were added to the river network, for example in Berlin whose landscape is shaped by several important canals (Teltow, Landwehr, Berlin-Spandau shipping canal, and Hohenzollern canal).

Due to physical modifications, urban river spaces suffer from a lack of several functions, as illustrated in the table below.

Table 4 Impacts of physical modifications on functions of urban rivers

Functions of urban river spaces	Impacts of physical modifications
Ecological functions	Lack of habitat and biotope network function Lack of permeability/passability Lack of retention areas Pollution and contamination
Social functions	Lack of accessibility of rivers and streams Lack of attractive open spaces next to water Inadequate perception of rivers by the public
Spatial functions	Separation of urban spaces and rivers due to technical infrastructure Neglected areas along rivers

Based on Bender et al. (2012)

Lakes within cities have also been physically modified as their natural shores were replaced by concrete structures and/or their hydrology modified to serve human uses.

The next sections describe the responses of cities and towns to impacts of physical modifications on their rivers, streams and lakes in recent decades. This report distinguishes between activities that aim at a) hydromorphological restoration mainly of rivers and streams of medium/small size, b) activities of de-culverting covered streams and rivers and c) restoration of urban water bodies with strong links to flood risk management. In practice, all these types of activities are strongly interconnected and often take place simultaneously in the context of the same restoration scheme.

3.3.2 Hydromorphological restoration of urban rivers and lakes

Since the 1980s, in several parts of mainly western and northern Europe, an increasing number of river restoration projects has been developed and realised in urban areas. Many of these have been based on the insight that attention to ecological aspects of river maintenance can enhance the creation of attractive open spaces and the establishment of a more natural landscape. A multitude of benefits related to urban river restoration has been recognised especially:

- Leisure and recreation for residents, nature experience for individuals, enhancement of city aesthetics;
- Flood control and protection;
- Climate change adaptation, e.g. related to retention areas which give room to the river and measures addressing impacts such as urban heat islands or stormwater; and
- Freshwater ecology and cross-linking of habitats, creation of retreat areas for endangered species, enhancement of biodiversity.

Since the adoption of the WFD in 2000, urban river restoration is partly driven by the goal to reach good ecological status or potential also for physically modified stretches of rivers in urban areas.

Especially in densely populated and industrialised areas, restoration of urban rivers contributes to a high quality of the environment as well as to a high quality of life. Urban rivers are often the only functioning or potential reservoirs of biodiversity and open spaces in cities. Thus, the active protection and restoration of such areas is part of the repertoire of fundamental practices for shaping cities' spatial order and sustainable development (Bender et al., 2012).

Much of urban river restoration concentrates on small rivers and streams, which are often developed in the context of broader city strategies on restoration. The small River Mayesbrook in London, for instance, has become a flagship urban restoration project as part of the London Rivers Action Plan. After restoration (of riverside wetlands, woodland planting, the creation of new meandering channels and the improvements of the river banks), the River Mayesbrook reached good ecological status according to the WFD. The restoration of the stream Igelbäcken in Stockholm has greatly improved habitat characteristics for the rare fish species stone loach, which also plays a strong communicative role for stimulating restoration actions in the Swedish context.

Mayesbrook, London: Enhancement of community space and natural landscape through stream restoration

The restoration of the Mayesbrook Park in east London is a flagship project for the London Rivers Action Plan published in 2009, the first ever plan for restoring all of London's rivers (see section 2.5). Before its restoration, run down sports facilities, two polluted artificial lakes and a straightened, realigned and fenced river sunk into a deep concrete channel made up the landscape at the Mayesbrook Park (Natural England, 2013). The Mayes Brook was characterised in the Thames River Basin Management Plan 2009-2015 as one of the worst water bodies in the area, failing to achieve Good Ecological Potential due to hydromorphological modifications, poor water quality and low ecology (Thames River Trust, 2015). The main driver for the restoration project on the River Mayesbrook in London was the identified need for revitalisation of the park where the river is located, as well as water quality improvements. The restoration of the Mayes Brook and Mayesbrook Park lakes in London was also identified as a measure to improve hydromorphology and water quality in the first River Basin Management Plan for the Thames River Basin District.

The main aim of the restoration measures implemented was to enhance the community space and achieve a more natural landscape that, at the same time, could become a model for climate change adaptation in a city environment (Greater London Authority, n.d.). The river restoration measures implemented included the creation of a new floodplain (1.5 ha), riverside wetlands, woodland planting, the creation of new sinuous water channels and the re-grading of river banks.

After restoration, the river is showing rapid morphological recovery and improved ecological resilience, helping the water body progress towards Good Ecological Potential.

In addition to the ecological benefits, the restoration of the River Mayesbrook in London has provided many additional benefits such as health benefits, and improvement in the quality of life and wellbeing of the local inhabitants, improved safety through greater park usage, socio-economic benefits to local sports clubs as well as an educational resource for the local schools. An assessment of the ecosystem services provided by the restored Mayesbrook published estimated a substantial lifetime benefit-to-cost ratio of £7 of benefits for every £1 of investment (Everard et al., 2011). The study highlighted the social and health aspects improving the quality of life and wellbeing of local communities as the more important benefits of the intervention.

Photo: @xxx

The Igelbäcken stream in Stockholm: Important for ecology and recreation

The Igelbäcken is, in a city context, a relatively undisturbed stream. It is considered one of Stockholm's most ecologically valuable rivers and provides access to nature and recreation for a huge number of inhabitants in the northwestern parts of Stockholm.

The stream has a unique population of the (for Sweden) rare fish species stone loach, which has become an iconic indicator species of the stream and is widely used communicatively for stimulating restoration and other environmental measures. Previously implanted signal crayfish is believed to impair the preconditions for stone loach. Fishing is prohibited in the stream. Restoration efforts in River Igelbäcken have included re-meandering parts of its stretches and adding bottom substrates such as gravel and stone. The purpose of these measures was to increase the turbulence in the water and achieve better oxygenation. Trees and shrubs has been planted along the river to increase shadowing and lower water temperature during hot summer periods In 2006, the City of Stockholm established the Igelbäcken Nature Reserve. The nearby municipalities of Solna and Sundbyberg have formed reserves for their parts of Igelbäcken valley. Within the inter-municipal Igelbäck

Group collaboration between municipalities, the County Administrative Board and several NGOs has been conducted over 15 years.

Stone loach. Photo:@xxx

Some urban restoration projects target the recovery of floodplain ecosystems from historical river regulation and drainage. Such an example comes from the city of Leipzig in Germany where ongoing restoration efforts on the urban River Luppe aim to improve the floodplain dynamics, increase the quality of habitats for plants and animals and to maintain and increase ecosystem functions and services for people.

Leipzig: Revitalization of an urban floodplain forest

The city of Leipzig is situated between the floodplains of the rivers White Elster, Pleiße and Parthe, which form a green belt classified as a significant Central European floodplain ecosystem resulting from widespread floodplain forests. Interventions such as river regulation measures, extensive diking and the drainage of agricultural and pasture fields have had significant impacts on the floodplain. Furthermore, the creation of the river section Neue Luppe (New Luppe) to serve flood protection in the 1930s also resulted in several impacts. Former river sections were cut off and could not provide the floodplain forest with water anymore. As a result, the formerly water-rich floodplain landscape now suffers from massive drop of the groundwater table and is drying out. Today the area consists of many dry river beds without connectivity and a decrease of dynamic floodplain ponds and oxbow lakes. This is a threat among others also to the biodiversity of the floodplain forest and related ecosystem services. At the same time, the floodplain of Leipzig has an important function as recreational area and significantly contributes to quality of life of the city residents.

The restoration project “Lebendige Luppe” (Living Luppe) is one of the largest projects on floodplain and river restoration in Central Germany and it started in 2012. The objective is the revitalization of more than 16 km of a former river course in the floodplain ecosystems. Dried-up river arms of the former water-rich floodplain, especially of the river Luppe, are to be filled and reconnected again with water and create a continuous water landscape. The aim is for significant floods to reach large areas of the floodplain via the new river course. It is planned to achieve inundation of at least 30% of the floodplain area via the new river. The groundwater table should be stabilised and raised by about 1 meter in most parts of the project area. The project is considered part of a mosaic of different measures needed to achieve more extended revitalisation of the floodplain in the future and is planned as a no-regret measure.

Major flood events in January 2011 and in June 2013 inundated most of the project area and showed that, as a result of the project Lebendige Luppe, the floodplain is fulfilling its function of protecting the city against inundation.

