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1. Introduction

Urbanization has now accelerated everywhere in the world, and this process is steadily increasing. The sustainability of integrated river basin management is thus fundamentally dependent on understanding the elements of urban hydrological systems and the relationships between them, and on planning our cities accordingly to improve the quality of life of the people living in them. Integrated urban water management requires a holistic, integrated approach to fill the gap between urban planning and water management and even between different water sectors, in order to understand the different interests, the aspects of water planners in a city.

In the Danube River Basin, the planning of river basin management and of urban hydrological systems have so far been completely separated, although the same water resources are used, thus generating a number of conflicts in various decision-making processes. Conventionally, parts of urban water management are discussed and taught in many disciplines separately: engineering, natural and environmental science, nature conservation, etc. Thus the communication between water experts from different field of urban planning is inadequate, which is a great barrier in joint collaboration and integrated measures in the field of sustainable urban water management. Therefore urban hydrological systems themselves have different and less coordinated decision-making mechanisms in many large cities where rainwater, drinking water and sewage treatment are not integrated into a common framework. This does not allow for closing the hydrological cycle in urban areas, which makes it necessary to maintain expensive or underdeveloped systems. Stakeholders ought to be involved in the optimization of local water management opportunities in the future in a more extensive way, without considerably hindering the decision-making processes. In the decision making process, the significant risk and uncertainty of climate change, already well under way, must also be taken into consideration. It is easy to accept that, if urban water catchments successfully meet the requirements of the Water Framework Directive, it will contribute greatly to the decreasing of the existing problems of the entire river basin, such as non-point pollution, organic matter, nitrogen and phosphorus inputs.

The Manual developed in the frame of the WP4.4. in the JOINTISZA project provide a holistic framework to link the knowledge on different water sectors in the city. Due to the multidisciplinary task a detailed theoretical background of IUWM were developed in the Manual. Since the manual is written not only for UH experts but also for decision makers or stakeholders working in other various fields of city management, this manual aims to promote the details and the background information of the organization parameters of the integrated planning process in urban hydrology for readers from the different fields of knowledge. However, due to space limitations, it is not possible to discuss all the technical details of the planning process. Therefore, it focuses on the most important aspects and highlights an integrated water management approach referring to urban sites as a complete hydrological unit.

The introduction presents the characteristics of an urban climate. Next, the differences between traditional and integrated urban water management and decision-making mechanisms are discussed. The reader will be acquainted with the international strategies that municipalities can take into account in the development of their own strategies.

In the following chapters, the possibilities for the implementation of rainwater management, drinking water supply and waste water treatment are presented in integrated urban hydrological systems, specifically addressing the SMART city databases and technological solutions in water management available in an information society.

At the end of the book, the authors provide a number of references, including internet data sources, to those who would like to know more details on any of the subtopics of the book. The authors give a

special thanks to the participants of the INTERREG JOINTISZA project for their help with professional comments and suggestions for the final design of this Manual.

a.) Urban climate

Urban microclimate

The Intergovernmental Panel on Climate Change (IPCC) for Europe has predicted that extreme events will increase in the future, including changes in the magnitude and frequency of heavy rainfalls that generate flooding, the occurrence of heat waves or days with high air pollution, which are especially dangerous in combination with high temperature periods[1].

Based on 30 years of data, cities in the northern hemisphere have an average 2°C higher temperature, 12% less solar radiation, 8% more clouds, 14% more rainfall, 10% more snowfall and 15% more thunderstorms annually, compared to the conditions of rural environments. Experts distinguish different microclimatic layers in the urban environment[2,3]. As air flows from rural to urban areas, an internal boundary layer (IBL), known as the urban boundary layer (UBL), stretches downwind of the city edge.

The air layer above the UBL has the characteristics of rural areas. The area/space between the rooftops and the ground region is referred to as the urban canopy layer (UCL), within which there are urban street-canyon flows, ducting and trapping of airflow and multiple reflections of radiation. Above the UCL is the turbulent-wake layer, within which the wakes occur and IBLs develop from individual buildings, groups of buildings and plumes of heat, humidity and pollutants. Above the turbulent-wake layer is the urban surface layer (USL), also known as the inertial sub-layer or constant-flux layer), where the momentum and heat budgets are influenced by the average effects of a larger part of the urban area, and within which individual wakes are not important[4].

Above the USL is the urban mixed layer (UML), which extends upwards to the top of the UBL. The characteristics of the UML are affected by the presence of urban surface heterogeneity larger than the local scale. Hence, the processes present are generally mesoscale phenomena operating over spatial and temporal scales larger than individual buildings and streets. During the day, the influence of a large city may extend up to 1.5 km. At night, the UBL may contract to less than 0.3 km in depth as stability increases, suppressing vertical transfers through turbulence. The urban surface is mainly artificial and thus quite heterogeneous, more or less, impermeable, with significant differences arising from different land uses (parks, rivers, etc.) and building types (high-rises, business quarters etc.). This fact has led to "zero infiltration" in the city centres and overburdens the collection systems in case of heavy rains. This has significant implications for the interpretation of measured energy budgets and weather phenomena. The temperature may be quite different in the centre of cities compared to the surrounding rural areas. This effect is known as urban heat islands (UHI). Selecting models for investigating the extent of Urban Heat Islands and the impact of climate change for Central European urban regions can be useful in urban planning.

As an example, the Mesoscale and Microscale Meteorology Laboratory (MMM) of the National Center for Atmospheric Research (NCAR) in the USA supports the Weather Research and Forecasting (WRF) system. WRF is a state-of-the-art atmospheric modelling system designed for both meteorological research and numerical urban weather prediction[5]. It offers a host of options for atmospheric processes and can run on a variety of computing platforms. WRF excels in a broad range of applications across scales, ranging from tens of meters to thousands of kilometres.

The RayMan model can calculate short and long-wave radiation fluxes affecting the human body. The model considers complex building structures. The atmospheric model REMO consists of three different hydrology models and three ocean/sea-ice models. An on-line chemistry module for tropospheric chemistry is available. The Micro-Climatic Model RayMan assesses climate change on a city scale where boundary conditions come from the REMO regional climate model.

SURFEX combined with TEM (Town Energy Model) is the surface modelling platform developed by Meteo-France. It computes averaged fluxes for momentum, sensible and latent heat for each surface grid box boundary condition for a meteorological model. These boundary conditions are applied in ALADIN-Climate models. Based on the results, SURFEX captures the main characteristics of urban climatology: temperature excesses in the hearts of cities (Budapest, Szeged) and the daily cycle of an urban heat island[6].

ENVI-met basic is a freeware program based on different scientific urban research projects. ENVI-met is a prognostic model based on the fundamental laws of fluid dynamics and thermodynamics to characterize flow around and between buildings, exchange heat and vapour processes at the ground surface and by walls, bioclimatology and particle dispersion and pollutant chemistry.

Data sources and data quality are important inputs for every modelling process. The meteorological elements of urban environment to be measured, in order of priority, are: air temperature; surface temperature (natural, artificial); air humidity; wind speed and direction, mean wind profile; precipitation; radiation, incoming fluxes, outgoing and net fluxes, sunshine duration; visibility, meteorological optical range (MOR); evaporation; soil moisture and temperature; atmospheric pressure.[7]

Solar radiation data are very useful inputs for several climate variables, such as atmospheric stability; daytime cloud activity; turbulence statistics; the fluxes of heat and water vapour; determination of mixing height; pollutant dispersion and models.

In urban areas, the instruments and methods for the measurement of precipitation are the same as at an open site. The measurement of precipitation (such as rain or snow) is very susceptible to changes in airflow in the vicinity of the measurement site/point. In urban environments, measurement errors are associated with the following main causes: the interception of precipitation by trees and buildings, splash-in into the gauge from a hard surface; eddy wind turbulence leading to under or over-catch. Wind speed and direction are very sensitive to flow distortion by obstacles, including sharp changes in the roughness or elevation of the surface, perturbation of flow around clumps of trees and buildings, disturbances induced by the physical bulk of towers or skyscrapers. For humidity measurement, the same sensor is used as in temperature sampling. Because urban environments are far dirtier than rural sites (in terms of dust, oils and pollutants), thermometers and hygrometers require increased maintenance and frequent service.

Urban areas are particularly well situated to utilize wireless technology, as there is an increasing number of municipal wireless access points, allowing almost complete coverage in most towns and cities. Recent developments in the miniaturization of electronics have produced advances in communications and computing power, with environmental sensors becoming more innovative, reliable, compact and inexpensive as a result.

Climate change and other adverse effects on urban microclimate

Climate change, together with social, economic and environmental vulnerability, aggravates the negative consequences of the more frequent and intense water hazards. Important connections exist between urban water management as well as the environmental and economic future of many Tisza regions entails the need for intensified efforts to train an increasing number of hydrologists specializing in urban hydrology and integrated water management.

With the present growth of the urban population, it is becoming more and more difficult to find new sources of water or water saving methods to meet the increasing demand for water. Thus, the role of the UH as multidisciplinary applied science will increase the sustainability of urban societies.

The urbanized environment changes the atmosphere in a complex way. The total energy balance of urban areas is similar to that of rural areas; however, there are differences in the ratio of short-wave and long-wave radiation. Due to high aerosol concentration, the incoming direct, diffuse and atmospherically reflected short-wave radiation is low, and the short-wave radiation reflected from the surface is also low due to the low albedo. Urban heat islands (UHI) are typical microclimatic phenomena in urban areas. The air temperature of urban areas is significantly higher at night compared to rural areas. According to the typical UHI thermal profile, a steep temperature gradient occurs at the rural/urban boundaries, and thereafter the temperature increases along a steady horizontal plateau and the highest peak temperature is at the urban centre. Vertically, the positive temperature anomaly can be observed as reaching up to 200-300 meters. In general, a 0.5-1°C positive anomaly can be identified in urban areas compared to rural areas, depending on the density and extent of built-up areas. Local urban climate is a phenomenon comprised of several complex processes. The micro-climate of the horizontally and vertically diverse urban surface is influenced by macro factors such as elevation, aspects, relief, etc. At the meso level, the impact of urban surfaces (UBL) can be detected up to 9-11 km depending on the urban structure. The use of satellite remote sensing has suggested somewhat different temperature anomalies from the air temperature of UHI. The UHI displays a stronger dependence on microscale site characteristics, particularly street geometry.

More recent remote sensing work in Szeged, Hungary has suggested that time series analysis delivers more important details on the density impact of urbanized areas and the occurrence of different types of artificial surfaces with UHI. Urban parks, especially if irrigated, may create an 'oasis effect' because they are anomalous moisture sources in an otherwise dry area[8].

Over the last two decades, many studies have indicated that the rainfall patterns of cities are modified. The presence of aerosols and ice nuclei are closely associated with the formation of precipitation. More intense rainfall events in urban areas will lead to the local flash flooding of properties and transport systems and to the pollution of receiving waters.

The IPPC report (Figure 1) shows the schematic relationships between disaster risk and climate and socio-economic change.

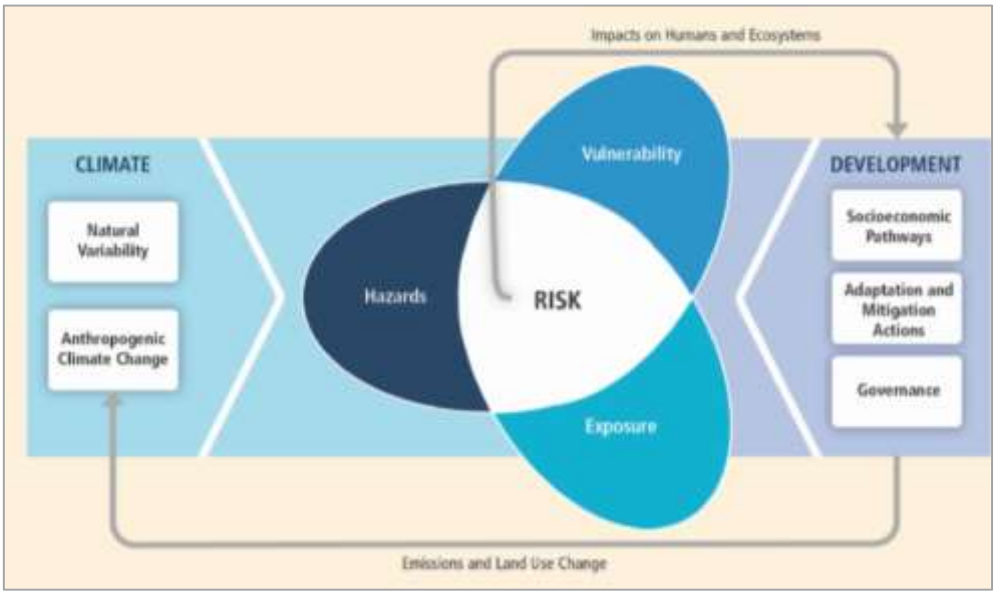

Figure 1. Core concepts of IPCC report on Climate Change 2014: Impacts, Adaptation and Vulnerability (Source: IPCC, 2014[9])

The IPCC WG II report highlights the need for performance indicators to assess adaptation, vulnerability and risk. However, it states that this is a challenging task and that we are still far from adopting common standards, paradigms or analytical languages.

Sustainable solutions to these challenges need to be sensitive to long-term investment needs but also to increasing energy prices, demands for low carbon intensity solutions, and the need to reduce gas emissions from urban activities.

The role and influence of urban water management on urban microclimate-change prevention, adaptation and mitigation

Since urban development will continue, and no doubt accelerates, in many areas, it is imperative that urban effects on the weather and local water management are included in designing the built environment. Climate change and its uncertainty can undermine the performance of high-value urban physical infrastructure, and high capital investment requirements create the risk of the misallocation of capital if or when actual conditions fail to coincide with projections. The state of water in the city is one of the key determinants of the quality of urban life. In the case of poor water management, the health and wellbeing of a city’s population, its economy and its natural environment are all compromised (public health, environment, security, economy). Cities are facing increasing pressures, which aggravate current challenges and also lead to entirely new ones (Figure 2).

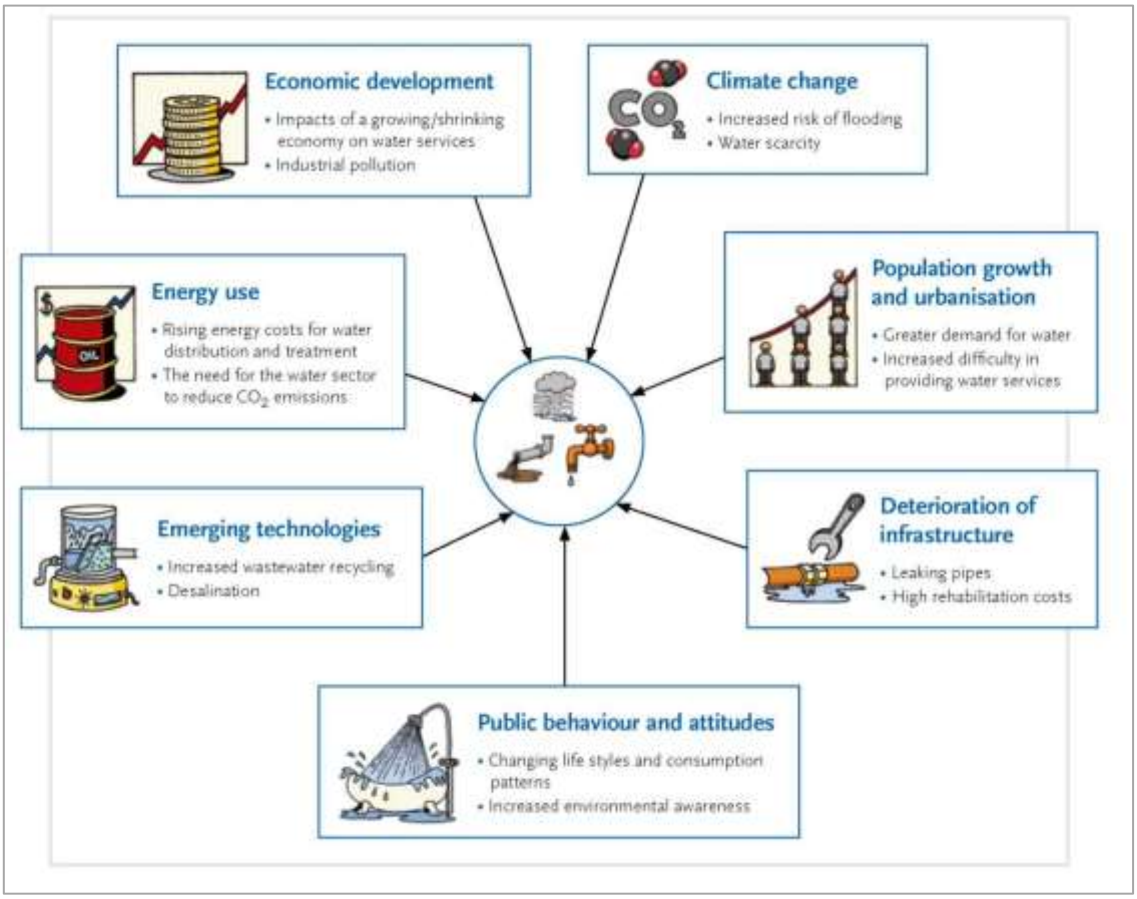

Figure 2. Developments challenging water management in cities (Source: SWITCH)

Rather than isolating the various tasks regarding stormwater, water supply and waste water, designing and managing all of them in an integrated manner leads to the more efficient and sustainable use of resources. A crucial aspect of Integrated Urban Water Management (IUWM) is the early and effective involvement of stakeholders[10].

IUWM recognises that problems encountered in one area of the system may be the result of mismanagement in another. In IUWM, all aspects of the urban water cycle are treated as one system, and all relevant institutions are involved in ensuring that such integration is achieved. Preference is given to innovative and flexible technologies that have been selected on the basis of a holistic evaluation of the water cycle and the long-term sustainability of the system as a whole. Water innovation should comprise an important part of smart specialization strategies, operational and cooperation programmes for cohesion policy, rural development programs as well as implementing IUHM projects in climate change adaptation plans[11]. Guidelines on climate change adaptation and risk assessment in the Danube macro-region was produced in the SEERISK project[12].

b.) The definition of urban hydrology

EU DG ENV is looking at the River Basin Management Plans across all countries to assess the implementation of the WFD. Although specifically UH are not involved in the implementation of the WFD at the moment, stakeholders are recognising that this should change since two thirds of all European inhabitants will live in cities by 2030. Water scarcity as well as floods are becoming more and more of a reality and cities face both technical and legal challenges. Cities generally have complex systems for sanitation, utilities, land use, housing and transportation. The concentration of development greatly facilitates the interaction between people and businesses, benefiting both parties in the process, but it also presents challenges to the managing of urban growth.