The idea for the restoration of the River Luppe and the revitalisation of the floodplain was based on preparatory work of the Green Ring Leipzig, an initiative of Leipzig and the neighbouring municipalities for a number of projects to enhance the environmental character of the city.

Lebendige Luppe – Heuwegluppe at inundated state. Photo: @Maria Vitzthum

Despite the potential benefits of hydromorphological restoration both in ecological and recreational terms, restoration of urban rivers and streams is not always feasible or desirable to the extent of similar restoration activities in rural areas. Flood risk protection of densely populated areas in downtown parts of cities remains a priority and is, in the same time, a barrier to extensive restoration projects. Due to such limitations, the administration of the city of Vienna follows a stepping stone approach to improve the hydromorphology of rivers. According to this approach, restoration has started from the outskirts of the city and moves into the city step by step, as the urban sections of the rivers are more difficult to restore.

Vienna: A stepping stone approach to river restoration

Vienna, Austria, is crossed by three main rivers (Danube, Wien and Liesing) which were heavily modified in the 19th century to protect the city against floods. As a result of the changes in hydromorphology, problems with eutrophication arose. Most of the water bodies in Vienna are heavily modified water bodies, so the environmental objective according to the WFD is to achieve good ecological potential in most cases.

In recent years the Vienna city administration has started to execute a series of projects on all three rivers, with the goal to achieve good "ecological potential" of urban water bodies, to reduce eutrophication and to enable migration for fish and benthic invertebrates, by removing migration barriers where possible. Measures executed were targeted at restoring the riverbed and semi-natural riverbanks, re-introducing meanders, replacing bed drops with bed sills so as to remove migration barriers and enhancing wastewater treatment. In improving the hydromorphology of rivers, the administration has started activities from the outskirts of the city and moves into the city step by step, bearing in mind that the urban sections of the rivers are more difficult to restore partly due to the lack of space in the urban area. For the urban stretches, master plans are developed in each case for the entire stretch, starting the implementation with the River Liesing (2015-2021) and continuing with the River Wien in the next WFD period (2021-2027). The restoration is foreseen to continue until 2027.

River Liesing before (left) and after (right) restoration. Photo:@MA45 Webel.

3.3.3 Uncovering Europe's hidden rivers

Urban rivers are frequently culverted and diverted to enable urban development. The extent of historically covered (or culverted) rivers in some European cities is considerable. For example, there is an entire network of rivers culverted under central London (Barton 1992), many of which were once noted for their rich fisheries (Walton 1653). Other examples of covered rivers in major European cities include the River Bièvre in Paris, River Fleet in London, Ladegårdsåen in Copenhagen, and the Zenne in Brussels.

The result of covering rivers is that in many urban areas, local communities may be completely unaware of the existence of a river or a stream running beneath streets, buildings or open spaces (Wild et al 2011).

Culverted rivers are widely considered to exhibit very low ecological integrity, due to dark or reduced light levels, habitat modifications, geomorphological changes and increased diffuse and point source pollution, especially due to misconnections into surface water sewers. The darkness and other modifications to the channel often prevent passage of fish just like weirs do (Wild et al 2011).

Awareness of the problems associated with culverted rivers has increased significantly over the last decade. For example, the London's Lost Rivers project has documented dozens of tributaries of the Thames which flow largely underground as a subterranean tangle of unseen streams.

De-culverting (uncovering or daylighting) rivers involves opening up buried water courses and restoring them to more natural conditions. Projects can vary from the simplest form – removing the 'roof' of a culvert and retaining existing bank walls and natural bed material – to the major reconstruction of both bed and banks using soft-bioengineering measures and river restoration techniques (Wild et al. (2011).

De-culverted rivers and streams have less of a flood risk due to underground blockages or collapse and it is easier to spot and tackle sources of pollution when you can see the water. People can see and enjoy the wildlife that de-culverted streams support, with knock-on positive effects for health and well-being, education and recreation. Open rivers and streams can also help to reduce the urban heat island effect and can (and are) being used to drive regeneration in downtown areas.[3]

In western and central Europe, there are already several cases of reopening covered rivers. In Berlin, large parts of the urban stream Panke has been covered or moved to underground pipes in the last 200 years. Nowadays, the restoration of this urban stream is being planned in order for the stream to obtain its natural structure.[4]

In the outskirts of Paris, a section of the river Bièvre has recently been reopened in Fresnes park and this was an important step for the local residents to rediscover this riverside area.[5] Indeed, projects of reopening urban rivers are often connected to city initiatives to enhance the aesthetics of the city and actions to improve surface water quality.

In the city of Aarhus, the city authorities decided in 1989 to uncover the urban river which was initially covered to its full stretch across the city due to water pollution from sewage and general waste, new traffic requirements and ambitions to develop the town into a modern city (see section 3.2.2).

In the city of Leuven, covered branches of the River Dyle are opened up, as part of a bundle of activities of the city and the Flanders Environment Agency to enhance the role of rivers in the urban fabric and live in close vicinity with the water. Opening up the river and the creation of green river banks within the city, improves the structural quality of the river and makes it more interesting for nature (even within the city). The realisation that open water

[3] http://freshwaterblog.net/2014/07/08/daylighting-urban-rivers

[4] http://www.tagesspiegel.de/berlin/bezirke/pankow/renaturierung-der-panke-in-berlin-unser-fluss-soll-schoener-werden/12101444.html

[5] http://www.ecrr.org/Portals/27/_rex_r9_bievre_vbatGB.pdf

courses in the city create significant added value is gaining in importance, not only among public administrations, but also among private project developers.

In Brussels, about 400 metres of the Woluwe stream, which had been enclosed since the mid 19^{th} century, and its banks have been restored in recent years. This has created an open natural stream and a green corridor that is also part of the region's Green Network. The project also involved the separation of stormwater and sewage flows and therefore reduces the undesirable dilution of the influent into the Brussels wastewater treatment plant (OECD, 2007). The opportunity to proceed with the re-opening of the Woluwe stream was given after the Brussels Central Region program Blue Network was set up (partly to link up with the existing Green Network).

In the UK, specific policy has been developed to prevent culverting, promote the removal of these structures and restore urban rivers back to a more natural condition. A few rivers have already been reopened, such as the formerly "lost" River Quaggy, whose course was recently brought back to the surface as part of the broader strategy London Rivers Action Plan. Its restoration entailed breaking the river out of a narrow concrete channel and recreating a functional floodplain as part of an attractive parkland landscape. The project had the effect of decreasing local flooding and achieving an additional integrated set of biodiversity, leisure, amenity and educational benefits, contributing to the regeneration of the area (Everard & Moggridge 2011). Since then the Quaggy has become a major feature of Sutcliffe Park in south London.

In Zürich, a clean-water concept for separating uncontaminated water from sewage channels has been extended into a stream restoration concept (Zürich stream daylighting program). The goal was to re-open (daylight) as many streams as possible, re-aligning them on the surface so as to increase ecological and recreational values within the urban area of the city of Zurich (Conradin & Buchli, 2004).

As mentioned in previous sections, a strategy dedicated to de-culverting streams has been developed in the city of Oslo. The Oslo de-culverting strategy has succeeded in recuperating the value of natural streams, in retaining and cleaning urban stormwater, thus leading to an improved water quality in the larger streams of the city.

The de-culverted Quaggy (London, UK): A multi-functional blue-green city space

The Quaggy river is 5.6 km in length and crosses London's Sutcliffe Park, a large area of open parkland. For years, the Quaggy was culverted at Sutcliffe Park, and local residents only became aware that a river was there when their homes flooded more frequently as development in the floodplain increased. From 2003-2007, a project to de-culvert the Quaggy was implemented in a multi-disciplinary scheme combining flood risk management with river restoration to benefit the local community.

The project was part of the London Rivers Action Plan (2009) and entailed the establishment of a new 'low-flow' meandering channel through the park, following the Quaggy's original alignment. The previous culvert was retained, enabling it to take excess water in times of extreme flood events. Flow is now regulated between the two water courses by a sluice. To provide further flood water storage, the park itself was lowered and re-shaped to create a floodplain capable of storing a maximum of 85,000 cubic metres of flood water. A network of boardwalks, pathways and viewing points were designed to encourage access to the river and ponds, all of which were an integral part of the scheme. Furthermore, the project employed a community liaison officer, interacting with schools, colleges and local charities, who also became actively involved in the delivery of the project.

The project has been successful in achieving a flood risk reduction for the surrounding area, and in reconnecting people to nature (since opening the park visits have increased by 73%). The implementation of the project as part of a wider catchment scheme has enabled other habitat mitigation measures in more constrained environments downstream to be implemented.

River Quaggy before and after restoration. Photo: @xxx

De-culverting the streams of Oslo

Most of the streams passing through Oslo on their journey towards the Oslo Fjord were culverted as they entered urbanized areas since the 19th century, in order to reduce water pollution and allow for infrastructure development.

The city of Oslo has developed a dedicated strategy for de-culverting its streams. The implementation of the strategy, which focuses on the major streams (River Akerselva, River Alna), but also covers smaller tributaries, started in November 2013. In some cases where de-culverting took place in public parks and green spaces, substantial additional financing could be raised making it possible to develop blue-green solutions with high aesthetical and multi-functional values. As an example, the Bjerkedalen Valley section of the Hovinbekken stream was awarded in 2015 the City of Oslo Architectural Prize for its high aesthetical and functional values. In the stream segment of Hovinbekken stream where the Bjerkedalen Valley is located, there is now trout swimming.

Bjerkedalen Valley. Photo: @Tharan Fergus, Oslo Agency for Water and Sewerage Works

3.3.4 Restoration to cope with urban flood risks

Flood events in European cities: Causes and challenges

Flooding in inland urban areas has two main causes: failure of the urban drainage network to remove rainwater fast enough, causing accumulation; and flooding by an adjacent river as a result of rainfall in the catchment upstream. The former may be associated with insufficient system capacity by design and/or operation, as well as to poor physical condition of the infrastructure. The latter can be exacerbated by urban growth and land use change outside the main urban area (i.e. upstream peri-urban and adjacent rural areas) as precipitation that was previously absorbed or slowed down by vegetated land can then run off on the sealed surface of suburban infrastructure and through bare winter fields (Petts et al. 2002). In those cases where the two processes converge severe flooding may ensue in the highly populated urban centres.

Inland flood events can be classified and described based on the source of the run-off water (e.g. rainfall, snowmelt or a combination of both) as well as the intensity and duration of the associated rainfall. Cities located close to mountainous areas can also be affected by several other types of flooding such as flash floods which occur as a result of the rapid accumulation of run-off waters from the higher upstream areas (caused by extreme rainfall, cloud bursts, landslides, the sudden break-up of a dike or failure of flood control works). Around the world, the majority of cities are located towards the lower end of river catchments and in coastal areas, often making them vulnerable to all these types of flooding, sometimes in combination (Huntley et al. 2001).

In the urban context, sealed surfaces short-circuit the natural water cycle and increase the rate at which run-off water reaches the drainage network, saturating the system and intensifying floods (Anthonj et al., 2014). These more intense floods have become more frequent in recent decades, and they have strong implications on the quality of life in urban areas as they shut down basic infrastructure and interrupt economic activity, and in more extreme cases may destroy homes, businesses and public infrastructure (EEA, 2016a).

Many European cities have to deal with flood risk management issues on a regular basis and most of them have a history of catastrophic flood events. For example, in 1910 Paris was hit by a flood catastrophe, whereby the River Seine rose 8 meters above its ordinary level. Thousands of Parisians evacuated their homes as water infiltrated buildings and streets throughout the city shutting down much of Paris's basic infrastructure (1910 Great Flood of Paris, n.d.). The recent flood episode of June 2016 shook the city once more, with the river level rising to 6.1 meters above ordinary level causing the shutdown of transport and electricity systems.

In early 1995 large areas of cities located along the Meuse River in the Netherlands found themselves under water. Heavy rain events combined with snow melt from the mountains raised the river’s water level, flooding areas around the city of Maastricht and south of the city of Nijmegen. Around 75,000 people living along the Meuse and Waal rivers had to be evacuated (ESA, n.d.)

Dresden is another city that has repeatedly suffered from the impacts of flooding, with the latest major events taking place in 2002 (a centennial flood) and 2013.

Recent flood events in the city of Dresden

In August 2002, triggered by a long period of intensive rainfall in central Europe, the Elbe River and one of its tributaries, the Weißeritz, flooded parts of Dresden as well as other downstream villages. Reaching 9.40m, the water level was the highest in record since 1275 and exceeded the former maximum of 8.77m which was recorded in 1845 (Grollmann and Simon, 2002 as cited in Ulbrich et al., 2003). Damages were estimated at 80 million Euro for community services, 300 million Euro for flood protection infrastructure, about 45.6 million Euro for agriculture and forestry, all these on top of the damages to the central railway station as well as other public and private buildings (EEA, 2016a). This was an event that affected several countries in central Europe, and the total economic loss across the region which was associated with the floods amounted to over 14.5 billion Euro (Ulbrich et al., 2003). A renewed threat surged in late May 2013, when prolonged and intensive rain visited the city once more. The water reached similar levels to the ones registered in the 2002 events, putting to the test the flood prevention and flood risk management measures that had been implemented after the centennial flood. Overall, severe consequences for the city were avoided thanks to better, quicker and more effective official communication; effective use of mobile and stationary protection walls; and increased retention capacity and appropriate run-off pathways (UNU, 2013).

Floods are particular amongst other forms of disasters since the vast amounts of water that they leave behind can aggravate the immediate damages caused and extend the time of recovery. Apart from the immediate damages to infrastructure and property, crop destruction and disease are also common impacts of flood events (ESA, n.d.). Within cities, extreme events of flooding can have a number of impacts including material, economic and health impacts. Therefore, there is overall consensus that urban areas need to be made more resilient to flooding especially in the face of climate change.

At present, European cities also face specific climate change challenges which are and will continue to sharpen flood risk in urban centres. In a warmer climate, projections show a further increase in the risk of river floods in many western and central eastern European areas and in urban drainage flooding in particular western and northern Europe (EEA, 2016a; 2012b). In this context, appropriate run-off pathways should be ensured when elaborating new development plans and when defining urban drainage systems' capacity. This should help to enhance the resilience of urban centres against future flood events and reduce their social and economic impacts.

In most urban centres where buildings encroach to the edge of the rivers, flood risk has often been managed by encasing rivers in concrete with many culverts. These constraints result in river maintenance difficulties and reduce the ability of channels to cope with increasingly heavy summer rainfall. Many concrete-lined channels were designed to accommodate major flooding (i.e. every 20 – 30 years). This may no longer be adequate due to predicted climate change impacts. For this reason, flood risk managers are now increasingly committed to creating space for floodwater where possible through river restoration activities (London River Action Plan 2009).

Responses to urban flood risks: Links to river restoration

Increased urbanisation brings higher concentration of people, economic activities and assets, subsequently resulting in higher disaster risks (UNISDR, 2012). In terms of flood risk and resilience to flooding the importance of strategic planning and design becomes evident when reflecting upon the main causes for floods in inland urban areas described above. Design, operation and maintenance of the urban drainage network, as well as the mode and direction of the city's expansion are all variables that can be controlled or at least influenced by strategic planning. In this context, strategies and measures to protect and restore natural areas, especially in those parts of the city at higher risk of flooding, can become key to reduce disaster risk and ultimately the impacts resulting from catastrophic flood events.

Cities can carry out a number of actions to enhance their protection against flood damage. These can include 'grey' flood protection and appropriate urban designs but also green solutions, such as providing more space for the city rivers. In urban areas where appropriate spatial planning and disaster risk reduction efforts are undertaken (for instance, sensible building codes are developed and respected, human settlements are established away from floodplains or steep slopes and infrastructure and services are suitable), the consequences of flood events and other disasters are kept to a minimum (UNISDR, 2012). Sustainable urban drainage, stormwater management and green roofs are also long-term approaches to managing surface and groundwater by reducing the rate and volume of run-off.

As part of the United Nation's "Making Cities Resilient Campaign" the City of Venice elaborated a plan that encompassed structural and bio-geomorphological elements for flood protection. The plan includes a wide set of measures ranging from greener solutions like the reconstruction of wetlands and reclamation of polluted sites, through softer solutions like flood monitoring, early warning and public awareness raising, to more traditional interventions like city pavement elevation and urban maintenance (UNISDR, 2012). In several other European cities, flood protection measures are combined with the restoration of river banks and the redevelopment of waterfront areas to support recreation and green urban planning.

The need to address the risk of flooding has actually been one of the main triggers for restoration activities in case studies reviewed for this report. For example, persistent flooding events (often resulting in substantial financial damages) have triggered restoration activities in the urban areas of the River Waal in Nijmegen, the River Quaggy in London, the River Isar in München, the River Dyle in Leuven and the River Glinščica connected to the Podutik reservoir in Ljubljana.