The knowledge on urban hydrology relevant to preparedness, mitigation and early warning and its integration to a standardized framework has not been adequately studied and defined yet.

All components of the disaster management cycle should be addressed in a comprehensive hazard mitigation plan, but greater attention needs to be placed on pre-disaster activities. These challenges would require harmonised, preventive, complex urban water management[13].

The first phase of the evolution of the urban water system, which started in the seventies, focused on the building of treatment plants, flood defences and drainage systems. The second phase lasted from 2000 to 2015, when issues such as efficient water use and tariffs/water rates dominated. In recent years, the focus has shifted to climate resiliency, linking water to green infrastructure, energy supply and food production. The good status as prescribed by the Water Framework is only a starting point for the development of a sustainable IUHM. Clean water is no longer about point discharges only, but about the whole water system, including the upstream and downstream of the city.

Urban hydrology includes stormwater runoff from impervious surfaces, less evapotranspiration, less groundwater infiltration, treatment and distribution of potable water, and waste water treatment and discharge. Thus, the hydrology of urban areas is a complex interdisciplinary task[14]. Urban hydrology is a special case of hydrology applied to cities, i.e., areas with a very high level of human interference with natural processes. All hydrological sub-processes in urban areas must be considered on much smaller temporal and spatial scales than those in rural areas. This makes essential differences with respect to theory, data collection and calculation methods[15]. The chemical composition and the physical properties of many different types of water in urban areas are substantially different from those in rural areas. Furthermore, an urban hydrologist must cope with complicated hydraulic systems on the city surface and in the conduit-systems interplaying with heterogeneous, heavily disturbed soil.

Urban hydrology has been altered in order to manage urban runoff against flooding and to protect human health and the environment. In recent years, there have been important developments regarding the measurement and prediction of urban rainfall by using technological devices such as radar and microwave networks[16]. The predictability of urban hydrology has also been improved in order to provide models convenient for small temporal and spatial scales typical in urban and suburban applications. Contemporary stormwater management and application of its BATs is considering the needs of the human beings and environment.

c.) The evolution of the urban water system

Every urban landscape is significantly different from any other environment. The combination of dominant artificial surfaces and decreased vegetation creates an urban climate, which influences the air and water quality and human comfort. The urban water cycle is directly and indirectly linked to a range of other urban sectors, such as housing, energy and transport. An integrated approach to urban water management therefore requires coordination and cooperation between the different sectors or other stakeholders responsible for managing these. In reality, however, such linkages are often neglected in the Danube watershed when decisions for the different sectors are being made.

An urban or urbanizing watershed is one in which impervious surfaces cover or will soon cover a considerable area (Figure 3).

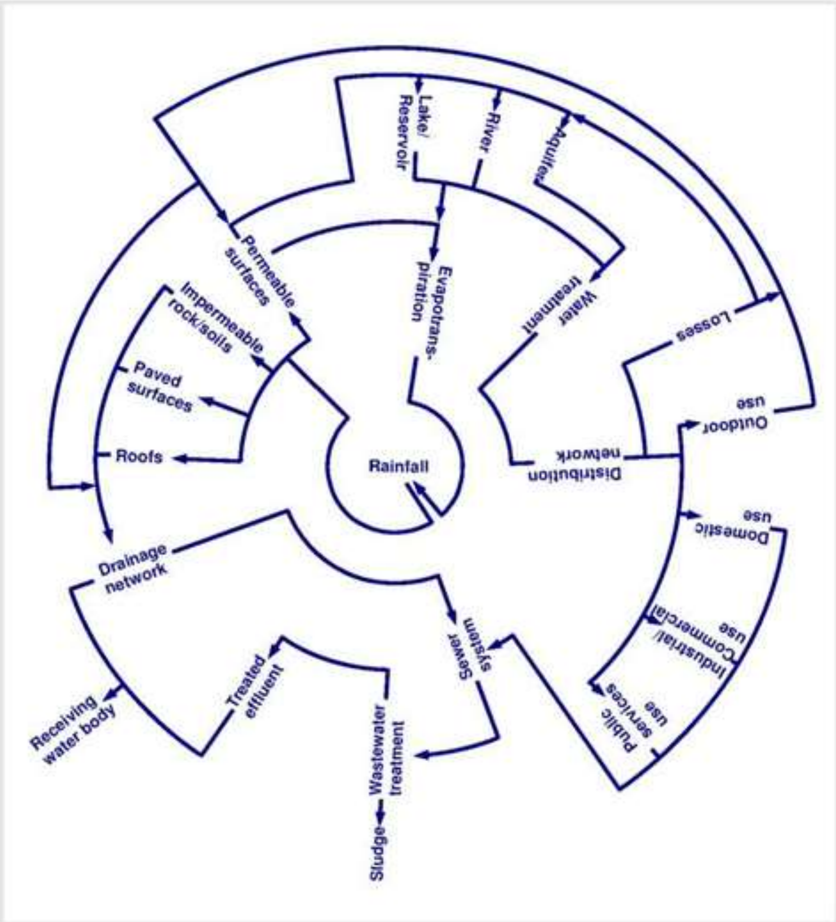

Figure 3. Urban hydrological cycle (Source: Switch)

Water-related infrastructure in urban areas represents a very large economic value. It requires constant economic input to maintain its functionality. It also has an enormous impact on the hydraulic, environmental, economic and social function of any city and the surrounding region within a river basin. Technical structures in a city generate water and material flows between the city and the rural areas. These flows, which are essential elements for all types of life within a river basin, are heavily disturbed in both the quantitative and a qualitative sense by human activities. The role of urban hydrology is to quantify these flows and manage them in the desired direction[17] (Figure 4).

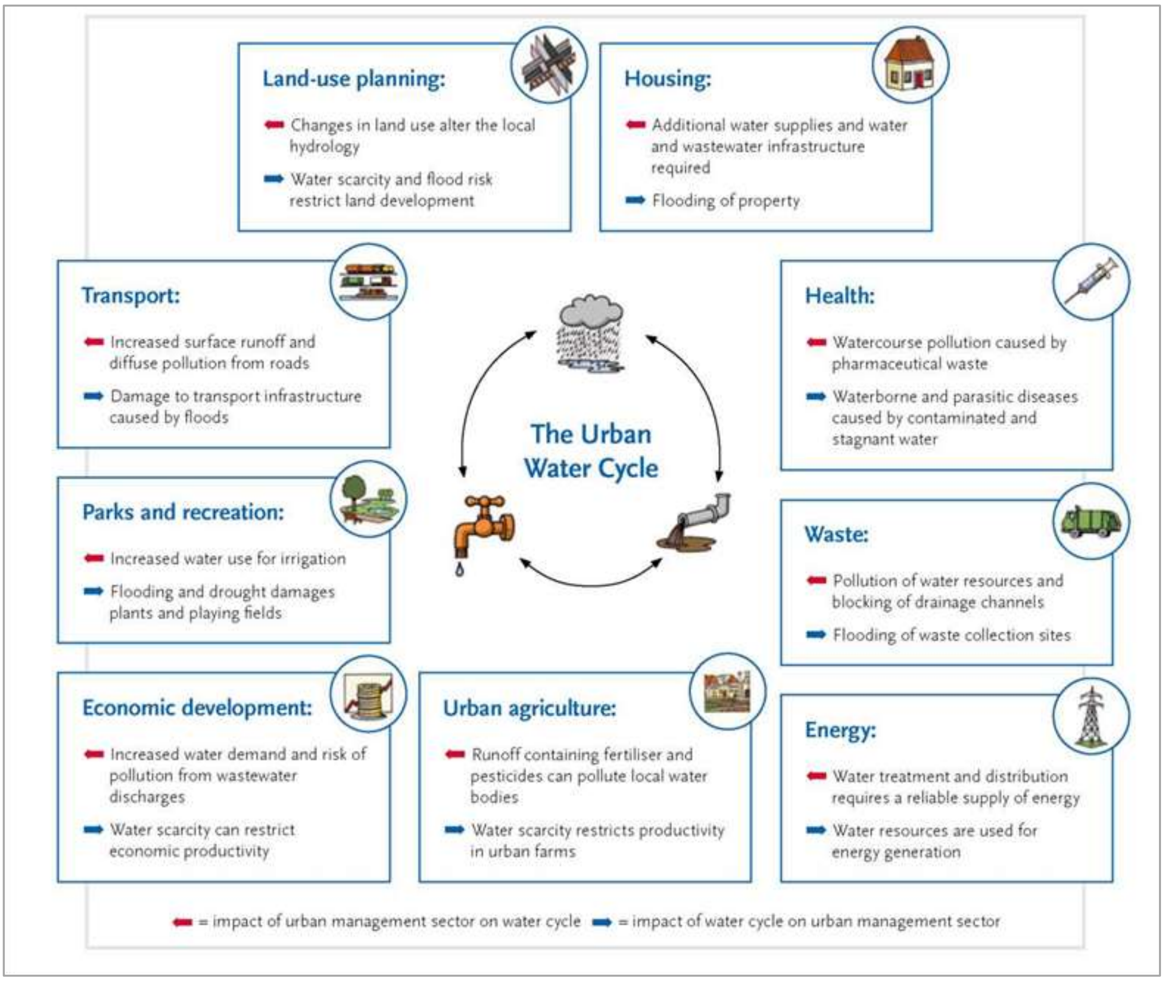

Figure 4. The urban water cycle is an important driving force for other urban management sectors (Source: Switch)

d.) Conventional versus integrated approach

The initial focus of urban hydrology planning in many cities was the identification of the most efficient ways to redirect stormwater flow in the shortest time. This strategy increased the impervious surface area designations beyond those designed for roadways and buildings, and which channelled streams above and below the ground surface. Urbanization, therefore, often creates unfavourable hydrologic regimes characterized by rapid runoff, urban flooding and reduced water quality. Urban planners, water resources engineers, and environmentalists agree with the fact that the spatial distribution of impervious surfaces has significant effects on water quality[18]. The conventional approach to water management, in both developing and developed countries, tends to address problems through large investments in a limited range of long-established technologies. The management of the urban water system is often fragmented, with the design, construction and operation of the various elements carried out in isolation from one another. Short-term solutions are selected with little consideration for the long-term impacts on the entire system[19]. Conventional and IUWM approaches are compared in the next table (Table 1).

Table 1. Key differences between the conventional approach to urban water management and an IUWM [20]

Aspect of urban water management	Conventional approach	Integrated approach
Overall approach	**Integration is by accident**. Water supply, waste water and stormwater may be managed by the same agency as a matter of historical happenstance but physically, the three systems are separated.	**Physical and institutional integration is by design**. Linkages are made between water supply, waste water and stormwater, as well as other areas of urban development, through highly coordinated management.
Collaboration with stakeholders	**Collaboration = public relations**. Other agencies and the public are approached when the approval of a pre-chosen solution is required.	**Collaboration = engagement**. Other agencies and the public search for effective solutions together.
Choice of infrastructure	Infrastructure is made of **concrete, metal or plastic**.	Infrastructure can **also be green** including soils, vegetation and other natural systems.
Management of stormwater	Stormwater is a constraint **conveyed away from urban areas** as rapidly as possible.	Stormwater is a resource that **can be harvested for water supply** and retained to support aquifers, waterways and biodiversity.
Management of human waste	Human waste is collected, treated and **disposed of into the environment**.	Human waste is a resource and can be **used productively** for energy generation and nutrient recycling.
Management of water demand	Increased water demand is met through an **investment in new supply sources and infrastructure**.	Options to **reduce demand**, harvest rainwater and reclaim waste water are given priority over developing new resources.
Choice of technological solutions	Complexity is neglected and **standard engineering solutions** are employed for individual components of the water cycle.	**Diverse solutions** (technological and ecological) and new management strategies are explored, which encourage coordinated decisions between water management, urban design and landscape architecture.

e.) Urban hydrology water balance

In hydrology, an urban water balance equation can be used to describe the flow of water in and out of an urban hydrological system. The water balance equation uses the principles of mass conservation in a different spatial/time extent (continental, national, local), which can be used to help manage water supply and predict where there may be water shortages. For example, the annual water balance equation of the national territory is based on the Data Collection Manual for the OECD/Eurostat Joint Questionnaire on Inland Waters:

$$P + Q_i - ET_a - Q_a - R - C = 0$$

where

- P is areal precipitation
- Q_i is external inflow
- ET_a is actual evapotranspiration
- Q_a is total outflow from the territory
- R is net recharge into the aquifers
- C is consumptive water use
- $P-ET_a = D$: internal flow (often also referred to as internally generated depth of run-off)

This Eurostat calculation method uses a simplified hydrological cycle at the national level (Figure 5). In the case of urban drainage of a particular city, the relevance of a catchment is greater for smaller catchments and decreases as the size of the catchment increases, in the sense that the relative effect of the quantity and quality of runoff water generated by that particular drainage system diminishes with the size of the catchment and with the distance from the point of stormwater disposal.

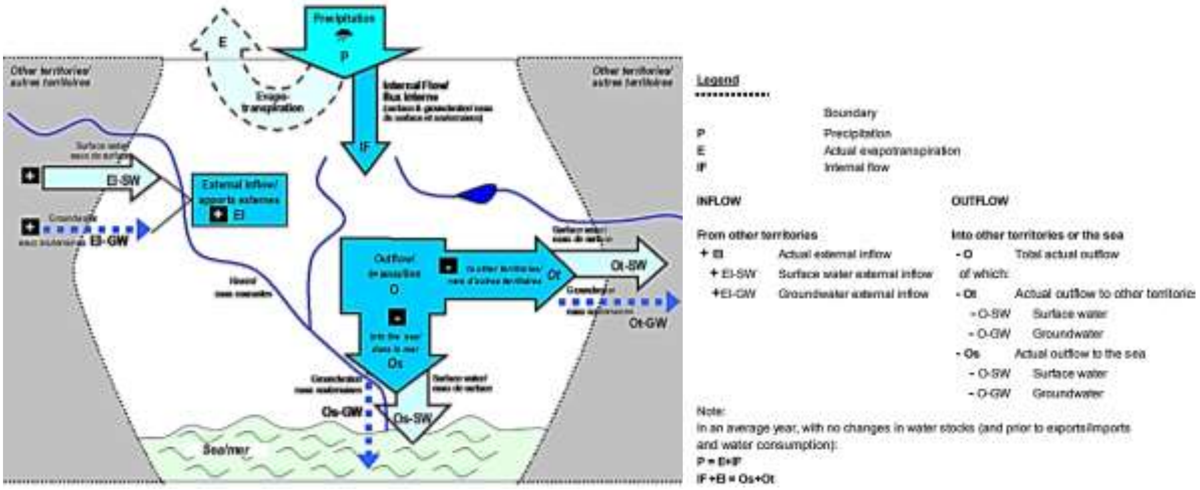

Figure 5. Schematic illustration of the water cycle as captured by Eurostat[21]

Changes in urban climate, enhanced evaporation, limited infiltration, changes in water abstraction, drainage, heat storage, etc. all potentially cause environmental impacts. These impacts are related to both the surface and subsurface-specific area of aquifers and related geological formations below the surface. There is a need for an analysis of the total impact on the entire water cycle. The surface energy balance is the key component of any model designed to simulate dynamical and thermo-dynamical patterns above the surface.

The main objectives of urban hydrology are to manage the urban water cycle in a sustainable fashion by taking into account both surface and ground water, flooding and impacts on waterway erosion and to maintain or return the flow regime back to its natural level as much as possible. It is also important to protect and restore, if possible, water quality (for both surface and ground water) and conserve water resources as well enhance the urban landscape and amenity by incorporating stormwater management measures, which offer multiple benefits, into the landscape. Below is the complex and detailed equation of the urban water balance expressed in metric units, in a manner meaningful and comprehensible to the user.

$$P_r + P_s + P_{mp} + Sw_{inf} + R_{off} + D_{in} + Th + Ir + Drin = D_{out} + Ev + Tr + Dp + W_w \pm S_{res} \pm S_{Wet} \pm S_{soil}$$

P_r	Rain	D_{out}	Drainage outflow
P_s	Snow	Ev	Evaporation
P_{mp}	Micro precipitation	Tr	Transpiration
Sw_{inf}	Inflow surface water (rivers, creeks)	Dp	Deep percolation
R_{off}	Runoff	W_w	Waste water
D_{in}	Drainage inflow	S_{res}	Reservoir
Th	Thermal water	S_{Wet}	Wetlands
Ir	Irrigation	S_{soil}	Soil water capacity
Drin	Drinking water		

The urban hydrological cycle includes more subdomains vertically and horizontally, where the mass balance equation is also valid. The parameters need to be measured for the calculation of the urban water balance, although this condition is partially or totally missing for certain parameters or the measurement is highly uncertain. Rainfall is often measured in non-representative station numbers with low spatial densities. In urban hydrology, hourly data or data from longer periods or averaged data are not satisfactory today, especially with respect to the increasing density of the high intensity precipitation phenomena in the future. It is more and more crucial to know the dynamics of the precipitation process itself. When the intensity of the precipitation falling on a unit area equals or exceeds the intensity of infiltration, it generates a runoff equivalent to the excess precipitation over infiltration. The same may be extended to estimate the overland flow generated from a modified urban catchment slope by multiplying the precipitation in excess of the infiltration by the catchment area. When the heavily modified urban soil profile is saturated, no more infiltration is possible and saturation overland flow occurs. Soil coverage and sealing are also changing rapidly due to human impact. In many cases, the peak flow generated by urban runoff is comparable to the conveyance capacity of the receiving stream. In these cases, the management of urban drainage has a significant effect on the receiving water and its downstream reaches. Consequently, the solution for the particular storm drainage problems has to be developed at the catchment level, and in an integrated manner. However, growing concerns over the quality of surface runoff require that the interaction of the pollution load of particular cities be addressed in conjunction with other pollution contributions from both upstream and downstream urban areas. The difference in the capacity of the main receiving water calls for the classification of the concepts of storm drainage solutions, depending on the ratio of the peak flows, likely to occur at the point of disposal, to the average discharge in the receiving stream.