Room for the River in the city of Nijmegen

In the east part of the Netherlands, a sharp bend within the course of the river Waal coincides with the location of the city of Nijmegen. Being enclosed by an urban area, the limited space for the river to discharge all the incoming water, especially during extreme events, results in a dangerous bottleneck (FDC, 2015). This has already caused major flooding events in the past (1993 and 1995) and continues to pose a threat (Gemeente Nijmegen & i-Lent, 2015).

Under the Room for the River programme driven by the Dutch government, an integrated initiative is underway that will reduce flood risk in the city of Nijmegen by moving an existing dike 350m inland, digging an ancillary channel to give the river more room, and building bridges across the new channel. This measure will be coupled with the creation of a river park and the redevelopment of waterfront areas, boosting the further development of the city and providing new opportunities for leisure and recreation (NWRM, n.d.). The long-term involvement of a range of stakeholders, the commitment of the local government and extensive planning and assessment efforts have gained the project the necessary public support to start the implementations (STOWA, n.d.).

Nijmegen has linked the river project to plans to expand the city on the northern banks of the River Waal. The new city bridge over the river and the Room for the River project will change the lie of the land. In future, instead of turning its back on the river, Nijmegen will embrace it. In 2011, the plan received the Waterfront Award in New York. In addition to increasing high water level protection, Room for the River has been a catalyst for urban planning (https://www.unesco-ihe.org/sites/default/files/13270-rvdr-brochure-governance-engels_def-pdf-a.pdf).

The new river park created on the River Waal as a result of the “room for the river” interventions in Nijmegen serves as a new public space (more than 80 hectares) in the heart of the city, where people of Nijmegen and Lent can enjoy the presence of water on a daily basis, do sports and experience the floodplains.

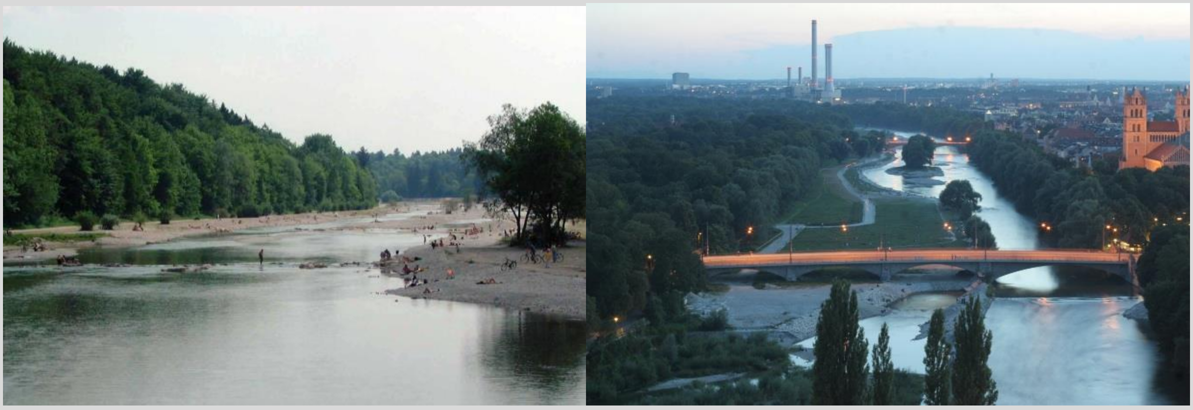
Photo: @Municipality of Nijmegen

Restoration of river banks and opening of the city of Munich towards its river

Hydraulic regulation measures introduced in the 19th century resulted in a gradual degradation of the ecology, flow conditions and water quality of the river Isar flowing through Munich. These modifications also increased the risk of flooding and damage to properties located at lower altitudes, as well as limited public access to the river (Arzet and Joven, n.d.; RESTORE, 2013).

In response to these issues, the Isar Plan was launched in 1995 as an initiative that integrated the goals of flood-protection, ecological restoration, landscape design and recreational use (Arzet and Joven, n.d.; Reiss-Schmidt, 2014). An 8 km stretch of the river that cuts across the city of Munich has been renaturated (Wulf and Schaufuß, 2013; Arzet and Joven, n.d.), including renaturation of the river banks, the enhancement of access routes and setting the flood defences back from the river bank. The benefits of the project included improved discharge of floodwater/lower risk of flooding, an almost natural river flow, enhanced aesthetics, better access to visitors, improved water quality and a restored habitat that supports local fauna and flora (RESTORE, 2013; City of Munich DUPBR, 2005).

Water quality in the River Isar has improved up to bathing water standards thanks to wastewater treatment plants. In addition, flood protection measures have been integrated with an attractive landscape design. As a result, a high number of people visit the River Isar, especially during the summer, as Munich is now a city with an 8 km bathing site.



River Isar after restoration. Photo: @ Wasserwirtschaftsamt München

Very often a city's current layout with its existing infrastructure and settlements may hinder the implementation of measures like floodplain widening and de-culverting of urban streams. The complexity and financial burden commonly related to major maintenance and upgrading works on the urban drainage network can also constrain a city's scope of action. However, the increased frequency and intensity of flood events will continue to call for disaster risk reduction measures in many European cities. In situations where an increase in flood protection is necessary, but the room for action within the city's boundaries is limited, combining inner-city measures with planning at the larger scale to include nature-based solutions in upstream areas can be an alternative. The measures taken to increase resilience in the city of Leuven, historically challenged by flooding, gives a good example of this.

Increasing resilience to floods in the city of Leuven

The flooding of the Dyle River in the city of Leuven has always been an issue as the naturally-occurring steep slopes and historical deforestation upstream of Leuven easily lead to rapid increases in flow rate and water level during high precipitation. These floods occurred after heavy rainfall or after sudden thaws following cold winters, resulting in the rivers overflowing. The most extreme flooding event in its recorded history took place in 1891, which led to a third of the city being flooded, and it remains a reference point for the river's destructive potential. Since then, flooding events (e.g. in March 1947 leading to extensive flooding in the upstream municipality) have remained a regular occurrence and prompted a number of interventions.

In the 1970s, the idea to protect the city of Leuven began with the design of traditional hydraulic solutions, in particular a large flood reservoir in Neerijse valley upstream of Leuven. The poor water quality and the agricultural land use (still very important in that period) made it a requirement that the flood reservoir would not take up more space than was absolutely necessary. During the design period of this traditional hydraulic solution, growing environmental awareness led Leuven to explore more nature-based solutions that take the ecological health and landscape value of the river valley into consideration (La Rivière 2014).

Using new modelling software and taking into account the ecological requirements, the protection measures were tested, yielding successful results. The tested measures included a controlled flood reservoir in Egenhoven and natural, uncontrolled flood zones in the Neerijse valley (La Rivière 2014.).

In this new approach, instead implementing a hard engineered solution with artificial flood reservoirs, the natural processes has been restored resulting in "wet" valley floors along the River Dyle upstream of Leuven. Infrastructure works are kept to a minimum and are intended to 'guide' the river rather than contain it (La Rivière 2014).

In addition to the provision of areas to store water upstream of Leuven, it may be possible to slowly enhance the capacity of the channel network within the city over the years, providing that there is sufficient support within Leuven. Although the capacity enhancements will be relatively small, when these are coupled with flood resistant and resilient constructions, they will help to reduce the amount of storage required upstream. In the EU project Flood Resilient City (FRC), the Flanders Environment Agency implemented a number of measures to enhance the capacity of the channel network within the city. The existing quay-walls were improved to maintain the discharge capacity in the city centre. This was done in close contact with the riparian owners. In that way they became more aware of the river flowing next to or close to their houses. At one location it was possible to build a terrace alongside the river and a small park for people to enjoy. During high water the steps can flood. This increases the capacity for the river in the city centre. Additionally the terrace helps to make more people in Leuven aware that the Dijle is a living river, and that there is an ongoing threat of flooding (Source: http://www.floodresiliencity.eu).

Terraces alongside the River Dyle in the city of Leuven. Photo: @Flemish Environment Agency

Resilient cities should be well integrated into their surrounding hinterlands through green and blue infrastructure (i.e. forests and other natural areas, rivers, lakes, parks, green roofs, etc.), providing people with the opportunity to reconnect with nature despite ongoing urban growth. This type of multi-functional approach linking flood risk reduction objectives with the protection of a city's heritage and increased quality of life through the integration of the wider landscape is well exemplified by the restoration of the River Guadiana in the city of Mérida.