Evaporation, which is also an important parameter of the water balance, relies on estimated values in a city river basin in most cases. This parameter changes continuously within a few meters and within the same day, depending on the dynamically changing radiation and airflow conditions[22].
Figure 8 demonstrates the airflow and vapour around different structures, such as tall and short buildings, streets and their different combinations. Different scenarios are shown here: (A) the strong flow is deflected down the building, (B) a calm zone develops between buildings, and (C) the combination of large buildings with streets form canyons yielding accelerated airflow. Water as a flowing medium also significantly affects the urban climate in that solar energy is stored by masses of

water. As the temperature of water changes much more slowly than that of land, water modifies the temperature of the land. Meanwhile, the evaporation of water consumes energy and reduces the temperature of air, which might be regarded as natural air conditioning – an important urban planning tool[23].

2. Strategic planning and stakeholder roles in the planning process

a.) Water in the city

Linkages within the urban water cycle

Not only is the urban environment very sensitive to climate change but it also contributes significantly to it. Urban planning can thus greatly help in reducing the local adverse effects of climate change.

Cities are concentrated centres of production, consumption and waste disposal. They drive land change and a host of global environmental problems, and are highly dependent on other cities and hinterlands to supply materials (including water), energy, and to dispose of waste. The competencies for the different elements of the urban water system (water supply, flood management, waste water treatment, etc.) are split and experts working in one sector, for example water supply, are little concerned about what their colleagues in other sectors, such as waste water management, are doing[24]. Thus, it goes unnoticed when decisions and actions in one area clash with those in another. This also means that certain costs of (poor) water management are transferred from one actor to another, making the overall costs of water management higher than necessary.

Poorer water user groups easily lose out in the fight for equal rights to water supply and sanitation. Without sufficient economic standing, they cannot bring their justified requests to bear mainly on undeveloped cities or parts of cities.

As the ecological processes in an urban environment are comparable to those outside the urban context, the methods and studies in urban ecology are similar to ecology in general. Urban ecology dictates that local-scale dynamic interactions between socioeconomic and biophysical forces leading to the development of a concept called *city*. Urban ecology is basically concerned with the relationship between the spatial-temporal patterns of urbanization and ecological processes[25].

Climate is an important element for pollution control and regional transportation policies; whereas, for the urban planner, landscape architect and architect, small- scale climatic variations are important.

In urban design, the groundwater relations and surface flow characteristics of water collection basins are of vital importance for the city's water demand and supply. Within the framework of urban hydrologic processes, trees as well as soils can play an important role in the intercepting and retaining or slowing of the precipitation flow. The physical features of soil, such as depth, mechanical structure, general characteristics, level of ground water, and geological basis, are not only important for tunnels and edifices, but also for all urban structures (road system, sewage, cesspools, etc.). Soil is the natural environment for plants[26]. Therefore, determining the soil features is of particular importance for the planned green areas in the city[27].

Wildlife in cities is generally undervalued[28]. In recent years, urban wetlands, abandoned industrial sites, roadside verges, vacant lots and derelict lands, ruins, allotment gardens and cemeteries - together with arboreta, residential gardens and villas, botanical gardens and individual balconies, have begun to be seen as potential conservation areas for urban biodiversity[29]. From the perspective of urban planning, the protection of biodiversity in cities is a high priority for stakeholders during the planning process. Urban greenery makes cities centres of attraction; it prevents urban sprawl and saves space for biodiversity. In addition, as in-city services increase, the city's footprint is decreased; as a result, potential negative effects on biodiversity and the environment are also decreased. Creating sustainable urban hydrology is a key task for planners in order to maintain urban ecology.

Linkages between the water cycle and other urban management sectors

Water efficiency is a requisite for sustainable development and a low-carbon economy as well as involves innovative approaches with the participation of many stakeholders. Regional research-driven clusters can play a major role on supporting innovation through problem-oriented solutions by bringing knowledge links between the "Quadruple Helix" (Society-Research-Business-Public Authorities); demonstrative sites for water efficiency innovations at a regional scale; and raising awareness of water efficiency to stakeholders (integrate-demonstrate-validate)[30].

The torrential rainfall and impervious surfaces inside the city cause this precipitation water to be lost in a short time; rainwater does not contribute to the water economy efficiently. The city's annual rainfall is around 5 - 31% higher than that of open area and forest designs, depending on the land surface shape, height, climate characteristics and the size of the structures. The increased impervious cover is among the most significant modifications affecting streams in urban sites; it transforms hydrology and also funnels accumulated pollutants from buildings, roadways and parking lots into streams. The storms and low flow-discharge of cities lead to local, even regional pollution downstream, which are particularly caused by pesticides and persistent organic pollutants[31]. Water pollution is categorized by origin as point source and diffuse source contamination (Table 2). Point sources by definition are emissions from a well-defined activity, located in a confined area. Diffuse pollution comes from a wider area usually in a small concentration, the emission is dispersed and its exact location is unknown. Urban precipitation runoff is an additional, though not well characterized contamination source. Runoff may carry rubbish, petroleum compounds, salts and contaminants from air deposition.

Table 2. Contaminants from urban precipitation runoff[32]

Pollutant	Source
Rubbish, solid materials	Construction works, erosion from unpaved surfaces, air deposition (of transportation and industrial emission), built environment deterioration, stormwater outlets
Oxygen-demanding (organic, degradable) substances	Plant debris (leaves, grass), animal faeces, street waste and other organics
Microbial contaminants, pathogens	Animal faeces, combined sewage outlets
Nutrients (N, P)	Air deposition, erosion of unpaved surfaces, combined sewage, fertilizer used in gardens or parks
Heavy metals (Zn, Cu, Cd, Ni, Cr, Pb)	Air deposition (of transportation and industrial emission), outdoor metal objects (e.g. gutters), drainage of waste dumps
Oil, grease	Transportation (vehicles), pumping stations, car-wash
Other organic phenols, PAHs)	Micro-pollutants (pesticides, air deposition (of transportation and industrial emission), pesticides used in gardens
Salts	De-icing of pavements

The different load-based method calculates diffuse emission from the difference of the upstream load and point source emission. The pathway-based method estimates the load by transportation pathways. This is used e.g. for the estimation of a heavy metal load, as a large proportion of it is derived from precipitation runoff and other not well defined, combined sources. The source-based method follows the chemicals from manufacturing through use to point and diffuse pollution. All three methods can be used to derive a list of relevant substances for water monitoring.

In unified sewage systems, heavy precipitation may also lead to combined sewage overflow, significantly increasing the release of contaminants. The estimates for total heavy metal load indicate that urban precipitation runoff is the major source of toxic heavy metals, carrying diffuse pollution from transportation (Cu, Ni, Cr and Cd) or metal roofing (Zn). While the contamination itself is point source or linear, due to the diverse transport pathways, urban precipitation runoff appears as a diffuse contamination in waters. Industrial sewage from industrial or commercial activities either directly impacts the receiving water or, if the facility is located within a municipality, its sewage is generally combined with communal sewage after pre-treatment or storage if necessary. The emissions from industrial and communal sewage in the latter case cannot be separated at the emission point but are estimated on the basis of the scope of the industrial activity. The potential point sources include previously contaminated sites and active or recultivated waste dumping sites. Mining is considered a diffuse source of heavy metals[33].

Water and quality of life

Every year in the European Union (EU), 247,000 million m^3 of water is extracted from ground and surface water sources (streams, lakes and rivers). The largest proportion of abstracted water (44%) goes to the energy-production sector for cooling processes, with most being returned to rivers. Agriculture and food production use 24% of abstracted supplies, with 17% used for public water supply and 15% for industry[34]. In Europe, 75% of the population live in big cities (Figure 6) and 80% will do so by the year 2020.

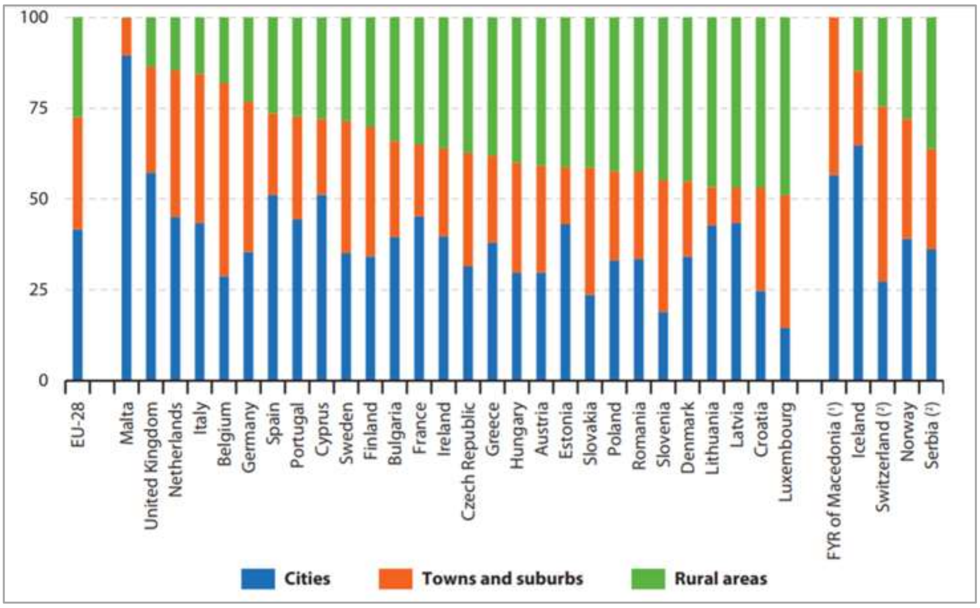

Figure 6. Distribution of population, by degree of urbanisation, 2014 (% of total population)[35]

The impact of urbanization has multiple effects. A total of 1,088 agglomerations with 2000 PE are located in the Tisza River Basin. Of these agglomerations, 22 are larger than 100,000 PE with a total of 4,693. In the Tisza River basin, the number of the total population is stagnating or slightly decreasing while the number of urban populations is increasing - an internal migration towards larger cities can be observed.

One of the major challenges facing the cities of the Tisza watershed is climate change and its potential physical, social, economic, environmental and cultural impacts. Climate change adaptation measures should help to moderate harmful effects and/or exploit beneficial opportunities for cities and regions. In this context, the development and maintenance of water-related green infrastructure plays an important role, since green infrastructure helps, for instance, in alleviating floods, drought, runoff and preventing soil erosion.

The mitigation of harmful processes (traditional climate protection) depends largely on broad international co-operation, but there are differences in how and to what extent each national policy implements the given international programme and the purpose; therefore, achieving the goals is often uncertain at the national level. At the same time, since climate adaptation can be handled with individual and local urban community actions, in many cases higher levels of local engagement may be more effective in certain areas than the national programmes. The depositaries of adaptation to a changed climate can be individuals and local communities, by developing methods adapted to each community's environment. Therefore, individuals and local communities need much more knowledge and intention. Climate policy must shift the focus from climate protection to climate adaptation. The basis of this change is changing the viewpoints and establishing its background database. Effective adaptation to the consequences of climate change can only be achieved through co-operation between governments, large and small communities, NGOs and individuals.

Local authorities have a significant role in disaster management; they must devote special attention to the careful preparation of protective measures against the detrimental effects of extreme climate weather phenomena, because these preparations are crucial for developing an effective adaptation strategy. An effective action plan is an important tool for local governments in heat wave alert situations. Special protection must be provided for the drinking water infrastructure, particularly strategic reservoirs and water mains, maintained by water utilities to provide high-quality drinking water for the population. As an example for water supply in urban area streets supplied by less public drinking water wells, hydrants can be converted to drinking wells on hot summer days (Figure 11).

In the event of disruptions of the electricity service during heat waves, all consumers can be provided with electricity during blackouts averaging 2-3 hours. During longer heat waves, energy demands may increase, which might require the imposition of limitations on consumption.

The European Commission Green Paper, June 2007, draws attention to, among other things, the dangers posed by heat to human health; thus, it is extremely important to prepare an action plan to protect the population during heat alerts. Heat waves are usually possible to predict and, therefore, the public must be informed about preventive measures they can take to protect their health in cities. If the local authorities are to issue a warning, attention must be paid to the following considerations: Communication may be effected in writing or as a personal announcement. It may take the form of a press release, a public announcement, a briefing or interactive communication, during which attention must be called to the negative effects of heat waves on health; the necessity of remaining hydrated; the need to seek shelter in shady places; and the dangers of leaving one’s place of residence. Special attention must be paid to minimizing health risks for participants in outdoor programmes.

Employers must seek to protect the health of employees working outdoors; during heat waves, they must provide their employees with ample drinking water, periods of rest in shady areas, appropriate working clothes and protective gear. It is an important role of local governments and NGOs to give special advice to different urban groups to mitigate the harmful effects of water shortage.

The Internet plays an increasingly important role in informing and alerting the public. The Network of European Meteorological Service (EUMETNET) has implemented the Meteoalarm webpage (Figure 7). It will alert users to the possible occurrence of severe weather, such as heavy rain with risk of flooding, severe thunderstorms, gale-force winds, heat waves, forest fires, fog, snow or extreme cold with blizzards, avalanches or severe coastal tides. The colours used on the website maps indicate the severity of the danger and its possible impact. On the European map, each participating country is coloured consistently with the highest colour assigned to a current warning. Clicking on a country will link you to national and regional warnings.

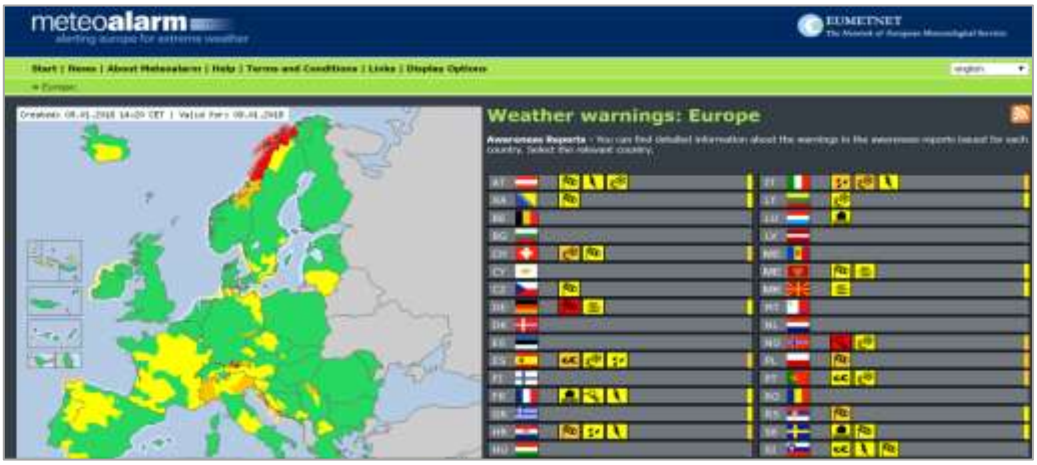

Figure 7. European meteoalarm web-based systems[36]

The quality of life of urban populations is also closely linked to the quality of nutrition, which is influenced by the quantity and quality of water used in the food or the life cycle of food.
Food security is basically dependent on the actual and virtual (to be discussed later) water consumption of the members of the food chain. The concept of food security and food safety should be distinguished. Food security is a condition related to the supply of food and individuals' access to it. Food safety includes a number of routines that should be followed to avoid potential health hazards. The tracks within this food chain are safety between the industry and the market and then between the market and the consumer. In this way, food safety often overlaps with food protection to prevent harm to consumers[37]. Water determines food security, safety and good nutrition in numerous ways, as shown in Figure 8.

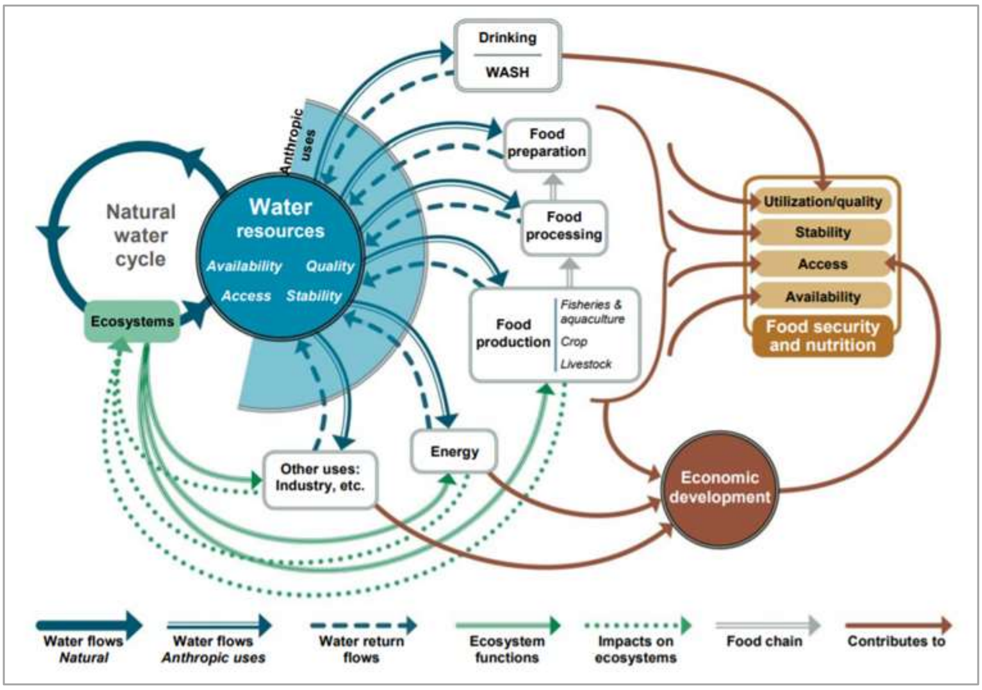

Figure 8. Food chain and the water cycle[37]

Access to a safe and continuous supply of water for drinking, cooking and personal hygiene is an essential prerequisite for health. An inadequate water supply, whether as a result of poor access or quality, low reliability, high cost or difficulty of management, is associated with significant health risks. These health risks are experienced most strongly by the poorest households. The quality of drinking water ensures the effective absorption of nutrients by the human body. A poor water supply impacts health by causing acute infectious diarrhoea, repeated or chronic diarrhoea episodes and non-diarrhoeal diseases, which can be caused by chemical elements such as arsenic and fluoride[38]. It has been estimated that a minimum of 7.5 litres of water per person per day is required in the home for drinking, preparing food and for personal hygiene. This is the most basic requirement for water. At least 50 litres per person per day is needed to ensure all personal hygiene, food hygiene, domestic cleaning, and laundry needs[39].

The two widespread trends of urbanization are the concepts and practices of "SMART" and "GREEN" cities, which affect the quality of life by optimizing urban hydrological systems.

'Smart cities' may be defined as ones seeking to address public issues via ICT-based solutions involving multi-stakeholder partnerships. Smart cities have the potential to improve the quality of life: they are innovative, making traditional networks and services more efficient through social innovation and the use of digital technologies, creating more inclusive, sustainable and connected cities for the potential benefit of their inhabitants, public administration and businesses. Through smart measures and the optimization of water resources, the efficiency of decision-making processes is improving.

'Green cities' combine higher levels of efficiency with innovative capacity and reduced environmental impact, addressing issues like congestion through the implementation of, among others, road charges, integrated public transport and water systems. This 'greening' of cities has the potential to reduce pollution and the harm that may be caused to an individual's health, for example, by reducing water pollution and promoting the use of cleaner or renewable water resources or creating more green areas.

The green infrastructure in the urban landscape consists of recreational parks and gardens, unmanaged natural open spaces, wetlands and rural lands. The quality of life for most urban dwellers is closely related to the amount of green areas around their homes.

Urban quality of life is also significantly influenced by the level of access and the quality of service of the urban water supply, sewerage, the status of sewage treatment, and the pricing policy applied to them, which is discussed in the following chapters.

b.) Sustainable water management

Sustainability programmes at different levels deal with the sustainability of water as a natural resource. In 1977, the UN Conference on Water was held in Mar del Plata, Argentina, and this conference was an important cornerstone for the sustainability of water resources management. The Dublin Conference was expected to formulate sustainable water policies and an action programme to be considered by UNCED in 1982[40]. Several more conferences have been organized, for example the Second World Water Forum & Ministerial Conference (The Hague, 2000), the International Conference on Freshwater (Bonn, 2001), the World Summit on Sustainable Development (Johannesburg, 2002), the Third World Water Forum (Kyoto, 2003) to achieve the recommended goals of sustainable water resources management. The 2005 World Summit on Social Development identified sustainable development goals, such as economic development, social development and environmental protection[41].

In 2015, the UN announced 17 Sustainable+ Development Goals (SDG) with 169 associated targets, which are integrated and indivisible. The title of document was TRANSFORMING OUR WORLD: THE

2030 AGENDA FOR SUSTAINABLE DEVELOPMENT, in which SDG 6 is dedicated to water resources and ensuring the availability and sustainable management of water and sanitation for everyone[42]. To achieve this goal, water quality has to be improved, water efficiency increased, water-related ecosystems have to be protected, water management integrated and the participation of communities in water management has to be strengthened. For the UN, the human right to water and sanitation is defined by the following criteria: availability, accessibility, acceptability, affordability and safety. In order to achieve SDG6 in Europe, cities could focus on three specific issues in the strategy, since they are issues for which decisions are made at the local level:

- The need for investments in water infrastructure
- The issue of affordability for households
- The resistance of the water infrastructure not only to climate change but also to natural disasters and security threats.

The New Urban Agenda, also referred to as the “right to the city”, was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador, on 20th October 2016[43]. The Quito declaration stated that by 2050, the world’s urban population is expected to nearly double, making urbanization one of the twenty-first century’s most transformative trends. One principle of the declaration was to ensure environmental sustainability by promoting clean energy and sustainable use of land and resources in urban developments, by protecting ecosystems and biodiversity, including the adoption of healthy lifestyles in harmony with nature, by promoting sustainable consumption and production patterns, by building urban resilience, reducing disaster risks and mitigating and adapting to climate change[44].

The Principles and Commitments of the “right to the city” programme:

- Transformative Commitments for Sustainable Urban Development

    a. Sustainable Urban Development for Social Inclusion and Ending Poverty (18 points)
    b. Sustainable and Inclusive Urban Prosperity and Opportunities for Everyone (20 points)
    c. Environmentally Sustainable and Resilient Urban Development (18 points)

- Effective Implementation

    a. Building the Urban Governance Structure: Establishing a Supportive Framework
    b. Planning and Managing Urban Spatial Development
    c. Means of Implementation

EUROCITIES and ICLEI have been selected in 2017 by the European Commission’s DG Environment to develop a strategic plan for the Urban Water Agenda 2030. This initiative aims to become a platform for cities that commit to managing water resources in an integrated and sustainable manner. The Urban Water Agenda 2030 (UWA2030) will be a new component in the European Union’s ambitious water policy, which aims to achieve the good status of all water bodies and help all member states prepare for extreme weather events as reflected in the Water Framework Directive (adopted in 2000) and the Floods Directive (adopted in 2007).

The EU New Urban Water Agenda 2030, also called the Leeuwarden Declaration, was launched at the Cities and Water conference in Leeuwarden (NL) in February 2016. 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 measures to achieve these objectives and target values around the following core areas:

1. Water efficiency
    - Leakage reduction (target 10%)

- Consumption reduction (20% compared to 2015)
- Water reuse (50% of urban use)

2. Resource efficiency
   - Energy efficiency of urban water systems (50% reduction)
   - Recovery of materials from waste water (75% of nutrients and 50% of organic matter)
3. Water quality
   - Safe drinking water for inhabitants
   - Treatment of waste water
4. Treatment of storm/runoff water
   - Addressing emerging pollutants
5. Sustainability of the urban water infrastructure
   - Water pricing
   - Investments
6. Flood prevention and nature-based solutions
   - Land use planning to prevent damages
   - De-sealing/increasing infiltration
   - Green infrastructure and storage of rainwater
7. Citizen involvement
   - Raising awareness and empowering citizens[45]

Other important EIP Water policy initiatives aim to stimulate creative and innovative solutions that contribute significantly to tackling water challenges at the European level and to develop more useful IUWM tools[46].

c.) The strategic planning process for IUWM

The methodology of a strategic planning process provides the framework that facilitates the shift to more integrated policies, governance structures, practices and the choice of technology for more sustainable water management. If developed on the basis of a formal decision by the local government or another relevant public authority, it provides the backing and legitimacy for all organisations involved to take the required water sector reforms forward[47].

The process consists of the development and implementation of a flexible strategy that holistically considers all areas of the urban water cycle as well as its linkages to other urban management sectors. It facilitates the optimisation of the entire urban water system and the selection of solutions more likely to succeed under the different scenarios of an increasingly uncertain future. A strategic planning process consists of a number of phases, the outcomes of which are reviewed in Figure 9.

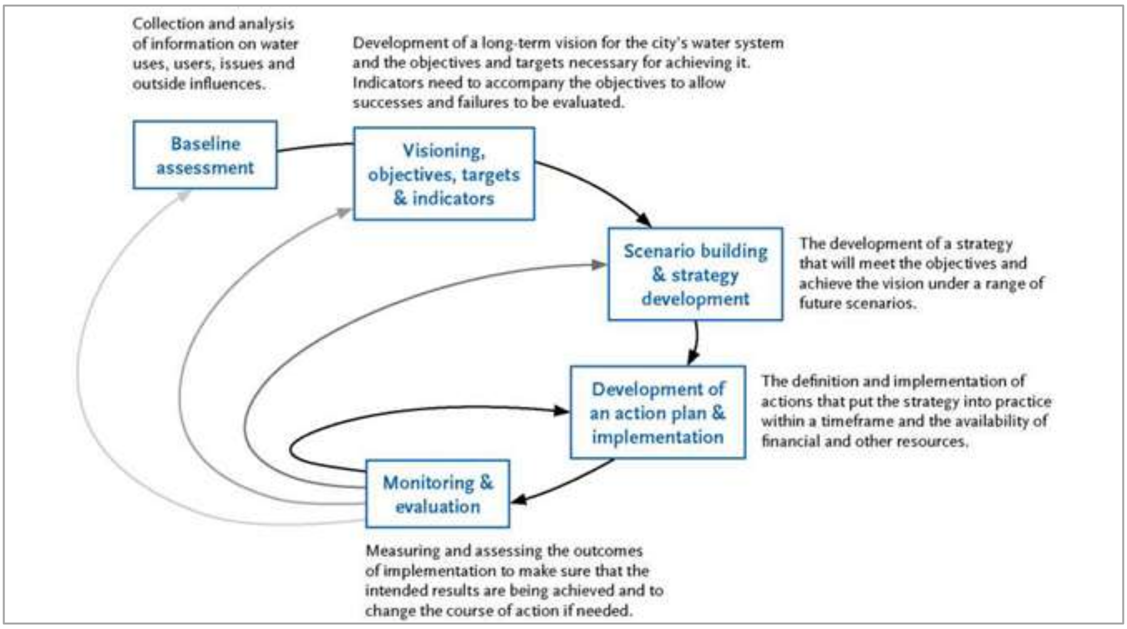

Figure 9. The strategic planning process for IUWM (source SWITCH)

The process in Figure 14 is shown as a logical sequence of steps, although in reality there is a great deal of reiteration and revisiting of the different phases. The order of the tasks can also vary. However, what is consistent in the strategic planning process is the need for the continuous review of the results against a set of indicators designed to measure progress. The ability to react to unplanned circumstances is the key to its success.

City needs can be determined by policy frameworks and urban planning tasks, which will differ between countries, regions and municipalities. Driving forces that frame city needs and urban planners include:

- Policy framework (legislation, political decisions and directives, etc.)
- Planning level (scale, type of urban planning task)
- Planning phase/stage
- City characteristics (economy, physical environment, planning characteristics and availability of data).

Such a "city needs analysis" ought to be based on local subsurface challenges and/or the resources of the city. It should also be adapted to match legislation, the expected development of the city and available subsurface information[48]. The Climate Change Act (CCA) (Figure 10) creates a framework for building the UK's ability to adapt to climate change based on the Climate Change Risk Assessment (CCRA)[49].

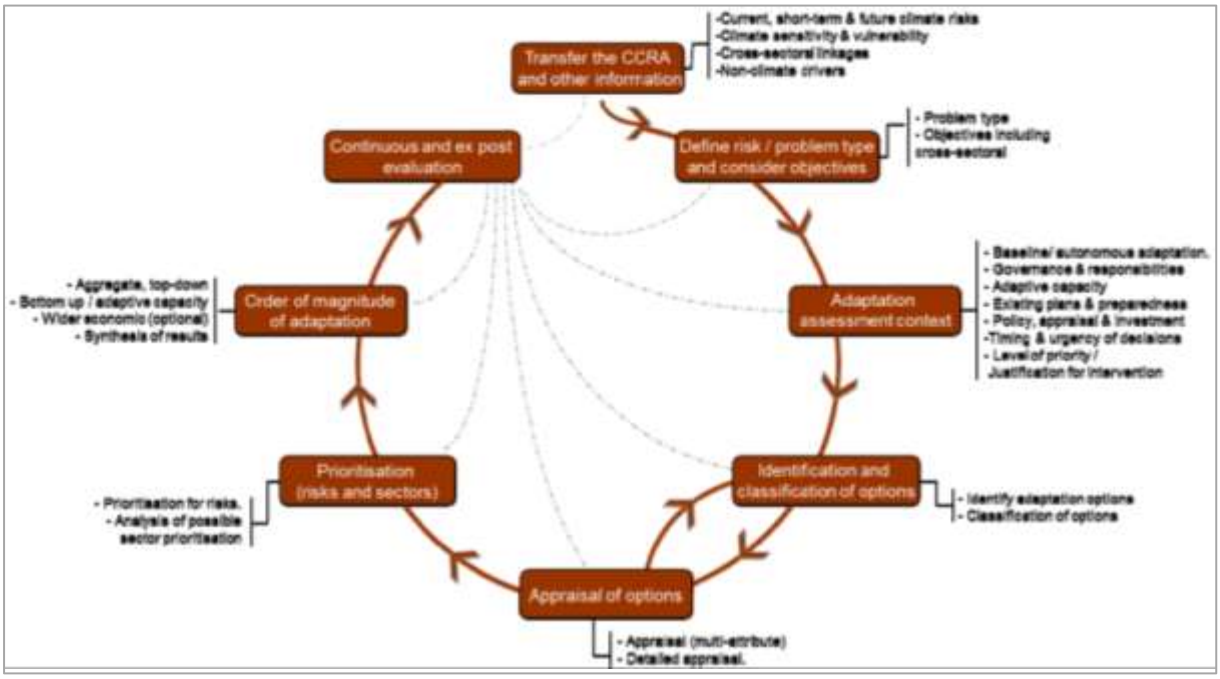

Figure 10. Different steps of the CCA method[49]

A similar 'National Adaptation Programme' (NAP) is being produced by each Tisza watershed country from the regional to the local urban level. Several studies have emphasized that the following methodological issues are key for these programmes:

- The need to explicitly consider uncertainty (climate and otherwise) in the analysis of adaptation, and to move to a framework of robust and flexible options and decision-making under uncertainty;
- The need to ground the analysis of adaptation options in the context of current vulnerability policy and the adaptive capacity of institutions, organisations and society.
- The need to consider adaptation as a process as well as an outcome and implement this through the consideration of options.
- The need to focus on a planned adaptation and on immediate, current and short-term actions, in the context of both short and longer-term risks;
- The need for an iterative approach, so that the adaptation is considered part of the current and future CCRA.
- The need to ensure that action is economically viable and appropriate at multiple levels, encouraging the flexibility and robustness of action on other scales.

The next figure illustrates the adaptation pathways concept. The starting point is the 'risks' that will potentially increase over time to a greater or lesser extent, depending on future scenarios and projections. These are then placed in the context of the sequential cycle of the CCRA and the NAP (policy cycles). Together, these provide the basis for an iterative cycle that allows subsequent information to be included to help redirect and inform adaptation over time. On the left – in green) are the early priorities. These are primarily focused on capacity building, no-regret options and early planning for long-term decisions (Figure 11).

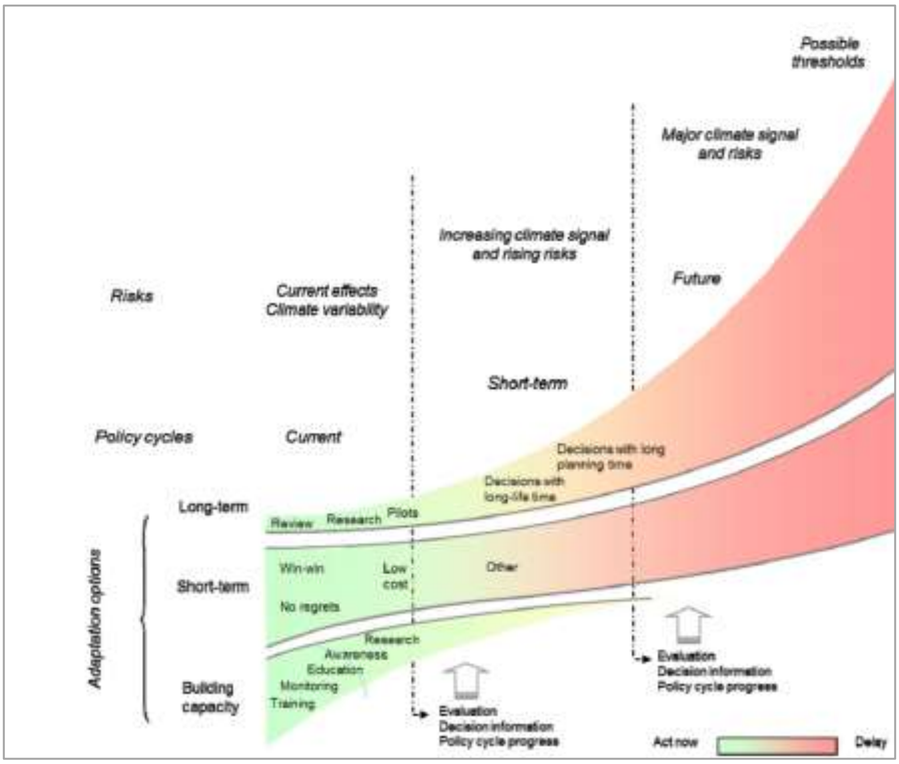

Figure 11. Pathway of Climate Change Adaptation [50]

It is important to note that the shape of each adaptation pathway will vary with each specific risk. There are key issues related to uncertainty, including across-the-climate projections, future socio-economic signals, vulnerability, the level of acclimatisation, impacts, etc. These translate into the analysis of adaptation benefits (the reduction of risks from specific options) and the residual impacts after adaptation. The classification of adaptation options into short and longer-term options and the used iterative pathways framework help address this uncertainty by focusing on options that are robust; along with the identification of different future options that may more or less be relevant as information on risks evolves over CCRA cycles.

d.) Stakeholders in urban water management

Stakeholder involvement should not be confused with a few public workshops or an isolated one-off awareness-raising campaign. Instead, it is a systematic and inclusive process of sharing responsibility for better urban water management in a strategic planning process[51]. The local governments of the River Tisza cities generally have a major responsibility in providing the space for water stakeholders to collaborate for better water management in a meaningful and effective fashion. Water authorities, as key stakeholders in the strategic planning process, are usually more concerned with the technical side of managing an urban water system.

The provision of a platform in which all stakeholders can talk to each other helps gain a better understanding of the different water uses in the urban setting (Figure 12). Once the ground rules for cooperation are established, developing a joint vision for water in the city increases the awareness of key issues.