Restoration of the River Guadiana in Mèrida

In Mérida, capital of the region of Extremadura in Spain, the overall area adjacent to the Guadiana River was suffering a progressive environmental degradation caused by invasion of the river margins by the adjacent landowners, uncontrolled excavations for the extraction of gravel and sand, dumping of debris and rubbish and degradation of the natural vegetation. While the urban section of the river suffered from these problems to some extent, further issues were also prevalent. One of them was the presence of urban infrastructure very close to the river, which called for their protection against floods. Furthermore, the Montijo dam (a dam constructed for irrigation purposes and located downstream of the city) caused frequent oscillations of the river's water level, subsequently resulting in dramatic visual impacts on the urban landscape. This became an issue as well since Mérida is a historic city with an important archaeological and monumental heritage (declared a UNESCO World Heritage site in 1993). Some elements of this heritage are closely related to the river, as the monumental Roman bridge, the longest (ca. 800 m) Roman bridge that still stands today.

In the late 1980s the "Confederación Hidrográfica del Guadiana" (Spanish Water Authority in the Guadiana River basin area, a part of the Ministry of the Environment) decided to act in the area to solve, or at least reduce, the series of problems faced by the city and its river. In the urban areas the project allowed to properly integrate the riverbanks with the city, paying special attention to the aesthetic and archaeological aspects and taking advantage of them to provide the citizens with new green zones (parks) which in turn are compatible with occasional flooding and prevent the improper use of the areas adjacent to the river. The restoration project on the River Guadiana was linked to the Urban Plan of Mérida.

Urban integration has been one of the most important targets of this restoration project and achieved to a high extent. Currently, most of the urban river banks have become parks or riverside promenades, allowing an adequate transition between the city and the river and embellishing the environment surrounding the existing monuments. The restoration measures have been very well accepted by citizens, who widely use both the urban and suburban restored areas for sports and recreation (e.g., walking, trekking, cycling, fishing and kayaking).

River Guadiana at Mérida after the restoration measures. Photo: @ Confederación Hidrográfica del Guadiana

4 Lessons learned and way forward

The case studies on urban river and lake restoration reviewed for this report reveal that there are several critical aspects to think about when planning and running such restoration activities. This section summarises some key lessons learned from the reviewed case studies and frames some key contextual issues, which are potentially relevant to different urban settings across Europe. These are aspects related to local planning processes, the multi-functionality of urban restoration, availability of space for urban restoration, public participation and the involvement of multiple actors. This section also highlights some significant future challenges for the restoration of rivers and lakes in an urban setting.

4.1 Local planning

Restoring the water environment in urban areas has very important links with local planning and with flood risk management. Local authorities can use land use planning processes to deliver improvements to urban rivers and lakes. Strategic development plans and local development plans are produced by planning authorities with input from a wide range of stakeholders. They can identify aspirations and assist delivery of restoration, and offer an important opportunity for interested parties to become involved in the decision making process (Natural Scotland – Scottish Government, 2015).

In this context, the planning process and financing of restoration measures in urban areas requires strong collaboration of water and city development authorities, authorities responsible for urban and spatial planning and local residents.

Several examples for such collaboration and links to local planning and spatial planning processes can be found in the cases reviewed for this report.

- The spatial development plan of the city of Leuven treated the Dyle river as a separate structure with high importance to be a blue-green corridor throughout the city. The main aim was to enhance the way the watercourse is experienced. General principles such as higher water storage, improved water quality and erosion measures are also integrated in this plan. In addition, cooperation with project developers makes it possible for the Flanders Environment Agency to do more in terms of restoration in the city centre with less money. The project developers are responsible for opening up covered parts of the river and working out the design of the blue-green corridor. The Flanders Environment Agency participates in the river enhancements.
- In the city of Nijmegen, the main factor that influenced the selection of the interventions on the River Waal, i.e. moving the dyke back from the riverbank and digging a second river channel in the resulting new area of floodplain, was the possibility to combine them with a larger city redevelopment project. In fact, the restoration project has created a catalyst for an integral development of the area, including a new residential neighborhood on the new island created on the River Waal and on the north shore, the revitalization of the other shore at the old city centre and the creation of a unique new river park.
- In the city of Mérida, the restoration project on the River Guadiana was linked to the Urban Plan of Mérida.
- In the city of Łódź, the ability to motivate urban developers to consider innovations linked to stormwater management in development projects has been an important aspect for the stream and river restoration. The restoration of the River Sokołowka and its valley showed that local town plans (spatial development plans) are basic tools for the right investments (green infrastructure, water retention, biologically active areas) to achieve revitalization of the valley to its natural form.
- Ongoing urban restoration projects also show that except for opportunities, there are also many challenges ahead when it comes to linking restoration with other planning processes. In the city of Leipzig, there are still considerable planning challenges on the way to a full revitalisation of the Leipzig floodplain, because the interests of other water users and owners must be taken into account (flood protection authorities, hydropower producers and urban sanitary environmental engineering). It has also become clear that a full floodplain dynamic cannot be achieved only via the measures of the restoration project (Lebendige Luppe).

4.2 Multi-functionality

In designing restoration projects for urban rivers and lakes, it is important to aim for multi-functional schemes. Multi-functional schemes contribute to the achievement of multiple benefits for different sectors, and are thus in a better position to raise different funding sources and enhance cooperation between different actors in the governance setting.

Multi-functional urban restoration measures are seen as win-win measures that help deliver synergies, e.g. to implement different policies such as the WFD, Floods Directive and Habitats Directive. Except for the strong links of restoration with flood risk management, it is additionally important to create spaces that allow experiencing nature. Such win-win restoration measures can easier gain public and political acceptance and secure multiple sources of (co-)funding.

- In the London Rivers Action Plan, there are several examples of multi-purpose restoration. For instance, the design of the restoration of the Quaggy was driven by a multi-disciplinary scheme, which enabled wider community and environmental benefits to be achieved. Demonstrating multiple benefits has enabled a wider range of funding sources to be approached for future schemes. Similarly, in the case of restoring the Mayesbrook Park in London a "mosaic" funding model could be applied, with numerous funding partners collaborating to deliver multiple benefits in the project.
- Also in the case of the Oslo city strategy for de-culverting streams and rivers, an important lesson learned from the development and implementation of the strategy is that multi-functionality is very important to consider. Several ecosystem services have been considered and justified the de-culverting efforts in Oslo throughout the last decades, with improved urban stormwater handling as a starting point. In addition, several other services required due attention in the implementation of such a strategy, in order to to ensure good and operational inter-agency cooperation within the city administration (including agencies responsible for the implementation of the WFD and planning agencies seeking to maximise the usefulness and attractiveness of green areas). When de-culverting projects took place in public open spaces, substantial additional financial resources could in some cases be provided that allowed for developing landscape blue-green solutions with high aesthetical and multi-functional value.
- In the case of the River Dyle, it has been possible to integrate the objectives of the Floods Directive with those of the WFD by carrying out natural flood protection measures upstream of Leuven to reduce flood risks for the city. In addition, a large part of the valley upstream of Leuven is designated as Natura 2000 area, therefore measures taken there for flood protection should always take into account the natural importance of the valley. Most of the land upstream of the city is property of government and it could be used in multiple ways by combining flood protection with nature protection objectives.
- In Ljubljana, a reservoir has been re-designed in a multi-functional way to address pollution and flood risk issues as well as enhance nature conservation values.
- In the heavily industrialised and urbanised area of the Ruhr in Germany, a Master Plan has been adopted to frame the restoration of the River Emscher (Master Plan "Emscher Future"). This addresses several objectives in an integrated way, especially water quality degradation, flood prevention, river restoration and urban landscape design that serves for the living and recreation of people.

The multi-functional Podutik reservoir against pollution and floods (Ljubljana)

The Podutik reservoir, constructed in 1986 to protect part of the Ljubljana Urban Region from floods, receives water from the Glinščica River and stormwater from the nearby settlements. The reservoir is facing water quality problems, as it is affected by occasional overflows from leaking septic tanks, polluted tributaries and urban runoff from gardens, parking places, etc (Griessler Bulc et al. 2015).

In 2001, the Glinščica River as a main recipient of the water from the Podutik reservoir was found to be increasingly toxic. With the objective to provide additional flood prevention and pollution mitigation, as of 2006, in scope of the Environmental Action Programme of Ljubljana (2014-2020), the authorities started to implement green infrastructure in the catchment of the Glinščica River. Part of the flood reservoir Podutik was redesigned into a multi-functional flood reservoir with enhanced ecosystem services, provided by a constructed wetland and a new, meandering river bed.

The re-design of the Podutik reservoir into a multifunctional flood reservoir has enhanced water quality and improved nature conservation value, as well as encouraged recreational and educational use (Grant, 2016). Efforts to include civil society and provide education have contributed to public awareness and have stimulated communication between public authorities, polluters and end users of the flood reservoir.