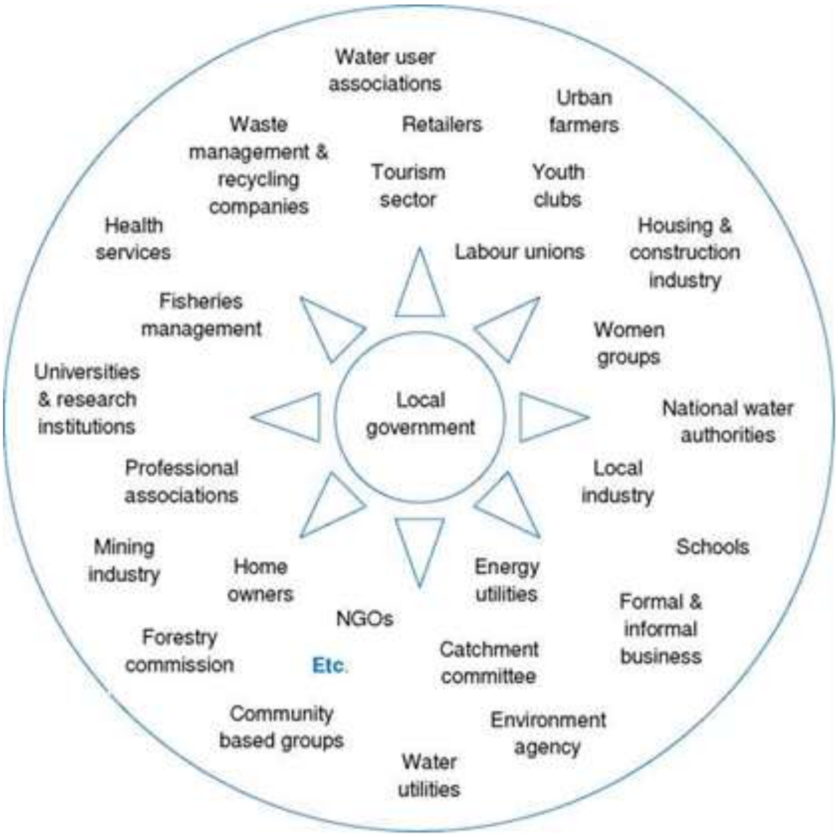

Figure 12. Water-related stakeholders consist of sometimes heterogeneous and fragmented pressure groups (source SWITCH)

Stakeholder categories in urban water management can be divided in different ways but in the planning process, the two basic groups are the following: Group a) is directly related to water (water supply, waste water treatment, stormwater management) and Group b) is indirectly related to water (land use planning, health service, parks and recreation, industry, commercial sector, etc.). Good coordination within the local administration as well as professional facilitation for involving external stakeholders are key for achieving successful outcomes from the planning process.

Nevertheless, individuals, households and communities have a crucial role in water management, and governments can play a critical role by establishing a framework that encourages and enables changes in behaviour that reduce the footprint of individuals (Figure 13).

A growing intensity of calls for more decision-oriented research has been evident in recent years, as priorities have moved from estimating impacts and vulnerabilities in order to make the case for mitigation, to adaptation planning. There are more decision-support tools to address different aspects of climate change. Social Cost-Benefit Analysis (CBA) can value all relevant costs and benefits of government and society in all options, and estimates the net benefits/costs in monetary terms based on climate sensitivity, which can be small compared to total costs/benefits if climate risk probabilities are known[52]. A Real Options Analysis (ROA) extends the principles of CBA in order to learn about the nature/extent of climate change and its impact on the adaptation option(s) being considered. This is incorporated through the estimation of the value associated with providing information that reduces the uncertainty related to climate risks[53]. Risk-Based Rules (RBR) Ranking (ordinal or cardinal) is guided by the risk attitude of decision-makers when climate risk probabilities are not well established or do not exist[54].

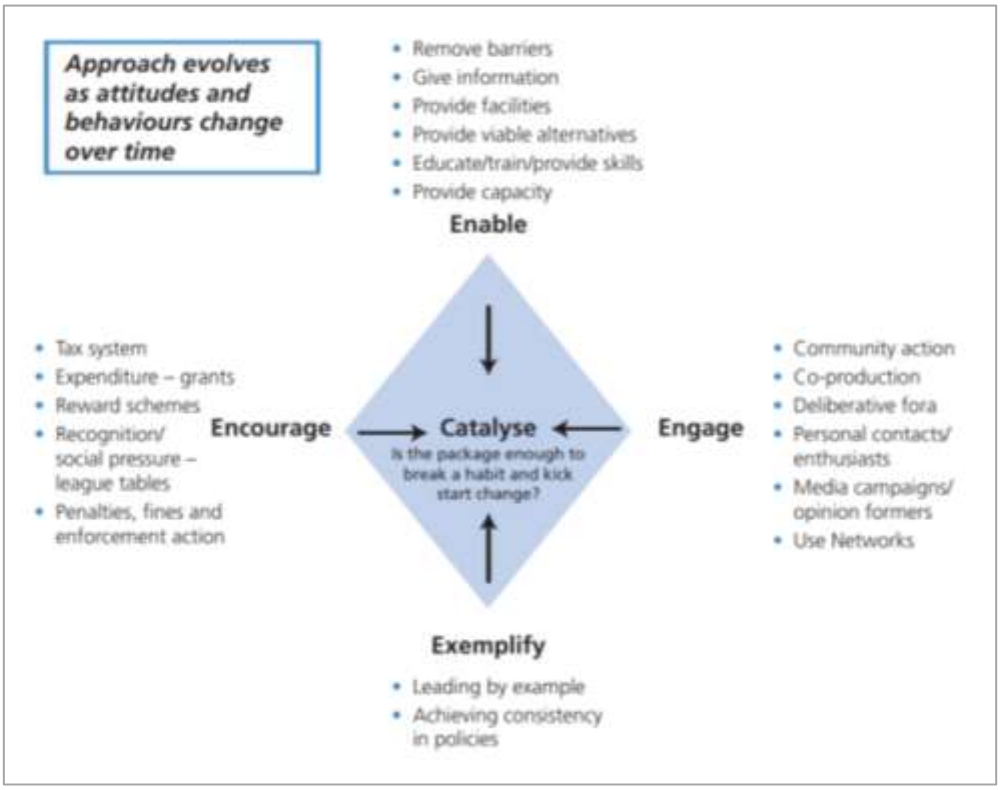

Figure 13. Stimulating actions by individuals[55])

e.) The need for effective stakeholder involvement

Stakeholder involvement has to be based on the principles of good governance including accountability, transparency and equity as well as mutual trust and respect. Literature on stakeholder involvement has become ubiquitous[56]. Sometimes, there are shortcomings in the practice of stakeholder involvement literature, such as the following. Stakeholders are composed of a number of hand-picked people that do not represent the sector at large; stakeholders are only invited during hot election periods to serve a questionable political agenda; researchers focus on their own scientific needs; the water-related institution initiating the stakeholder process lacks the professionalism to lead and coordinate it in all its dimensions in the long run, which results in frustration and 'stakeholder fatigue'; stakeholders are reduced to listeners without any mechanism for interactive feedback[57].

The call for stakeholder involvement in water management is based on the assumption that water can be managed 'better' if all those work together who either (1) have a say in this field; (2) are (major) water users themselves; or (3) are potential victims of poorly managed water. However, even if all those parties come together for a joint project, this does not mean that every voice is equally heard based on a set of legally-defined mandates specifying their rights and obligations[58,59,60,61]. The water authorities, water agencies and/or official water bodies disseminate information to the stakeholders – and often to the wider public – for various reasons. The information might just be intended to generally create a better understanding of water issues among citizens through one-way communication. Consultation processes (two-way communication) raise stakeholders' expectations that their views and suggestions will eventually be taken into consideration. If this is not the case, decisions taken and actions implemented by official bodies might be publicly questioned by stakeholders and, depending on political circumstances, they might have to be revised. The official water bodies carry out their tasks by sharing them with other stakeholders (multilateral partnership).

This might happen in the form of a partnership in which both sides have something to offer to each other. Empowerment is the highest level of involvement and refers to sharing power by sharing decision-making (multi-stakeholder decision-making). This requires that all involved parties meet each other as equals and have the desire, skills and legal mandate to share that power. The involvement of stakeholders can be organised in many different ways. In principle, informal processes can be set up by any recognised player in the field of water management that has enough professional or societal standing, meaning that the other stakeholders have enough trust and are keen to become a part of it. They are personally interested in improving the local situation and intrigued by experimentation and innovation. The advantage of informal processes is their relative freedom to organise themselves according to self-agreed rules. They typically provide for an open space for everybody to speak their mind without facing any threats of being penalized for controversial opinions. The disadvantages are that the group might be rather unstable, the participating people coming of their own accord without a formal mandate from their institution and stakeholders invited to participate but not interactively[62].

A formal process has to be initiated by one of the official water bodies or alternatively by an institution acting on behalf of an official body. In this case, the stakeholder process receives a recognised status in the local water governance system. Stakeholders are invited in their official capacity to represent their institution. The rules of discourse and the rights and responsibilities of the participants are clearly defined. The main shortcoming here is that the participants will be more 'careful' in how they contribute to the process, trying to avoid any undesired implications for their institutions ('decision-making is not in my responsibility).

The stakeholder process needs to be equipped with clear and measurable goals and these have to be monitored and evaluated regularly. Given the ever-rising complexity of urban water affairs, science and technology become increasingly important. The Learning Alliance (self-study) approach provides a format for involving researchers so that they can assist the identification of up-to-date and locally tailored solutions while also promoting a broader uptake of innovation and lessons learned.

f.) IUWM implementation

Strategy is the central milestone of the IUWM strategic planning process (Figure 14). If developed and accepted by all stakeholders and approved by the city council (or other relevant political body), the strategy becomes the guiding framework for all actors in their joint efforts to improve water management. Furthermore, it can also give direction to urban planning as a whole by informing the priorities and plans of other departments or sectors.

The phases of the strategic planning process will have to be adjusted to the local situation for which it is intended. No city will be starting from scratch and the process will have to be aligned with existing strategic planning initiatives in the city.

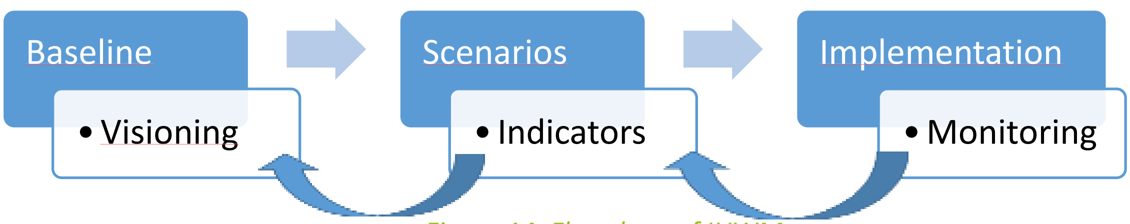

Figure 14. Flowchart of IUWM

Objectives are chosen based on what is required to move towards the overall goal, or 'vision', for urban water management. The successful achievement of an objective should therefore result in the city being closer to reaching its overall aim of increased sustainability. Indicators and targets need to be added to each objective in order to measure progress and quantify the desired change. These indicators and targets need to be realistic as well as easily measurable.

The key characteristics of a good indicator are the following: easy to access; easy to understand; timely and relevant; reliable and consistent; credible, transparent and accurate, and developed with the end-user in mind. The choice of indicators is per definition subjective. The scores of cities are dependent on data availability and quality mainly in the base line implementation phase.

3. Water supply (drinking water, industrial/commercial water, irrigation, thermal water)

a.) The conventional approach to water supply – sustainability problems

In the Tisza watershed, rainwater should be applied as a rediscovered water resource. During the past several decades, central municipal systems have been in operation in many places, but several factors have caused anxiety regarding water utilities such as infrastructure breakdowns, financing problems, stormwater runoff overcharging sewers, droughts, costs of moving and treating water, so rainwater as a source can bring something back to the urban hydrological cycle. Rainwater harvesting can allow water to be used at the source. More authors indicate that gardening has been a primary use, which keeps water treated according to potable standards from being used for this non-potable purpose[63]. Communities that promote the use of rainwater e alleviate stress not only on the water utility, but by requiring the treatment and distribution of less water. Energy utilities are also relieved of some of their load. Communities struggling with drought, and even some that have adequate precipitation but face the aforementioned challenges (infrastructure breakdowns, high treatment costs, etc.) can benefit[64].

Standardization is an important tool in the design and sustainability of a unified water supply framework. The EN 15975:2013 European Standard describes the principles of a risk management approach to improve the integrity of the drinking water supply system. This European Standard addresses all entities and stakeholders sharing responsibility in the provision of safe drinking water throughout the entire supply chain from the source to the point of use. Part 1 of the EN 15975 standard focuses on crisis management (06/2011). It describes the fundamentals of crisis management, including relevant recommendations for drinking water suppliers and offers examples drawn from disaster and crisis management. Part 2 of the standard describes risk management (08/2013): it incorporates fundamental elements of the WHO Water Safety Plan (WSP) approach (2004) and supports water suppliers in order to actively address safety issues in the context of routine water supply management and operations. Implementing a risk-management approach is of added value, since it supports the systematic evaluation of the drinking water supply system, the high performance of the system management as well as the identification and prioritisation of the improvement and the upgrading of needs. Furthermore, it improves communication among stakeholders, particularly those sharing responsibility for the water supply chain. The overall drinking water risk-management approach employs the more general principles of value analysis, which can be applied across many fields of business activity. This approach helps reinforce the significance of drinking water supply risk-management within the organization[65].

The degree of implementation of WSPs and of their impact on drinking water quality varies significantly between European countries. The preliminary results of a WHO/IWA global and regional survey on WSP concerning Europe were presented at the IWA Berlin workshop in 2014 with the following outcome.

- Approximately 40% of all countries in the WHO European Region have experiences with WSPs,
- Approximately one third of all countries in the WHO European Region have national scale-up strategies for WSP implementation and
- In approximately 1/10 of all countries in the WHO European Region, WSPs are actively enforced[66].

The Eurostat definition of water use refers to water that is actually used by end users for a specific purpose within a territory, such as for domestic use, irrigation or industrial processing and excludes returned water[67].

b.) The issues facing the conventional approach to water supply and barriers to an integrated water supply

The traditional water supply system focuses on the safety of water extraction and preparation, based on control limits that take into account the local characteristics of the water supply to a lesser extent. This makes the system more expensive and non-flexible in the case of hazardous circumstances. Many cities have centuries of historical background of water supply systems. Their construction, the materials used and their current state are very mixed and different. This is also the case for cities in the Tisza River Basin, although significant developments have been made in the EU Member States. The leakage loss of asbestos and lead-containing networks is also a problem in many instances. The leakage is estimated to be about 20-30% around the world, but cities with over 50% loss are not rare. The terrain and the saturation of the pipeline can also be very varied, which pose significant risks with the infiltration of waste water into the ground water. The quality of different water sources is different, requiring different treatment systems. In the Tisza River Basin, sand, iron and manganese, methane, arsenic and other organic and inorganic contaminants are also regular issues in the urban water supply. Nowadays, water purification plants can maintain limit values in drinking water in most places, but there are risks due to the very long pipe network in varied technical condition. Thus, depending on the water source, the cost of drinking water can be 3-7 times higher in certain cities, resulting in conflicts between regions. Therefore, the introduction of an integrated drinking water management approach and practice is an urgent task everywhere in the world.

The European water service providers have to implement the Preventive Drinking Water Risk Management (PRM) system, referred to in the WHO Guidelines as Water Safety Plans (WSP)[68]. The Guidelines are primarily addressed to water and health regulators, policy makers and their advisors, to assist in the development of national standards. The Guidelines and associated documents are also used by many others as a source of information on water quality and health as well as on effective management approaches.

EUREAU is the European federation of national associations of drinking water suppliers and waste water services. Their members collectively provide sustainable water services to around 405 million European citizens. The vast majority of the 70,000 supplies represented by Eureau are small supplies. A position paper of Eureau in PRM suggested an effective and transparent PRM, together with an independent verification process, which requires the participation of all stakeholders. The combined effect of the 3 components, highly emphasized for safe drinking water from catchment to consumer, starts with:

- an effective protection of resources designated for drinking water supply (groundwater, spring water, rivers, dams and lakes), under the responsibility of the catchment authorities.
- drinking water intake, treatment and distribution, should be based on a professional management system related to codes of practices, due diligence and well-trained staff/operators,
- maintaining the high quality of drinking water up to the consumer’s taps needs their domestic installations to be properly designed, installed and maintained, according to a PRM approach, under the owner’s responsibility[69].

WHO Guidelines for drinking water describe the reasonable minimum requirements of safe practice to protect the health of consumers and derive numerical “guideline values” for the constituents of water and the indicators of water quality. When defining mandatory limits, it is preferable to consider the Guidelines in the context of local or national environmental, social, economic and cultural conditions. The Guidelines should be part of an overall health protection strategy that includes sanitation and other strategies, such as preventing food contamination. This strategy would also normally be incorporated into a legislative and regulatory framework that adapts the Guidelines to address local requirements and circumstances. The main reason for not promoting the adoption of international WHO standards for drinking water quality is the advantage provided by the use of a risk-benefit approach (qualitative or quantitative) in the establishment of national standards and regulations. Moreover, the Guidelines are best used to promote an integrated preventive management framework for safety applied from catchment to consumer. The Guidelines provide a scientific point of departure for national authorities to develop drinking water regulations and standards appropriate for the national situation. In developing standards and regulations, care should be taken to ensure that scarce resources are not unnecessarily diverted to the development of standards and to the monitoring of substances of relatively minor importance to public health. The approach followed in these Guidelines is intended to lead to national standards and regulations that can be readily implemented and enforced as well as protective of public health. The nature and form of drinking water standards may vary among countries and regions. There is no single approach that is universally applicable. It is essential in the development and implementation of standards that the current or planned legislation relating to water, health and local government is taken into account and that the capacity of regulators in the country is assessed. Approaches that may work in one country or region cannot necessarily be transferred to other countries or regions. It is essential that each country review its needs and capacities in developing a regulatory framework. The judgement of drinking water safety or the question of what is an acceptable level of risk in particular circumstances are matters in which society as a whole has a role to play. The final judgement as to whether the benefit resulting from the adoption of any of the guideline values as national or local standards justifies the cost is up to each country to decide.

The basic and essential requirements to ensure the safety of drinking water are a “framework” for safe drinking water, comprising health-based targets established by a competent health authority, adequate and properly managed systems (adequate infrastructure, proper monitoring and effective planning and management) and a system of independent surveillance. Water quality is influenced by all elements of the water supply system. The best available water quality is not the same as the legal thresholds or limits, but determined by local technology.

A preventive, holistic approach to the risk assessment and risk management of a drinking water supply increases confidence in the safety of the drinking water. This approach entails the systematic assessment of risks throughout the drinking water supply, from the catchment and its source water through to the consumer, and identification of the ways in which these risks can be managed, including methods to ensure that control measures are working effectively.

The German water safety plan (WSP) approach to the WHO guideline comprises hazard analysis, risk assessment and systematic process control. It is an operational quality management concept based on the Best Available Practice. The first step of the WSP approach is for the senior management of the water supply to assemble a team. The WSP-team is responsible for independently developing a WSP and for implementing it in the routine operation of the supply. A committed team, which is capable of acting and which encompasses the expertise required for a comprehensive risk assessment, is a prerequisite for successful WSP implementation. The description of the water supply system is the basis of every WSP. It has to cover the catchment area, abstraction, treatment, storage and the distribution system, including pumping stations and pressure boosting systems. The system assessment consists of a hazard analysis and a risk assessment. In WSP terminology, a hazard is any biological, chemical, physical or radiological agent in the water supply system that may cause harm to public health. Hazardous events in the WSP context are incidents or situations which cause hazards to occur in the drinking water supply. As part of the risk assessment, the WSP team evaluates the risk caused by every identified hazardous event. A risk comprises the two aspects of likelihood to occur and the potential severity of the consequences. The key questions for risk assessment are "What hazards and hazardous events are significant?" and "What is important and why?"

Measures for controlling the risks ensure the quality of the drinking water and the reliability of the water supply. Such measures include all actions, activities and processes intended to permanently eliminating or reducing risks. In this step, the team also has to check and confirm to what extent the existing measures actually control the risks. This means answering the question: "Is the chosen measure suitable and effective?" for each measure identified. Should this validation process show that the already existing measures are not sufficient to control the identified initial risk, action for improvement or upgrade needs to be adopted, and the team should change, optimise, complement or replace the measures respectively. If the validation indicates that measures are absent, the team should identify and implement suitable technical, organisational or staffing measures.

Operational monitoring comprises regular planned inspections, controls or measurements of selected parameters. It aims at ensuring that the control measures have been implemented and are operating effectively and according to plan. Operational monitoring is NOT the same as testing the 'end product' drinking water in accordance with the requirements of the German Drinking Water Ordinance, but includes parameters that can be easily measured or observed and for which the measurement results are, if possible, instantly available. Its purpose is to show that a measure is working within its operational limits (e.g. turbidity at a filter effluent). The next step is verification, an integral part of a WSP in order to confirm that the limit values and requirements of the German Drinking Water Ordinance and water supply goals are attained. Verification means the traditional end product testing of drinking water in terms of regular control by the water supply utility when the water leaves the waterworks and within the distribution system. This end product testing should not be mistaken for operational monitoring. It is important that the team documents the results of each WSP step as well as the underlying considerations. The type and extent of the documentation vary, depending on the tasks and the size of the water supply. A WSP is never "completed", but should be continually and regularly updated and improved by the team. The aim of this planned, periodic review is to "step back to see the bigger picture" in order to confirm the validity of the WSP[70]. The engagement of customers and stakeholders are fundamental in order to achieve an understanding of mutual priorities and needs to develop WSP in the cities.

Different water categories must be distinguished for human consumption, such as natural mineral water, well water, medicinal water and drinking water. Each of these is regulated by legislation that must be obeyed by bottlers and distributors. Natural mineral waters may be distinguished from ordinary drinking water by their purity at the source and their constant level of minerals. Spring waters are intended for human consumption in their natural state and are bottled at the source. Directive 2009/54/EC regulates the marketing and exploitation of natural mineral waters. Certain provisions of this Directive are also applicable to spring waters such as microbiological requirements and labelling requirements. Commission Directive 2003/40/EC of 16 May 2003 establishes the list, concentration limits and labelling requirements for the natural mineral waters and the conditions for using ozone-enriched air for the treatment of natural mineral waters and spring waters[71]. Medicinal waters, which have a proven medicinal effect, can be either cold or hot and they are suitable for both bathing and drinking.

In addition, the excess water that remains on the surface and the used thermal water, due to its high temperature and considerable salt and organic material content, increase the pollution level of underground and ground waters as well as the soil, thus endangering the delicate balance of the natural ecosystem[72]. High salt content is extremely dangerous if thermal water, mixed with plain water is used for irrigation. It leads to salinification. The best way to store used thermal water is in special closed tanks and later pumping it back to its source[73]. The protection of our underground waters should take priority over local economic interests.

Tap water is water which is either spring water, water coming from below the ground or is collected on the surface and prepared, i.e. filtered and cleaned before being channelled into the pipes. Its quality parallels the limit values by definition of the law. In order to provide consumers with tap water paralleling provisions in force, water service companies use different water treatment technologies, if needed. In households, carbonated or soda water is simply drinking water saturated with carbonic acid, enriched with carbon dioxide and unobjectionable from the bacteriological and chemical aspect. It is a popular drink and is distributed in soda water siphons or refillable plastic bottles[74].

The other important groundwater resource is geothermal water. Geothermal water resources play many important roles such as providing energy, heating or spa water. The geothermal potential of the Pannonian Basin is outstanding in Europe, as it is situated on a characteristic positive geothermal anomaly, with heat flow density ranging from 50 to 130 mW/m^2 with a mean value of 90-100 mW/m^2 and a geothermal gradient of about 45 °C/km[75].The joint assessment of geothermal resources is important, as many of the large hydro-geothermal reservoirs in the Danube Region are in transboundary settings, where the abstraction of thermal groundwater may have negative impacts (depletion or overexploitation, even environmental issues) without harmonized cross-border management[76].

The overexploitation of some geothermal aquifers is a potential problem in several Tisza river countries. Furthermore, as the number of users (recreation, greenhouses, energy production) is increasing, potential interference among the different sites and disputes between nearby users may also arise. Therefore, users, national authorities and regions should establish unified and objective monitoring systems for geothermal resources as soon as possible, by controlling the groundwater level, temperature, yield and chemical composition of the thermal water. In most of the countries, the lack/low level of reinjection is a straightforward consequence of the low level of use for energy purposes[77]. Reinjection wells require a large investment cost which, without suitable financial support, is not feasible for most users. However, thanks to the positive effects on aquifer hydraulic conditions and the mitigation of environmental pollution, reinjection into the same aquifer should be required of all users utilising non-treated thermal water for the purpose of geothermal energy utilization[78].

If we compare the two most relevant EU Directives (Renewable Energy Directive - RED and WFD) in relation to hydro-geothermal resources, the different objectives, measures and time frames of the policies are striking. The WFD is focusing on the protection of resources (i.e. achieving and maintaining the good status of waters by 2015), while the RED puts the maximum utilization of resources in focus, in line with the target numbers of the National Renewable Energy Action Plans (NREAP).

The directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration (adopted 12 December 2006 – Groundwater Directive - GWD) definitely establishes the “emission” principle. This means that any pressure (emission, input) to the water body should not cause any significant actual or future impact on the groundwater body. Any direct discharges of pollutants into groundwater are prohibited, while the reinjection of water used for geothermal purposes into the same aquifer may be authorized under specific conditions provided that such discharges do not compromise the good quality status of groundwater[79].

As thermal groundwater aquifers/groundwater bodies constitute hydro-geothermal reservoirs, it is obvious that during the exploitation of hydro-geothermal reservoirs (for energetic purposes), the main principles of the WFD of keeping the aquifers at good quality and quantity status have to be taken into account. Thermal groundwater abstraction could provoke the alteration of natural water level regime in such a way that the discharge of natural springs is diminished. The overexploitation of thermal groundwater could cause the “mining” of water resources (no natural replacement from recharge) and therefore the decreasing of available groundwater resources could cause the intrusion of less suitable water from neighbouring aquifers. The good chemical status of groundwater is achieved when the concentration of pollutants does not exceed the quality standards, nor diminish the ecological quality of surface water or cause any significant damage to terrestrial ecosystems. These provisions are less relevant to deep-seated thermal groundwater. Nevertheless, the quality status of groundwater becomes an important aspect when considering the reinjection of thermal waste water, which has to be taken into account during the utilization of geothermal energy around the urban areas. The International Geothermal Association published the Best Practices Guide for Geothermal Exploration with an outline of various methodologies and strategies employed in the exploration of geothermal resources for power generation. This is performed within the context of typical geothermal development process, recognizing that the most appropriate exploration tools strongly depend on the geological setting of the project[80].

Geothermal energy utilization is diverse within variable geological settings in the Tisza watershed. At present, there is no internationally accepted standard protocol to estimate and report the potential of geothermal energy. In Slovakia, the smallest number of geothermal installations is located in the eastern part of Slovakia – in Košice County. On the other hand, the Košice depression is one of the most prospective areas of Slovakia with possibilities of using high temperature waters for electricity production in the future[81]. Geothermal energy in Serbia has a significant potential to contribute to the national energy balance, especially in power generation. For intensive use of thermal waters in agro- and aquacultures, balneology and in district heating systems, the most promising areas are the Subotica region and west of Belgrade[82].

The well-known geothermal resources in Romania are the geothermal aquifers under the Pannonian Plain. The main direct uses of geothermal energy are district heating (106 MWth/148GWhth/y), greenhouse heating (8 MWth/50GWhth/y), bathing, using about 40 wells in 16 spas, with a capacity of over 850,000 people/annum, industrial process heat, fish farming and animal husbandry. The annual utilization of geothermal energy in Oradea represents almost 35% of the total geothermal heat produced in Romania. Geothermal-based power production also exists (Oradea) with a 0.05 MWe installed capacity producing 0.4 GWhe/annum.

In Hungary, geothermal power production does not exist yet. Traditionally, the geothermal energy production of the country focuses mainly on the direct heat, with most of the thermal water used in spas.[83]. The majority of the abstracted water is used in balneology (265 MW_{th} / 5285 TJ/a). In direct heat utilization, the main sector is agriculture (241.84 MW_{th}/2800 TJ/a). About 75% of the resources are used for heating greenhouses and polytunnels and the rest for animal husbandry (Figure 24). As of 2011, geothermal energy contributed to the heating of 19 settlements in Hungary. Industrial use was relatively low[84].

Although all countries of the Tisza basin have profound knowledge of their geothermal resources, the available information is still not sufficient. Both geothermal developers and decision makers require detailed and up-to-date, scientifically based information on the available geothermal resources.

Several authors reported a set of technical problems, which are associated with the low thermal and utilization efficiency of the existing wells. However, their improvement would lead to a reduction in the total amount of abstracted thermal water[85]. With the more widespread use of heat pumps, a great proportion of the heat content could be still utilized, which is otherwise wasted. Geothermal resources can be utilized in the most efficient way in cascade systems, where the plants are connected in a series, each utilising the waste water from the preceding one (e.g. electricity generation –> industrial uses –> district heating –> agricultural applications) (Figure 15).

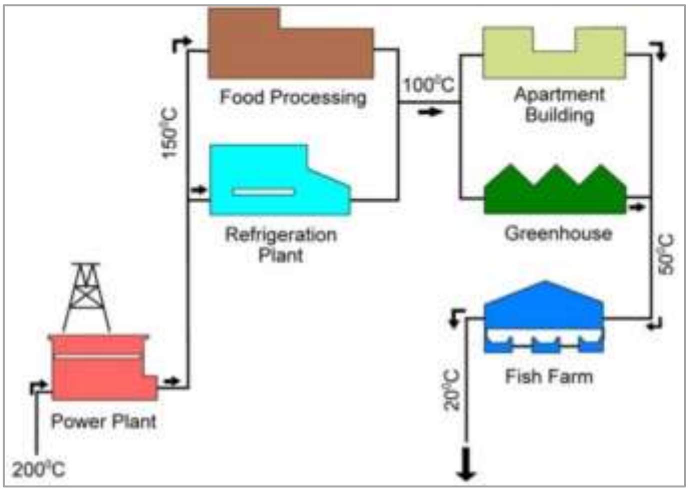

Figure 15 Cascade uses of geothermal energy[86]

Neither application of the cascade systems is widespread, although it would have a direct impact on decreasing the need for additional thermal water, thus increasing utilization efficiency[87]. As the lifetime of a geothermal project is quite long (15-30 years), stable and reliable political and economic conditions are essential[88]. The chemical composition of thermal water is imperative in its utilization, application and storage. Due to the high temperature, the dissolved salt content is higher than in surface waters and it contains several inorganic and organic components which do not occur in the lower temperature vadose waters or in natural groundwater. In the Pliocene Pannonian basin, the waters often contain significant amounts of organic content in the form of short chain aliphatic acidic anions, phenol and benzol/benzine[89].

When analysing the most important non-technical barriers, we can see that the management of geothermal resources is shared between different ministries and authorities, most commonly between the “environment/rural development” sector, which deals with the abstraction of thermal groundwater and the “energy/industry/economics” sector, responsible for geothermal energy utilization without water production[90]. A major missing instrument is a risk insurance system that would help to mitigate the high initial costs of a geothermal project, where the risks are the highest at the stage of drilling the first wells. The possible negative impacts of geothermal energy production, such as significant slowdowns of the thermal projects, are often highlighted and misinterpreted without emphasizing its definite advantages. The EGEC Geothermal Market Report 2016 shows that over the last five years (2012-2016), the use of geothermal energy, particularly for heating, has slowly but steadily increased across Europe[91].

As explained above, the drinking water, mineral water, medical water and geothermal water sources would also be treated in an integrated urban water hydrological loop.

c.) Linkages between waste water supply and other urban management sectors

The overall control goal for urban stormwater management is to ensure minimum impacts with regards to flooding, erosion and the dispersal of pollutants within and downstream of the urban environment (Figure 16).

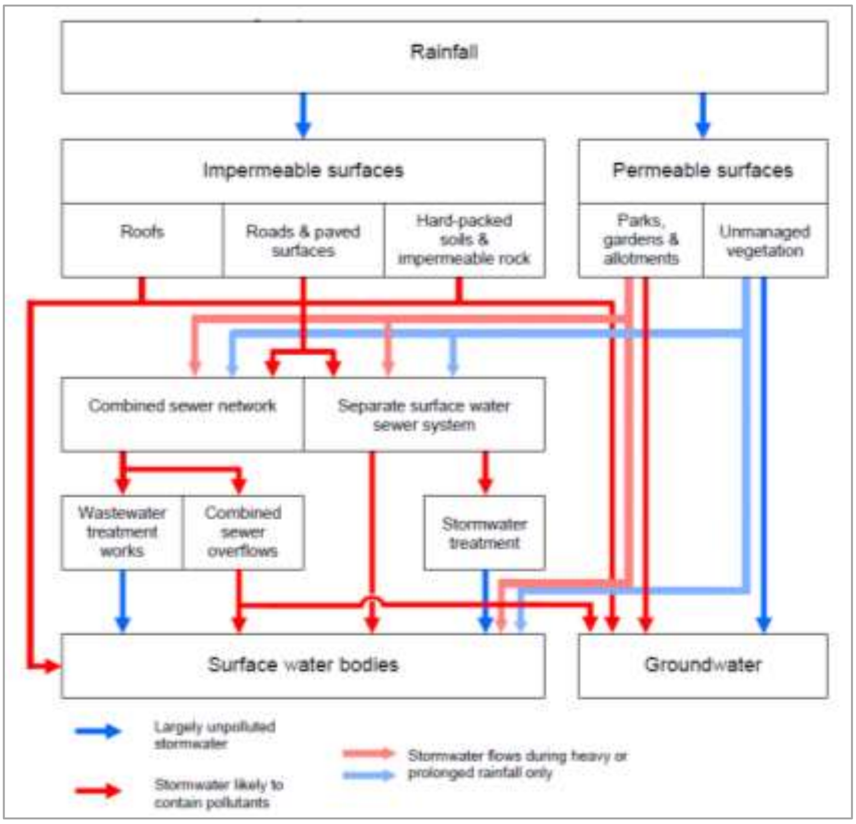

Figure 16. Stormwater and urban water bodies (Source: SWITCH)

The conventional approach to managing urban stormwater is to convey it away from the city as quickly as possible using drainage channels and underground pipes. Sustainable stormwater management highlights the limitations of conventional urban drainage and explores an alternative, more integrated approach to treat stormwater as a resource. Conventional stormwater systems are not well suited to the uncertainty of climate change and in many cities, the existing infrastructure may prove to be inadequate.

Sustainable stormwater has the potential to provide tangible benefits for a city, including flood risk management, environmental protection, urban greening and the provision of an alternative source of water supply. The important differences between the conventional approach to stormwater and a more sustainable one are intensive disposal versus attenuation and reuse; hard engineering infrastructure versus green/blue infrastructure (Table 5).

Most urban stormwater systems in the Tisza watershed were designed on the basis of historical meteorological data and predicted urban development patterns. The infrastructure commonly used to collect and convey stormwater according to the conventional approach includes drains, pipelines and drainage channels made of concrete and earth. In combined systems, collected stormwater is mixed with human and industrial waste water flows and treated at centralised sewage treatment plants. In separated systems, stormwater is discharged directly at high volumes to receiving water bodies. In combined systems, discharges occur as treated effluent from waste water treatment plants.

Some of the issues currently facing urban stormwater management are the following. Heavy rainfall causes combined sewers to exceed capacity resulting in the overflow of untreated waste water to the environment. Non-point source pollutants such as heavy metals and oils from roofs, roads and car parks, as well as nutrients, pesticides and herbicides from gardens, parks and allotments are dispersed by runoff into receiving water bodies. Increases in impermeable surfaces deplete aquifers by reducing natural recharge. High velocity runoff causes erosion and increased sedimentation in receiving streams, rivers and estuaries as well as reduces evapotranspiration, which results in a warmer urban microclimate when combined with the heating effect of a sealed surface. The end-of-pipe treatment of stormwater may be costly and energy intensive. The rapid collection and disposal of stormwater into receiving water bodies such as rivers and streams increases the risk of downstream flooding. The intensive drainage of stormwater from urban areas prevents it from being used for urban landscaping or as non-potable water supply.

Table 5. The main differences between conventional and sustainable stormwater management

Aspect of stormwater	Conventional approach	Sustainable approach
Quantity	Stormwater is conveyed away from urban areas as rapidly as possible.	Stormwater is attenuated and retained at the source, allowing it to infiltrate aquifers and gradually flow into receiving water bodies.
Quality	Stormwater is treated together with human waste at centralised waste water treatment plants or discharged untreated into receiving water bodies.	Stormwater is treated using decentralised natural systems such as soil, vegetation and ponds.
Recreation and amenity value	Not considered	Stormwater infrastructure is designed to enhance the urban landscape and provide recreational opportunities.
Biodiversity	Not considered	Urban ecosystems are restored and protected by the use of stormwater to maintain and enhance natural habitats.
Potential natural resource	Not considered	Stormwater is harvested for water supply and retained to support aquifers, waterways and vegetation.