The re-design of the Podutik flood reservoir is also used as a demonstration site. As Podutik is the first multi-functional flood reservoir in the Ljubljana Urban Region area, as well in Slovenia, it is used to outline new perspectives for future developments in water management and flood prevention.

4.3 Space for urban restoration

In urban areas, where available space is limited, river restoration projects are frequently restricted. However, there is potential to deliver improvements in physical condition, along with significant environmental and social benefits, by using innovative approaches. For example, in Munich, the flood corridor of the River Isar offered some space and thus could be integrated in the Isar restoration project.

Towns and cities are continually changing and it is this process of change which provides the opportunity for restoring river and lake environments. For example, there may be opportunities to remove redundant structures and buildings, and restore derelict land alongside rivers in order to improve local amenity and environment (Natural Scotland, 2015).

Because of the lack of space in urban areas, some cities have also been developing stepping-stone concepts for restoring the networks of their water bodies. On the one hand, restoration interventions are easier to plan and implement in the outskirts and peri-urban areas than in downtown districts. When it comes to restoration combined with flood risk management, this is even necessary as flood retention should be achieved before the flood reaches the city centre. On the other hand, restoration in the centre of large cities can be time-consuming, costly and technically difficult both in the planning and implementation process. To deal with such difficulties, the city of Vienna has adopted a stepping stone approach to restoring its urban water bodies. The activities have started in the outskirts of the city where the frame conditions are easier. For the more central urban stretches, which are very difficult to restore, master plans are developed in each case for the entire stretch, and implementation takes place in phases (starting with the River Liesing (2015-2021) and continuing with the River Wien in the next WFD planning period (2021-2021)).

The case studies reviewed for this report also show that urban restoration projects can be facilitated when the land in question is in public hands. In the city of Łódź, the investments for restoration are being implemented on land which belongs to the City or other public owners, which makes the implementation process more efficient. Similarly, in Leipzig, large parts of the project area for the restoration of the Luppe are already in public ownership, especially forest sites. Transformation of arable land into more floodplain-adapted land uses like grassland still remains a big challenge as compensation areas have to be found. In the case of the River Guadiana (Mérida), one of the goals of the restoration project was to increase the public domain areas on the river banks. Obtaining new areas close to the river to develop the restoration activities was necessary, and this was achieved by the means of expropriation (according to Spanish law).

4.4 Public participation

Planning and execution of measures in urban river restoration should not follow a top-down approach. Public consultation and engagement with local communities have emerged as a crucial step in the planning and implementation of restoration measures in cities. Civil society and the private sector are crucial for the development of cities and their hinterlands and will play a major role in coping with the challenges ahead.

Several examples of public participation processes are available in the case studies reviewed for this report.

- In Leipzig, a large communication process has been established to show the extent to which the Lebendige Luppe project can mitigate negative effects of the loss of floodplain functioning in the Leipzig area. Due to interventions of NGOs, nature conservation experts and scientific expertise, the objectives of the project have been enlarged to restore more flood dynamics in the river than originally planned. In parallel a floodplain management forum has been installed to bring forward future river and floodplain restoration measures in the Leipzig floodplain context.
- In London, due to the high public profile for the Mayesbrook restoration and Mayesbrook Park regeneration works, considerable pre-project engagement was undertaken to raise awareness of the potential gains in natural capital and social benefits. In particular, work with local school groups, awareness raising and stakeholder engagement activities were led by key partners. Formal public meetings were held regularly to inform local residents and businesses at key planning stages. These efforts allowed ensuring good knowledge exchange with local residents and park users (e.g. in relation to potential changes to the existing landscape which carried significance to individuals or families) as well as allaying concerns and identifying the best available solution without compromising the scheme objectives.
- In the city of Nijmegen, many of the regional partners and stakeholders were extremely critical of and opposed to the national Room for the River plans, which was to be implemented for the River Waal. The proposal to move the dike into Lent provoked widespread public opposition and demonstrations. In this case, the key to creating win-win solutions was to align the national goals such as on water safety and nature development with those of the regional stakeholder groups.

- In Munich, public consultation increased the acceptability of the project on the restoration of the River Isar. From the start of the Isar-Plan in 1995 the public was asked to accompany the planning process. People were interviewed about the new river and their preferences and the results of these interviews formed the guidelines for the planning process.
- In the case of re-designing the Podutik flood reservoir in Ljubljana, efforts to include civil society and to organise information events contributed to awareness on the multi-functionality of the reservoir. Consultation activities also counteracted the lack of communication of different end-users of the area of the flood reservoir especially regarding maintenance.
- Also in Oslo, experience gained with the city's stream culverting strategy shows it is important to engage the local communities surrounding the stretches being de-culverted. This requires a proper stakeholder analysis prior to the start of the work and their subsequent engagement. The de-culverting projects including complementary non-water related components may add substantial welfare benefits and improvements in quality of life to local residents with good local participation. Conversely, they may result in conflict-ridden projects if not well received and without good participatory processes.

4.5 Governance framework

Except for engaging with the public and citizens affected by restoration schemes, it proves equally important to establish effective cooperation between the different actors (especially government bodies and organised stakeholder groups) with a stake and influence on urban restoration.

- In the restoration of the River Isar (Munich), the level of cooperation achieved between all stakeholders involved within the Isar-Plan was excellent and one key success factor for the project. An interdisciplinary working group "Isar-Plan" was set up with members from the State Office of Water Management Munich and the City of Munich (different departments). Based on joint scoping work of this group, the development goals for the project were defined. The City Council and District Councils were involved during the progress of the project as well as the Isar-Alliance of NGOs.
- Similarly in the city of Łódź, stakeholder involvement through a Learning Alliance has driven the success of the restoration initiative for the River Sokołówka. It has also created links strong enough to last beyond the lifetime of the initiative and to sustain the upscaling of research results. Because research foci remained flexible and responsive to stakeholder needs, stakeholders participating in the initiative were able to really take advantage of their involvement. The Learning Alliance provided a well-structured framework to identify needs, develop capacities, define common goals and align the efforts of multiple actors towards reaching them and communicate decisions and achievements.
- In the restoration of the River Guadiana in Mérida, cooperation between governmental organizations (State, Region, City) has been absolutely fundamental due to the great number of aspects concerned. This approach has been replicated in similar projects.

- In Leipzig, the governance framework of the floodplain revitalisation project Lebendige Luppe is also highly challenging because of the multi-functionality of the floodplain in an urban setting. There are many actors involved given that the river network in and around Leipzig is a heavily managed system. The planning phase has to bring together many actors responsible for flood and river management, nature conservation, forestry, agriculture, the neighbouring public, NGOs and politicians; different levels of local to regional authorities and agencies are also involved.

4.6 Concluding remarks – Looking forward

The main challenges being faced by European cities and towns in terms of managing their rivers and lakes have been recently transforming. Due to improvements in water quality in the last decades, there is now increasing emphasis on improving the physical structure of urban rivers and lakes. In addition to benefiting water ecology, this new focus helps to create aesthetically pleasing open spaces and deal with new challenges such as adaptation to climate change. Having said that, we need to keep in mind that water quality problems are not fully resolved yet in all urban centres around Europe and they partly still remain a big challenge in several cities. There are still open issues in terms of compliance with European urban wastewater treatment requirements, in terms of stormwater management and chemical pollution of sediments.

Urban rivers and lakes are water systems where different water management issues and social needs come together and need to be dealt with in an integrated way. For this reason, it is critical to aim for multi-functional urban restoration schemes. Urban river and lake restoration cannot be designed using a single-objective approach, e.g. to achieve the environmental objectives of EU water policy. Instead, other objectives need to be taken into account such as improving the quality of life of citizens, linking water body restoration to urban regeneration schemes and delivering multiple benefits such as flood protection and recreation. This can prove crucial in gaining political, social and financial support. Decision-making for restoration projects in cities can also be supported in the future by providing more accurate definitions of the expected benefits (both direct and indirect benefits in terms of ecosystem services).

The value of restored urban rivers and lakes has been highlighted in terms of creating opportunities for leisure, recreation and enhancement of city aesthetic. In the same time, because of the attractiveness of restored water bodies in an urban setting, action needs to be taken on the planning level to minimise the risk of privatisation and overexploitation of areas close to restoration schemes. There is a need to balance the right of citizens to gain access to water with rising prices of private property in newly developed areas on the waterfront.