Producing drinking water from waste water does not seem to be a basic water management issue in the Tisza River Basin because of the relative abundance of water resources. However, there have occasionally been examples in the past when the drinking water supply was disrupted by various causes (water pollution, droughts, technical causes) or water restrictions were required. In the future, these risks will not disappear, so integrated urban hydrology must be prepared with different risk mitigation options. In terms of water use, it is necessary to distinguish planned and unplanned potable reuse.

Direct potable reuse (DPR) occurs when water intakes draw raw water supplies downstream from discharges of clean water from waste water treatment plants, water reclamation facilities or resource recovery facilities. For example, if you are downstream of a community, that community's used water is released into a river or stream and carried downstream to your community; after further treatment it becomes part of your drinking water supply. In Indirect Potable Reuse (IPR), water is blended with other environmental systems such as a river, reservoir or groundwater basin before the water is reused. Direct Potable Reuse water is distributed directly into a potable water supply distribution system downstream of a water treatment plant, or into the source water supply immediately upstream of the water treatment plant.

Potable reuse can produce large volumes of drinking water from waste water available from established collection systems in inland locations. In addition, it can reduce the negative impacts of microbial hazards and in some cases, nutrients from waste water discharges on marine and freshwater environments (Table 6). Urban settlements represent the main point sources of coastal and riverine water pollution with waste water discharges being significant contributors[92].

Table 6. Advantages and challenges of potable reuse

Advantages	Challenges
Climate-independent water supply. Existing collection systems and, in many cases, established conventional treatment processes in close proximity to population centres. Reduced environmental impacts from discharges (particularly from microbial hazards and in some cases from nutrients). Typically less expensive than seawater desalinization. Growing public acceptance.	Source waste waters are very poor quality with high concentrations of microbial pathogens and can potentially contain a broad range of chemical contaminants. Generally requires the use of complex treatment processes and a high level of technical expertise and understanding. Consequences of failure could be serious. While public acceptance is growing, concerns about the use of waste water as a source of drinking water need to be addressed by education and public participation.

Planned potable reuse typically includes the extensive monitoring of the receiving waters, while this is less common or less frequent in unplanned potable reuse. Although the volume contribution of unplanned reuse is often low, there are examples where waste water represents a substantial proportion of river flows, particularly during low flows[93]. The important point is that whatever the source water, the end product should meet drinking water quality requirements. This can best be achieved through developing and implementing risk-based WSPs incorporating control measures based on the multiple-barrier approach, to collectively deal with identified risks to ensure that health-based requirements are met[94].

A key to the successful implementation of potable reuse is planned and targeted public engagement to build acceptance, confidence and trust. Critical steps in the process are the agreement that drinking water supplies require augmentation with new water sources and that after the consideration of plausible alternatives, potable reuse is the preferred and accepted choice.

In the Tisza River Basin, drinking water quality is generally provided for households independently of their water use goal. In many areas of the EU, tap water is often not suitable for drinking, but water providers can supply water sufficient for other purposes (e.g. sanitation, washing). Taking into account the changes in consumer habits regarding drinking (the consumption of mineral water, the increase in purification costs and the high construction costs of a dual system (drinking water - potable water), it is expected that conventional urban water supply needs will have to be re-considered in both quantitative and qualitative terms.

d.) Sustainability objectives and indicators for water supply, options for sustainable water supply

Urban sustainability indicators are tools that allow city planners, city managers and policymakers to gauge the socio-economic and environmental impact of, for example, current urban designs, infrastructures, policies, waste disposal systems, pollution and access to services by citizens. They allow for the diagnosis of problems and pressures, and thus the identification of areas that would profit from being addressed through good governance and science-based responses. They also allow cities to monitor the success and impact of sustainability interventions. The indicators are a key tool for driving science-based urban planning and management as well as vary in their fundamental purpose, their approach to measuring sustainability, their scale, and of course, their selection of indicators. According to the FAO, without good data based on monitoring, it is not possible to develop indicators and performance measures imply that targets need to be set. Urban hydrological indicators must be able to take into account different multi-scale locations, timescale, people, cultures and institutions, which are robust and easy to interpret. The measurement of indicators tends to reduce uncertainty and to mitigate vulnerability. In a scenario of increased climate variability and climate change, the indicator-based framework could show what would be the average loss or gain per unit of available water resource recorded in terms of economic, social and environmental contributions of the sector to changes in water availability[95]. Indicators are most useful in sustainability planning when linked to sustainability thresholds or targets. Thresholds are scientifically determined points where the state of things would change dramatically. Targets are often determined by policy makers or through public consultation and point to levels that must be met in the future if sustainability goals are to be reached. There are a number of issues associated with the selection, use and reporting of sustainability indicators[96].

The challenge for urban authorities is to decide which tool best addresses the needs and goals of a particular city, which would be easy to implement and worth the financial and human effort.

Hereinafter, we will present some of the indexation solutions that address the sustainability of water resources and are globally usable and robust. To implement the tools in your city, please visit their websites[97].

City Blueprints is the tool that consists of 24 indicators, subdivided into eight broad categories: water security following the water footprint approach; water quality, which includes surface water and groundwater drinking water; sanitation; infrastructure; climate robustness; biodiversity and attractiveness and governance. City Blueprints attaches a score of 0–10 to each indicator, where 0 indicates poor performance and 10 indicates excellent performance requiring no further attention. The output of the tool is a spider-web diagram that clearly indicates regions of good performance or concern[98].

The overall aim of City Blueprints is to provide European city managers and other stakeholders with the base knowledge to implement integrated urban water management and thereby contribute to overall sustainability[99]. The City Blueprint is a practical communicative tool that can help cities on their path to be become sustainable, water-wise cities. The City Blueprint Approach is a diagnostic tool consisting of three complementary frameworks. The main challenges of cities are assessed with the Trends and Pressures Framework (TPF). How cities manage their water cycle is assessed with the City Blueprint Framework (CBF). Where cities can improve their water governance is assessed with the Governance Capacity Framework (GCF). The 12 descriptive trends and pressure indicators are scaled from 0 to 4 points, using the following values: 0-0.5 points: no concern, 0.5-1.5 points: little concern, 1.5-2.5 points: medium concern, 2.5-3.5 points: concern, 3.5-4.0 points: great concern. The overall score, the Trends and Pressures Index (TPI) provides a basic overview of the social, environmental and financial pressures.

The CBF indicators are divided into the following seven categories: water quality, solid waste treatment, basic water services, waste water treatment, infrastructure, climate robustness and governance. The performance-oriented set of indicators provides a snapshot of the current water-related performances. The indicator scores of each city are shown in a spider diagram (Figure 17).

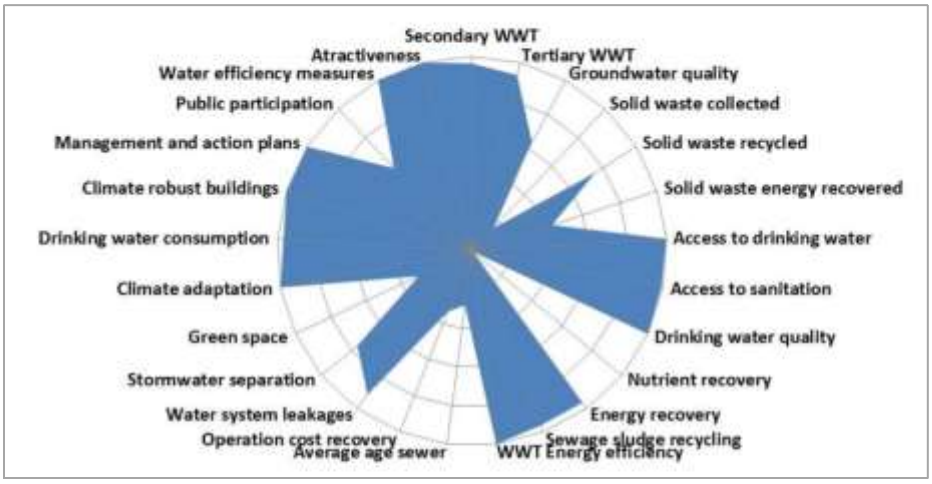

Figure 17. City Blueprint Framework indicators[100]

The Blue City Index is the overall score of the 25 indicators which vary from 0 to 10 points. The BCI shows profound differences between cities. Moreover, cities with a lot of pressure (cities that have a high TPI) are cities with low BCI performance scores. The Governance Capacity Framework focuses on 5 water-related challenges: 1) flood risk, 2) water scarcity, 3) urban heat islands, 4) waste water treatment and 5) solid waste treatment. These are amongst the most pressing issues that will steadily increase in importance due to global trends of climate change and urbanization. So far, City Blueprints have only been used to evaluate the capital cities of the countries, but may be extended to major cities of the Tisza watershed.

City authorities and state governments use the City Benchmarking Data method to measure and quantify performance. In 31 different segments of urban management, there are a series of standard indicator data produced with the "2thinknow" method[101]. This can also help to plan better cities, quantify the value of services or to promote civic achievements.

Sustainable Cities International works with local and regional authorities to help them develop governance approaches, organizational strategies, strategic planning processes and project implementation strategies. One goal of the framework is to create a tool kit that will support cities in the process of identifying which sustainability indicators they can use to accurately reflect the progress of their sustainability plans. The Indicators for Sustainability report concluded that the approach to selecting indicators generally falls into two general categories: top-down or bottom-up. The top-down approach means that policy makers define the goals and accompanying indicators, and that the data collected is usually highly technical and requires experts to interpret. The bottom-up approach is community-based and involves extensive consultation with stakeholders to select appropriate indicators. The key difference in the two approaches is complexity. Top-down processes involve more tools that permit greater depth of analysis, while bottom-up processes are more basic and broad. It is possible to combine the approaches to create a hybrid approach; however, this depends on the context.

The Urban Audit consists of hundreds of Eurostat variables stored in an Urban Audit database. Participation in the Urban Audit is voluntary and cities can join the audit by contacting Eurostat. The Reference Guide documents the metadata of the individual Urban Audit data collected at three spatial levels: cities, sub-city districts and larger urban zones (LUZ). The Guide provides users of the individual data with an insight into the range of different methodologies used by National Statistical Institutes in the data collection phase and, as a consequence thereof, to the extent to which the statistics collected for the various European cities can be viewed to be comparable. Moreover, it enables them to assess the validity of indicators which have been constructed by using individual statistics as a base. Further information on each of the indicators is available in the Urban Audit Reference Guide102.

The European Environmental Agency has studied the possibility of developing an Urban Metabolism indicator system based on publicly available municipal datasets generated with a headline data set of 15 indicators, chosen to be representative of the larger set[103]. It is informative at the European level rather than at an individual city level[104].

It is also interesting to evaluate the Ecosystem services. These are defined as services provided by the natural environment that benefit people. Some of these ecosystem services are well-known, including food, fibre and fuel provision, along with the cultural services that provide benefits to people through the recreation and the cultural appreciation of nature. Other services provided by ecosystems are not so well-known. These include the regulation of climate, the purification of air and water, flood protection, soil formation and nutrient circulation. The Millennium Ecosystem Assessment (MA) identifies four broad categories of ecosystem services: provisioning services; regulating services; cultural services and supporting services. Regulating services, i.e. benefits obtained from the regulation of green-blue urban ecosystem processes, are the following. Air quality maintenance: ecosystems contribute chemicals to and extract chemicals from the atmosphere. Climate regulation: for example, land cover can affect local temperature and precipitation; global ecosystems affect greenhouse gas sequestration and emissions. Water regulation: ecosystems affect e.g. the timing and magnitude of runoff, flooding, etc. Erosion control: vegetation plays an important role in soil retention and the prevention of land/asset erosion. Water purification/detoxification: ecosystems can be a source of water impurities but can also help to filter out and decompose organic waste. Natural hazard protection: e.g. storms, floods, landslides. Bioremediation of waste: the removal of pollutants through storage, dilution or transformation. DEFRA has published an introductory guide to valuing ecosystem services[105].

The European Green City Index is divided into quantitative indicators, which measure the cities' current performance, and qualitative indicators, which show the aspirations and commitments of a city to sustainable practices[106]. This indicator system was not intended for widespread use, but could easily be adapted to the task of evaluating other cities[107].

The Sustainability Tools for Assessing and Rating Communities (STAR) Community Rating System is a toolbox developed for community leaders in the USA to assess the sustainability of their community, set targets for the future and measure progress along the way[108]. STAR Communities have developed a robust set of programmes, tools and services to meet the needs of a wide range of communities. Certification allows communities to benchmark their sustainability progress against their peers and national standards. To achieve certification, communities report on as many STAR evaluation measures as desired, and when ready, submit an application for verification[109].

The China Sustainability Index is a scalable tool. Emphasis is placed on societal and environmental indicators such as water access rate, industrial waste recycling, waste water treatment rate, etc. The strength of the CSI Indicator set is that it is a tool to quantify urban growth and development rather than being a static benchmarking tool[110].

BREEAM is a sustainability assessment method for master-planning projects, infrastructure and buildings. It recognises and reflects the value in higher performing assets across the built environment lifecycle, from new construction to in-use and refurbishment[111]. By providing a rigorous and comprehensive sustainability assessment and rating infrastructure, CEEQUAL helps clients, designers and contractors to improve the specification, design and construction of civil engineering works[112].

JRC published a report that reviews the main concepts and metrics used to assess and manage climate change risk within an international context, which considers climate-resilient development as a central issue[113]. Other important indices are summarized in Table 7.

Table 7. Main characteristics of other risk indices

Index	Author	Objective	Sub-index	Ranking	Geographical coverage /Data
Global Climate change Risk Index (CRI)	Germanwatch (2013)	Quantified impacts of extreme weather events	No sub-index	At the top is the most affected countries of the last two decades (1993-2012)	MunichRe NatcaService Loss figures from 2012 and 1993 - 2012
World Risk Index (WRI)	JNU-EHS (2013)	Risk as interaction between hazards and vulnerability (comprising susceptibility, coping capacity and adaptive capacity)	1.Exposure; 2.Susceptibility • Coping capacities • Adaptive capacity	At the top is the country with the largest disaster risk worldwide	173 countries/ different data sources
Notre Dame Global Adaptation index (ND-GAIN)	University of Notre Dame (2013)	Defining a guide to prioritize and measure progress in adapting to climate change and other global forces	• Vulnerability: • Exposure • Sensitivity • Adaptive capacity • Readiness: • Economic • Governance • Social readiness	At the top is the most ready country (the most vulnerable country is at the bottom)	177 Countries /17 years of data (1995-2012)
Centre for Global Development (CGDev)	Wheeler (2011)	Quantification of vulnerability to more extreme weather; sea level rise and loss of agricultural productivity for cost effective resources allocation for adaptation	1. Vulnerability to changes in extreme weather 2. Vulnerability to sea level rise 3. Agriculture Productivity Loss	Ranking is calculated at sub-index level. At the top is the country with the highest probability of impact from an extreme weather event or sea level rise.	233 countries
Climate Vulnerability Monitor (DARA)	DARA (2010)	Measures of impacts of climate change on human health, weather, human habitat, and economies	1. Health impacts 2. Weather disasters 3. Habitat loss 4. Economic stress	No ranking but the countries are comparable on the basis of five levels of vulnerability: Acute Severe High	184 countries and 20 regions (observed and estimated data with different baseline years)

The water footprint is an indicator of freshwater use that examines not only the direct water use of a consumer or producer, but also indirect water use. The water footprint can be regarded as a comprehensive indicator of freshwater resource appropriation, besides the traditional and restricted measure of water withdrawal. The water footprint of a product is the volume of freshwater used for its production, measured over the full supply chain. It is a multidimensional indicator, showing water consumption volumes according to source and polluted volumes according to type of pollution; all components of the total water footprint are specified geographically and temporally. Blue water footprint refers to the consumption of blue water resources (surface and groundwater) along the supply chain of a product. Green water refers to the precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily remains on top of the soil or vegetation. Greywater footprint refers to pollution and is defined as the volume of freshwater required to assimilate the load of pollutants given the natural background concentrations and existing ambient water quality standards. Traditional national use of water accounts only refer to the water withdrawal within a country. They do not distinguish between water use for making products for domestic consumption and water use for producing export products. They also exclude data on water use outside the country to support national consumption. In addition, they include blue water use only, excluding green and greywater. In order to support a broader sort of analysis and better informed decision-making, traditional national water use accounts need to be extended. The water footprint of consumers in a country consists of two parts: the internal water footprint and the external water footprint. A similar approach should be applied when calculating the water footprint of a municipality, an administrative unit, a catchment or water footprint accounts for a nation. The water footprint of a product does not only indicate the total volume of water used but also indicates where and when the water was used.

The water exploitation index plus (WEI+), which assesses the total freshwater used as a percentage of the total renewable freshwater resources available, is an indicator of the pressure or stress on freshwater resources. A WEI+ of above 20 % implies that a water unit is under stress, while a WEI+ of over 40% indicates severe stress and clearly unsustainable resource use. A method of analysing water stocks is the water exploitation index, which represents the total volume of water abstracted in a given year as a portion of the total freshwater resources. This index depends on the fresh water resources naturally available as well as on the level of water use by households, industry, energy suppliers and agriculture. The index varies widely among EU member states. Many large cities have already developed wide networks for transporting water, often over distances of more than 100–200 km, to allow them to respond to water demands. An average European citizen uses 134 m^3/year of water from renewable freshwater resources. This corresponds to approximately 370 litres of water/capita per day. The highest estimated water use per capita occurs in the Mediterranean region, with the volume of 707 l/capita per day. This is followed by the Alpine and Continental regions, with use values of 380 and 275 l/capita per day, respectively[114]. This is significantly higher use than in the Tisza River Basin. Tourism is becoming a factor in the increasing pressures on public water supplies in many locations across Europe.

Waste water from households and industry represents a significant pressure on the aquatic environment because of the amount of organic matter and nutrients, as well as hazardous substances. With a large part of the population of EEA member countries living in urban agglomerations, a significant volume of urban waste water is collected by sewers connected to public waste water treatment plants. The level of treatment before discharge and the sensitivity of the receiving water bodies determine the scale of the impact on aquatic ecosystems. The proportion of the population connected to urban waste water treatment plants and the types of treatments used are seen as proxy indicators of the level of purification and the potential for improving the aquatic environment. The UWWT Directive (91/271/EEC) prescribes the level of treatment required before discharge to surface waters. It requires member states to provide all agglomerations of more than 2,000 population equivalent (PE) with collecting systems. Primary (mechanical) and secondary (biological) treatment must be provided for all agglomerations of more than 2,000 PE that discharge into fresh waters. Special requirements, with intermediate deadlines depending on the sensitivity of the receiving waters, are placed on agglomerations of more than 10,000 PE, with various sized agglomerations. The performance of the treatment is assessed using five different determinants (biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total nitrogen (N_{tot}) and total phosphorus (P_{tot})).