Future restoration of urban rivers and lakes also needs to be better balanced and coordinated with interventions in the broader catchment. Cities and towns are frequently affected by the impacts of activities taking place in rural upstream areas either in terms of water quality degradation (e.g. due to diffuse pollution from agriculture) or water flow changes (especially relevant to flood risk which is increased due to the lack of natural water retention upstream).

Last but not least, because of the complexity, multi-functionality and social relevance of river and lake restoration in urban centres, it remains a challenge to design transparent public participation processes and efficient governance structures to accompany urban restoration strategies and projects.

5 References

Aarhus Municipality (2008) New central urban waterfront and mediaspace in Aarhus. Competition Brief, Volume I

Anthonj, C., et al. (2014) Science Policy Report. Water in Urban Regions: Building Future Knowledge to Integrate Land Use, Ecosystem Services and Human Health.

Barton NJ (1992) The lost rivers of London: a study of their effects upon London and Londoners, and the effects of London and Londoners on them. Historical Publications Ltd, London.

Basso, L. (2010) Fact Sheet: Demonstration Project Aarhus. Integrated Real Time Control of Sewer Systems and Wastewater Treatment Plants combined with an Early Warning System for Water Quality in Lake, River and Harbour in the City of Aarhus, Denmark. WSSTP.

Bender, E. Bigga, L. & W. Maier (2012). Urban rivers – Vital spaces. Manual for urban river revitalization. Implementation, participation, benefits. REURIS project.

Blue-Green Cities Research Project (n.d.) BlueGreenCities. Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities. Available at: http://www.bluegreencities.ac.uk/bluegreencities/index.aspx

Blue Green Dream (2012). Blue-Green innovations in spatial planning. Resilient Cities 2014. Designing with nature: Global examples of holistic ecosystem-based adaptation. Available at: http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Resilient_Cities_2014/PPTs/E/E2_Maksimovic.pdf

Brandeis, A. et al (2014). Congress Summary and Conclusions. 50th ISOCARP International Planning Congress: Urban Transformation – Cities and Water.

Bruhn, A. (2015). Understanding and Managing Urban Water in Transition, Volume 15 of the series Global Issues in Water Policy pp 527-548, The "Renaturation" of Urban Rivers: The Case of the St Charles River in Quebec.

Bruxelles Environnement – IBGE/Leefmilieu Brussel BIM (2006). Biodiversity and Natura 2000 Reserve in Urban Areas: Nature in Cities across Europe – A Review of Key Issues and Experiences. Bruxelles Environnement – IBGE/Leefmilieu Brussel BIM, December 2006.

Chevalier, C. (2013). Ecosystem services for Wallonia, in Jacobs, S. et al. (eds). Ecosystem Services: Global Issues, Local Practices. Elsevier Publishing.

CLIMATE-ADAPT (European Climate Adaptation Platform) (2014) Zaragoza: combining awareness raising and financial measures to enhance water efficiency. Available at http://climate-adapt.eea.europa.eu/metadata/case-studies/zaragoza-combining-awareness-raising-and-financial-measures-to-enhance-water-efficiency

Conradin, F. & R. Buchli (2004). The Zürich stream day-lighting program. J. Marsalek et al. (eds). Enhancing urban environment by environmental upgrading and restoration. Kluwer. 277-288.

De Paoli, G., Agenais, A. L., Strosser, P., Anzaldua, G., Rouillard, J., Tröltzsch, J., Hinzmann, M., Ivarsson, M., Wallentin, E., Garrido, A., Blanco, I., Stroia, A. (2016) Managing Water Demand in Europe. Final Report to the EEA. Service Contract No. 3415/B2015/EEA.56130. March 2016.

Dublin (n.d.). In Wikipedia. Retrieved October 15, 2015, from https://en.wikipedia.org/wiki/Dublin

Dumm, M. et al. (2015). Current pollution load of sediments and suspended matter in Lake Rummelsburg (Berlin) and whose mobilization potential and ecotoxicological impact on the aquatic ecology. ContaSed2015 – Congressi Stefano Franscini, Monte Verità, Ascona, Switzerland – 8-13 March 2015, http://contased.org/images/docs/AbstractBook_WebsiteVersion.pdf, Accessed 2 October 2015

European Commission (n.d.) Zaragoza: water saving city. Small steps, big solutions. Project factsheet. Available on http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=1123. Last visited on 06.07.2016.

European Commission (2011) Cities of Tomorrow - Challenges, visions, ways forward. Available at: http://ec.europa.eu/regional_policy/archive/conferences/citiesoftomorrow/index_en.cfm

European Commission (2016). Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Eighth Report on the Implementation of the Urban Waste Water Treatment Directive (91/271/EEC) {SWD(2016) 45 final }.

European Commission (2013b). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Green Infrastructure (GI) — Enhancing Europe’s Natural Capital {SWD(2013) 155 final}. http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructures/1_EN_ACT_part1_v5.pdf

European Commission (2013c). The EU Strategy on adaptation to climate change. http://ec.europa.eu/clima/publications/docs/eu_strategy_en.pdf

European Commission (2014). Communication “’The urban dimension of EU policies – Key features of an EU urban agenda”. http://ec.europa.eu/regional_policy/sources/consultation/urb_agenda/pdf/comm_act_urb_agenda_en.pdf

ECRR (2014). New approaches for integrating river restoration in basin management. Newsletter December 2014; special edition ERRC.

ECRR (2015). Rivers in our Towns and Cities (http://www.ecrr.org/RiverRestoration/UrbanRiverRestoration/tabid/3177/Default.aspx) accessed 10 October 2015.

Eden S, Tunstall S (2006) Ecological versus social restoration? Environ Plann C: Gov Policy 24:661– 680

EEA (2009). Ensuring quality of life in Europe's cities and towns. EEA report No 5/2009.

EEA (2010). State of the environment report No 1/2010.

EEA (2012a). European waters — current status and future challenges. Synthesis.

EEA (2012b). Urban adaptation to climate change in Europe. EEA Report No 2/2012. European Environment Agency, Copenhagen.

European Environment Agency (2012c). Water in the city. Web article available at: http://www.eea.europa.eu/articles/water-in-the-city. Last visited on 19.05.2016.

EEA (2015a). Urban sustainability issues — What is a resource-efficient city? EEA Report No 23/2015. European Environment Agency, Copenhagen.

EEA (2015b). Urban sustainability issues — Resource-efficient cities: good practice. EEA Report No 24/2015. European Environment Agency, Copenhagen.

EEA (2015c). Urban sustainability issues — Enabling resource-efficient cities. EEA Report No 25/2015. European Environment Agency, Copenhagen.

EEA (2015d) The European environment — state and outlook 2015 (SOER 2015). European Environment Agency, Copenhagen.

EEA (2015e) Exploring nature-based solutions: The role of green infrastructure in mitigating the impacts of weather- and climate change-related natural hazards, EEA Technical report No 12/2015. European Environment Agency, Copenhagen.

EEA (2016a) Urban adaptation to climate change in Europe 2016 — Transforming cities in a changing climate. EEA Report No 12/2016. European Environment Agency, Copenhagen.

EEA (2016b) Use of freshwater resources. Indicator Assessment. European Environment Agency, Copenhagen.

European Space Agency (n.d.) Flood - Maastricht (Holland), February 1995. Available at: https://earth.esa.int/web/earth-watching/natural-disasters/floods/content/-/asset_publisher/zaoP2lUloYKv/content/maastricht-holland-february-1995. Last visited on 19.05.2016.

European Space Agency (n.d.) Natural Disasters – Floods Overview. Available at: https://earth.esa.int/web/earth-watching/natural-disasters/floods. Last visited on 19.05.2016.

Eurostat (2015) Eurostat regional yearbook 2015. Publications Office of the European Union, Luxembourg. Available at http://ec.europa.eu/eurostat/en/web/ products-statistical-books/-/KS-HA-15-001). Last visited on 05.07.2016.

Everard, M. & H. L. Moggridge (2011). Rediscovering the value of urban rivers. Urban Ecosyst (2012) 15:293–314.

Everard, M., Shuker, L. and Gurnell, A.M. (2011) Mayes Brook Ecosystem Services Assessment. Environment Agency summary online at [https://www.gov.uk/government/uploads/system/uploads/ attachment_data/file/291020/scho0610bsow-e-e.pdf]

Grant, G. (2016). The Water Sensitive City. John Wiley & Sons. 216p

Griessler Bulc, T., Jarni, K., Žitnik, M., Istenič, D., Krivograd Klemenčič, A., Šajn-Slak, A. (2015). Zelene tehnologije v naseljih prihodnosti - primeri uporabe v Sloveniji. Dimensio, 20, 48-49. In Slovene.

Greater London Authority (2011) Securing London's Water Future. The Mayor's Water Strategy. October 2011.

Grollmann, T. and Simon, S. (2002) Flutkatastrophen - Boten des Klimawandels. Z. Versicher., 53, pp. 682- 689.

Hvilshoj, S. and Klee, P. (2013) Adding new value to cities with urban water - Sustainable solutions of integrated urban water management. The Rethink Water network and Danish Water Forum white papers, Copenhagen. Available at www.rethinkwater.dk

Huntley, D. Leeks, G., and Walling, D. (2001). Land - Ocean Interaction: Measuring and Modelling Fluxes From River Basins to Coastal Seas, IWA Publishing (London), 279pp.

Kallis & Coccossis (2002). Managing water for Athens: from the hydraulic to the rational growth paradigm. Discussion Paper Series, 8 (11): 263-286. https://www.researchgate.net/publication/228640317_Managing_water_for_Athens_from_the_hydraulic_to_the_rational_growth_paradigm

Kallis & Coccossis (2001). Water for the city, METRON project.

Leal, W. et al.,2006. The River Elbe in Hamburg. A description of the issues surrounding the dredging of the River Elbe and possible means of conflict resolution. Case study report within the Coastman project. TuTech Innovation GmbH, Hamburg.

Leeuwen van C.J. (2013). City Blueprints: Baseline Assessments of Sustainable Water Management in 11 Cities of the Future. Water Resour Manage.

LRAP Partnership (2009) The London Rivers Action Plan. A tool to help restore rivers for people and nature. Available at: http://thamesriverstrust.org.uk/LRAP.pdf.

Martin-Ortega, J. and A. Markandya (2009) The costs of drought: the exceptional 2007-2008 case of Barcelona. BC3 Working Paper Series 2009-09. Basque Centre for Climate Change (BC3). Bilbao, Spain.

McCarthy, M. (2010). Britain's rivers come back to life, http://www.independent.co.uk/environment/nature/britains-rivers-come-back-to-life-2172580.html, Accessed 15 September 2015.

Municipality of Rotterdam, Hollandse Delta Water Board, Higher Water Board of Schieland and Krimpenerwaard, Higher Water Board of Delfland (2007) Waterplan 2 Rotterdam. Working on water for an attractive city. Available at http://www.rotterdam.nl/GW/Document/Waterloket/Waterplan%202%20samenvatting%20Engels.pdf.

Natural Scotland – Scottish Government (2015). Delivering Scotland's River Basin Management Plans: Improving the physical condition of Scotland's water environment. Available online: http://www.sepa.org.uk/media/37336/improving-physical-condition-scotlands-water-environment.pdf

OECD (2007). OECD Environmental Performance Reviews: Belgium. OECD Publishing. Paris.

OECD (2016). Water governance in cities. OECD Studies on Water. OECD Publishing. Paris.

Stahl Olafsson, A., Hjorth Caspersen, O., Steen Møller, M. (2015) Aarhus, Denmark. Case Study City Portrait; part of a GREEN SURGE study on urban green infrastructure planning and governance in 20 European cities. EU FP7 Project GREEN SURGE.

Oslo Kommune (2015). Prinsipper for gjenåpning av elver og bekker. Styringsdokument. Versjon 1.0. September 2015.

Petts G. et al (eds) (2002). Urban Rivers Our inheritance and Future.

Reifferscheid, G. et al. (2013). Comprehensive chemical, toxicological and biological analysis of the sediments of lake Rummelsburg (Berlin) to derive measures for a natural repopulation of the aquatic environment with benthic organisms. Topical Scientific Workshop on Risk Assessment for the Sediment Compartment, 7-8 May 2013, Helsinki, Finland, https://echa.europa.eu/documents/10162/13639/sediment_workshop_case_study_sediment_quality_rummelsburg_en.pdf, Accessed 2 October 2015

RESTORE (2013) Rivers by Design. Rethinking development and river restoration. A guide for planners, developers, architects and landscape architects on maximising the benefits of river restoration.

Rouillard, J.J., Vidaurre, R. et al. (2015) Governance regime factors conducive to innovation uptake. Deliverable 12.1, DESSIN FP7 project.

Saltveit, S. J. et al. (2013). The return of Atlantic salmon (Salmo Salar L.) and improved water quality in urban rivers in Oslo, Norway. http://onlinelibrary.wiley.com/doi/10.1002/rra.2670/abstract, Accessed 10 October 2015.

Salvini, M. (2011). Parliamentary question E-006188/2011 for written answer to the Commission. Subject: Lambro river pollution alert. http://www.europarl.europa.eu/sides/getDoc.do?type=WQ&reference=E-2011-006188&language=EN, Accessed 30 September 2015.

Saurí, D. and Cantó, S. (2008) Integración de políticas sectoriales: Agua y Urbanismo. Available at http://www.unizar.es/fnca/varios/panel/42.pdf. Last visited on 06.07.2016.

Stockholms stad (2015). Stockholms stads handlingsplan för god vattenstatus. Februari 2015.

Thames River Trust (2016) Restoring London's Rivers. Available at: http://thamesriverstrust.org.uk/strategy/restoring-londons-rivers/. Web page last visited on 01.04.2016

Thames Water (2016). Lee Tunnel, http://www.thameswater.co.uk/about-us/10113.htm, Accessed 15 May 2016.

The Telegraph (2009). Salmon return to France's River Seine, http://www.telegraph.co.uk/news/worldnews/europe/france/6013819/Salmon-return-to-Frances-River-Seine.html, Accessed 15 September 2015.

Ulbrich, U., Brücher, T., Fink, A. H., Leckebusch, G. C., Krüger, A. and Pinto, J. G. (2003) The central European floods of August 2002: Part 1 – Rainfall periods and flood development. Weather, Vol. 58. October 2003.

UNISDR (2012) Making Cities Resilient Report 2012. My city is getting ready! A global snap-shot of how local governments reduce disaster risk. Second Edition, October 2012.

United Nations University (2013) Dresden: Floodwaters Again Threaten City. Available at: http://unu.edu/publications/articles/dresden-floodwaters-again-threaten-city.html. Last visited on 19.05.2016.

Urban Agenda for the EU, Pact of Amsterdam (2016). Establishing the Urban Agenda for the EU 'Pact of Amsterdam'. Agreed at the Informal Meeting of EU Ministers Responsible for Urban Matters on 30 May 2016 in Amsterdam, The Netherlands. Available online: http://urbanagendaforthe.eu/wp-content/uploads/2016/05/Pact-of-Amsterdam_v7_WEB.pdf.

Urban Water Agenda 2030, Status: Draft, February 3, 2016, http://english.eu2016.nl/documents/publications/2016/02/11/urban-water-agenda-2030---draft, Accessed 2 May 2016.

Vujovic´, S. & Kolakovic´, S. (2015). Intergrated water approach for Serbia's Resurgence, http://www.waterworld.com/articles/wwi/print/volume-28/issue-4/regional-spotlight/intergrated-water-approach-for-serbia-s-resurgence.html, Accessed 30 October 2015.

Wagner, I., Breil, P. 2013. The role of ecohydrology in creating more resilient cities. Ecohydrol. Hydrobiol. 13 (2013) 113–134

Wagner, I., J. Marsalek and P. Breil (eds) (2007). Aquatic habitats in sustainable urban water management – Science policy and practice. Unesco publishing, Taylor & Francis group.

Walton I (1653) The Compleat Angler. [Available in many impressions.]

Wild, T. C., Bernet, J. F., Westling, E. L. and Lerner, D. N. (2011), Deculverting: reviewing the evidence on the 'daylighting' and restoration of culverted rivers. Water and Environment Journal, 25: 412–421.

World Watch Institute Blog (2016). Parks or People? Five Cities That Are Choosing Both (http://blogs.worldwatch.org/parks-or-people-five-cities-that-are-choosing-both/) accessed 2 May 2016.

Zalewski, M., Wagner, I., Fratczak, W., Mankiewicz-Boczek, J., Parniewki, P., 2012. Blue–Green city for compensating global climate change. The Parliament Magazine 350, 2–3., In: http://www.theparliament.com/ digimag/issue350

Zenne (n.d.). In Wikipedia. Retrieved October 15, 2015, from https://en.wikipedia.org/wiki/Zenne

1910 Great Flood of Paris (n.d.). In Wikipedia. Retrieved March 15, 2016, from https://en.wikipedia.org/wiki/1910_Great_Flood_of_Paris