The EU waste water treatment index is the overall proportion of the population connected to urban waste water treatment ranging from 70 to 85% (with the exception of Slovakia) in 2015. Hungary, Lithuania and Poland reported a tertiary treatment connection rate of 59-65 %. The percentage of the population connected to urban waste water treatment plants ranges from 48 to 87%. In Bulgaria and

Romania, about half of the treatment is tertiary. The indicator on urban waste water treatment collects data on the percentage of the population connected to sewage collection systems, as well as on the prevalence of primary, secondary and tertiary urban waste water treatment plants. The amount of urban waste water treated is expressed as population equivalent (PE)[115].

While numerous footprint calculations are available in the literature for some products and countries[116, 117, 118], very few calculations have been made for urban areas. It has not been made for the Tisza River or its tributaries, neither its cities. It is suggested that the water footprint or other indicators mentioned above should practically be applied in river basin planning as the comparison of performances in water management is becoming more and more important in decision-making.

4. Stormwater, excess water, flood, water storage

a.) The conventional approach to stormwater and excess water management – soil sealing, runoff issues

Impervious surfaces include roads, pavements, parking lots and buildings. Natural flow paths in the watershed may be replaced or supplemented by paved gutters, storm sewers or other elements of artificial drainage. Economic growth still highly depends on land take and soil sealing. Besides being the driving force for economic growth, soil sealing has negative effects on the environment. Therefore, responses are needed to mitigate its effect (Figure 18). In order to detach economic growth from land take and soil sealing, it is suggested by EU strategy to strictly follow the principle of prevention, limitation and compensation for soil sealing[119]. To "pave the way" for the successful prevention of soil loss, the following basic principles need to be implemented at the national and urban policy levels. According to individual regional needs, new developments ought to be steered towards already developed land or brownfield sites and agricultural areas as well as valuable landscapes designated for development restrictions. According to the European Environment Agency, since the mid-1950s, the total surface area of cities in the EU has increased by 78%, whereas the population has grown by only 33%.

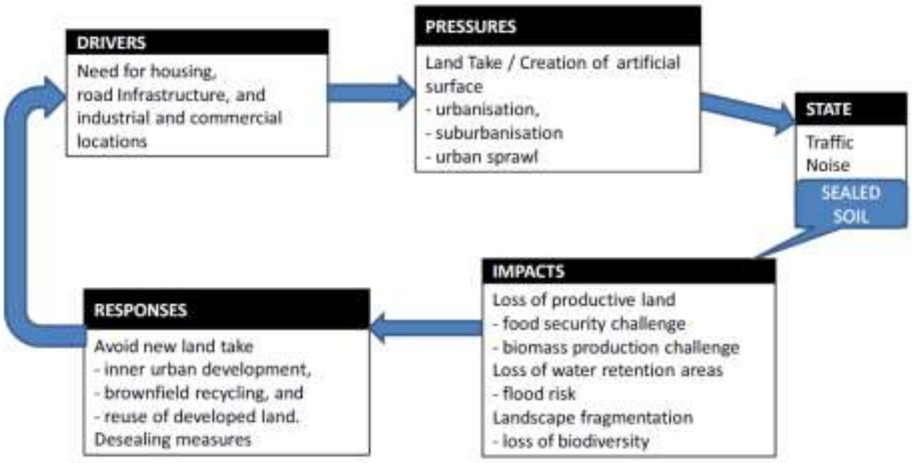

Figure 18. Soil Sealing in the context of DPSIR, negative effects and possible responses[120]

With regard to limiting soil sealing as much as possible, it can be concluded that whenever soil loss is inevitable, mitigation measures shall be implemented to the furthest extent. These can be implemented by respecting soil quality during the planning process and steering new developments towards less valuable soils by applying technical mitigation measures to conserve at least some land coverage functions (i.e. permeable surfaces in parking areas).

Even top quality soils will be lost and valuable landscapes fragmented for some infrastructure development. In such cases, controlled compensation measures shall be carried out to facilitate soil restoration measures. This can be achieved by taking qualified compensation measures and facilitating new opportunities. In the context of the Soil Thematic Strategy (COM(2006) 231)[121], the European Commission points out the need to develop best practices to mitigate the negative effects of sealing on soil functions. In 2011, the European Commission published an Overview of best practices for limiting soil sealing or mitigating its effects in EU-27, presenting land take and soil sealing trends in the EU. The report contains an exhaustive overview of existing Member State policies and technical measures used to reduce and mitigate soil sealing. On the basis of the report, the following actions are recommended to ensure that new projects are implemented with the least possible destruction of soil functions: to examine soil quality during planning and consider alternative scenarios; to protect green areas at the fringes of settlements; to promote inner urban development by implementing strategic projects; to promote the refurbishment and reuse of derelict sites; to avoid unnecessary soil sealing as much as possible by promoting mitigation technologies and prescribe sealing limits in building permits[122].

The critical part of sustainable urban drainage management is related to wet weather flow. The runoff from impervious areas must therefore be managed to avoid flooding related to the rate of urban runoff processes being accelerated in comparison to undeveloped conditions. Different strategies must be implemented when calculating these effects. The time-scale of managing the runoff water plays a central role when dealing with aspects of quality and quantity.

Each drainage network and their catchment have their specific characteristics in terms of construction and water governance (separate or mixed)[123]. The biofilm growth of pollutants that temporarily accumulate on sewer solids may be eroded and transported as part of the mixture of waste water and runoff water after high flow periods or runoff events, especially in combined systems[124]. It is important to analyse the relationship of rain and runoff waters.

Rainfall hyetograph is the graphical representation of rainfall distribution over time. This data source is useful in developing storm management systems. Rain intensity is typically measured by tipping bucket rain gauge, which can also incorporate weighing gauges. In these gauges, a strain gauge is fixed to the collection bucket so that the exact rainfall can be read at any moment. Important parameters of the precipitation events are intensity (µms-1), duration (min), and frequency of occurrence (yr-1). Intensity/duration/frequency (IDF) curves that combine the three rainfall characteristics represent the hydro-statistical properties of urban areas. These curves are used for the parameterisation of runoff treatment.

Hydrologic studies to determine runoff and peak discharge should ideally be based on long-term stationary stream flow records for the area. Such records are seldom available for small drainage areas. Even where they are available, an accurate statistical analysis of them is usually impossible because of the conversion of land to urban uses during the recording period. Therefore, it is necessary to estimate peak discharges with hydrologic models based on measurable watershed characteristics. Only through an understanding of these characteristics and experience in using these models can we make sound judgments on how to alter model parameters to reflect changing watershed conditions. Urbanization changes the watershed response to precipitation (Figure 19). Lag time can be significantly reduced as the watershed run-off characteristics are changed by paving and urbanization, vegetation change, overgrazing or weather pattern change[125]. The area integrated under the hydrograph represents the volume of runoff.

The most common effects are reduced infiltration and decreased travel time, which significantly increase peak discharges and runoff. Runoff is determined primarily by the amount of precipitation and infiltration characteristics related to soil type, soil moisture, antecedent rainfall, cover type, impervious surfaces and surface retention. Travel time is determined primarily by the slope, the length of the flow path, the depth of the flow and the roughness of flow surfaces[126]. The highest runoff rate is called the peak charge. The curve that depicts runoff flow during a rainfall event versus time is designated a runoff hydrograph.

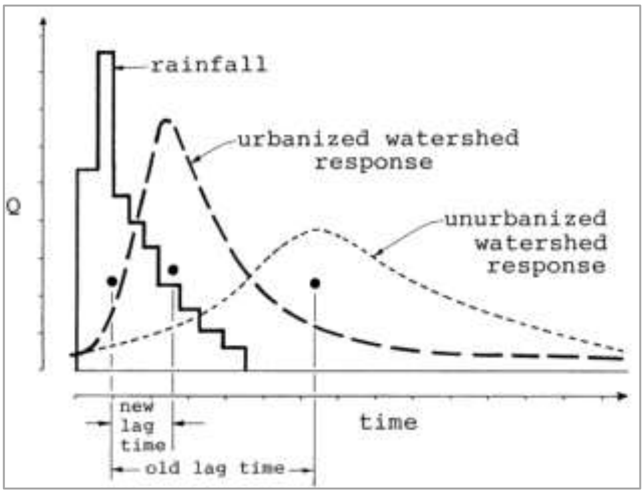

Figure 19. Schematic hydrograph curves of urbanized area[126]

Peak discharges are based on the relationship between these parameters and the total drainage area of the watershed, the location of the development, the effect of any flood control works or other natural or man-made storage and the time distribution of rainfall during a given storm event.

One critical parameter in the precipitation runoff model is the time of concentration (T_c), which is the time it takes for runoff to travel to a point of interest from the hydraulically most distant point. Normally, rainfall duration equal to or greater than Tc is used. Therefore, the rainfall distributions were designed to contain the intensity of any duration of rainfall for the selected frequency. Many methods are empirically derived from actual runoff hydrographs and watershed characteristics (for example, the Regression Equations Method; Hydrograph Method; Rational Method)[127]. The methods are based on the velocity of flow through segments of the watershed. Two major parameters are the time of concentration (T_c) and the travel time of flow through the segments (T_t). These and the other used parameters are the same as those used in the accepted hydraulic analyses of open channels.

There are two main approaches in rainfall-runoff modelling. Deterministic models assume that the same inputs will produce the same outputs. On the other hand, stochastic models assume both inputs and outputs are random variables and the same inputs may produce different outputs. Hydrologic routing is used to simulate the temporal and spatial variations of a flood wave as it traverses a river reach or detention reservoir. The inlet location may be determined either by roadway elements, hydraulic requirements, or both. Flow velocities within a sewer network should be no less than 1 m s^{-1} and no greater than about 3 m s^{-1}, but the actual values depend on the material used in its construction. At low velocities, sediment deposit becomes a serious maintenance problem. When low velocities cannot be avoided, access for maintenance must be provided. At high flow velocities, the momentum of the flow may have an adverse effect on the components and joints within the system.

A broad range of materials and concepts are available for permeable surfaces. In addition to their obvious ecological advantages, most permeable surfaces have lower lifespan costs compared to conventional impermeable surfaces. With regard to sustainability, most permeable surfaces are made of materials that are locally available and reusable. The main obstacle to their implementation is the fact that site-specific know-how and building competence is required to construct them correctly. Furthermore, regular maintenance is needed to ensure their proper functioning. Parking areas have the greatest potential for permeable surface application; especially large parking areas in urban fringes.

b.) The issues/challenges facing a conventional approach to stormwater and excess water management – balance in runoff – infiltration- evapotranspiration

The traditional approach in the urban drainage design is the rapid removal of surface water through artificial drainage systems as well as straightening and channelizing the existing streams. These practices shorten the time of concentration and increase flash floods and peak discharges downstream. Therefore, urban drainage solutions require the adoption of rapid removal structures as well as retarding structures and onsite techniques to minimize runoff generation and increase infiltration. The traditional "efficient conveyance" approach is gradually shifted towards the "water storing" approach, focusing on detention, retention and recharge. In most cases, natural depressions can be used to provide temporary or continuous storage for urban flows to relieve the drainage network and the downstream receiving bodies of excess discharges and pollutant loads[128].

Preventive measures for hydrological adverse impacts are always simpler and more cost effective than corrective measures. Some suggested measures include: maintaining the natural rainfall-runoff ratios, protecting hydrologically sensitive areas, sediment sources and sensitive habitat areas, minimizing and hydraulically disconnecting impervious areas, such as rooftops, rain gutters, parking lots and roads, minimizing topography changes and soil compaction, cluster development in less sensitive areas, integrating flood control and water quality control structures into the landscape. Stormwater is a significant source of pollution, and therefore concepts of source control, flow attenuation and treatment in natural and artificial biological systems are important.

A detention or retention pond or retarding basin is a facility for temporary water storage to reduce flood peaks. Detention ponds are usually constructed at natural depressions. The retention pond has a permanent pool of water that fluctuates in response to precipitation and runoff from the contributing drainage areas. The retention pond may be provided with control gates and may be maintained with minimum storage to keep aquatic life alive during low flow periods. The design capacity is based on the runoff generated from the basin due to a design storm. Sluices are designed to control releases and spillway is provided to discharge the excess water in order not to damage the structure and not to inundate the upstream in case of a heavy storm.

Infiltration ponds are similar to detention ponds but they are specifically provided to infiltrate the stormwater routed there into the soil. They are not usually equipped with sluices for releasing water. However, spillways and low level outlets for emergency operations are provided. Infiltration ponds are appropriate in places with pervious soils and a deep water table. The disadvantage of these ponds is possible odour problems and becoming a breeding ground for mosquitoes in hot seasons.

Wetlands are shallow ponds with growing aquatic plants constructed across streams at depressions for the removal of pollutants in water. They provide a detention time for the water to settle pollutants/sediments and for the aquatic plants to uptake pollutants. A low velocity has to be maintained through wetlands. They are effective at removing phosphorus, nitrogen compounds, metals and organic compounds and sediment from water. However, the required surface area of the wetland must be large enough to treat high discharges of stormwater runoff.

Infiltration trenches are provided to enhance the infiltration of stormwater into the ground. A trench is excavated in the ground and filled with crushed stones and the top of the trench is covered with fabric to avoid sediment and debris entering the trench. Trenches trap the stormwater and facilitate the infiltration of water into soil, thus recharging the groundwater. Therefore, the runoff volume is reduced. It is important to provide suitable sediment traps or setting basins upstream of the trenches so that sediment is removed from the water. The efficiency of an infiltration trench depends on the infiltration rate.

These are strips of grassed soil surfaces introduced between urban impervious surfaces and storm drains to slow down and partially infiltrate runoff. This is possible when the stormwater discharge can be spilled on to the grassed strip and spread across the width of the strip. The velocity of the flow over the grass is low and part of the flow is infiltrated and the suspended particles in the flow are trapped within the grass strip. Grass strips should be sloping very mildly and the grass should be dense to avoid erosion and the formation of channels. However, the efficiency of grass filter strips in reducing flood peak is low. Grass swales also perform similarly to grass filter strips when the slopes are gentle, less than 5%.

Pervious pavements are permeable surfaces where the runoff can pass and infiltrate into the ground. Pervious pavements facilitate peak flow reduction, ground recharge and pollution filtering. There are three types of pervious pavements: a) porous asphalt pavements b) porous concrete pavements and c) garden blocks. The main difference from conventional pavement is that there is no fine aggregate in the mixture used in their construction. A porous layer is constructed on a granular base laid on the soil surface. These pavements not only reduce flood peak but also abate pollutants in the surface runoff.

Some pervious pavements require frequent maintenance and the investment cost is higher. In conclusion, rainfall that contacts pervious surfaces is subject to losses (interception, infiltration, evaporation and evapotranspiration).

An empirical method to derive evapotranspiration rates as a result of urbanisation is needed to help fully determine the urban water balance. Evapotranspiration is being introduced as a sustainable technique for managing stormwater runoff and quantifying fluxes of ET in urban areas is crucial for the designing of such systems.

Evapotranspiration from a field can be either measured or estimated by means of a model based on empirical formulas. Measuring evapotranspiration is costly and not general. Generally, evapotranspiration is estimated indirectly by means of a model using data on climate and soil properties and crop characteristics as input. There are many alternative ways to model ET and crop growth (DSSAT, EPIC). The CROPWAT model was developed by the Food and Agriculture Organization[129] to simulate a different irrigation strategy. The AQUACROP model was specifically developed for estimating crop growth and ET in water-deficit conditions. The CROPWAT FAO model offers two different options to calculate evapotranspiration: the ‘crop water requirement option’ (assuming optimal conditions) and the ‘irrigation schedule option’ (including the possibility of specifying the actual irrigation supply in time). We recommend applying the second option whenever possible, because it is applicable for both optimal and non-optimal growth conditions and because it is more accurate (as the underlying model includes a dynamic soil-water balance[130]).

c.) Linkages between storm and excess water management and other functions or sectors, i.e. waste water management, storage and recreation, urban agriculture

EU Member States and cities have recognized that advanced understanding of stormwater overflows can be used as a new natural resource[131]. Stormwater management is a fundamental part of the urban water cycle as a whole. The close connection between stormwater, water supply and waste water treatment justify the need for cities to integrate the management of urban drainage into all other parts of the system. As rainfall becomes more intense, surface runoff levels can exceed the capacity of stormwater entry points or cause sewer overflows in combined sewer systems. This can cause street flooding, with associated health dangers due to contamination, but can also increase the cost of meeting related regulatory requirements.

The decisions that result in natural landscapes being converted into buildings, paved surfaces, drainage channels and managed vegetation are taken by a wide range of stakeholders. Few of them consider stormwater management to be a priority and legislation, regulation and financial incentives are often insufficient to persuade them otherwise. Road construction with impermeable paving causes an increase in surface runoff and results in an impact on stormwater pollutants such as oil, heavy metals, micro-organic pollutants and sediment. Urban organic and inorganic waste can block drainage channel sink function, creating localized flooding. Pollutants from uncontrolled landfill sites can also be non-point pollution sources through stormwater runoff. Green parks management potentially impacts stormwater quality through pesticides and nutrition leaching. New residential and industrial developments create an increase in the impermeable surfaces through roof area and paving. This alters the hydrological and water quality characteristics, so it is important to treat as much of the stormwater on site within the properties as possible. The drying and shrinking soil caused by droughts can generate cracks in stormwater drains and sewers.

The infrastructure of a waterworks must address complex, overlapping tasks. The supply chain of the water supply service can be divided into two parts: drinking water supply and waste water treatment. As shown in the following figure (Figure 20), drinking water supply runs from water extraction to users and sewage drainage to treated water and sewage sludge. In addition to the supply chain, production and operation processes and customer service activities are also carried out by the service providers, including customer relations management, water quality control at several points of the process and dispatching services as well as troubleshooting. Service providers often perform spa management and various, mainly water-related construction works using the organization's existing capabilities and resources.

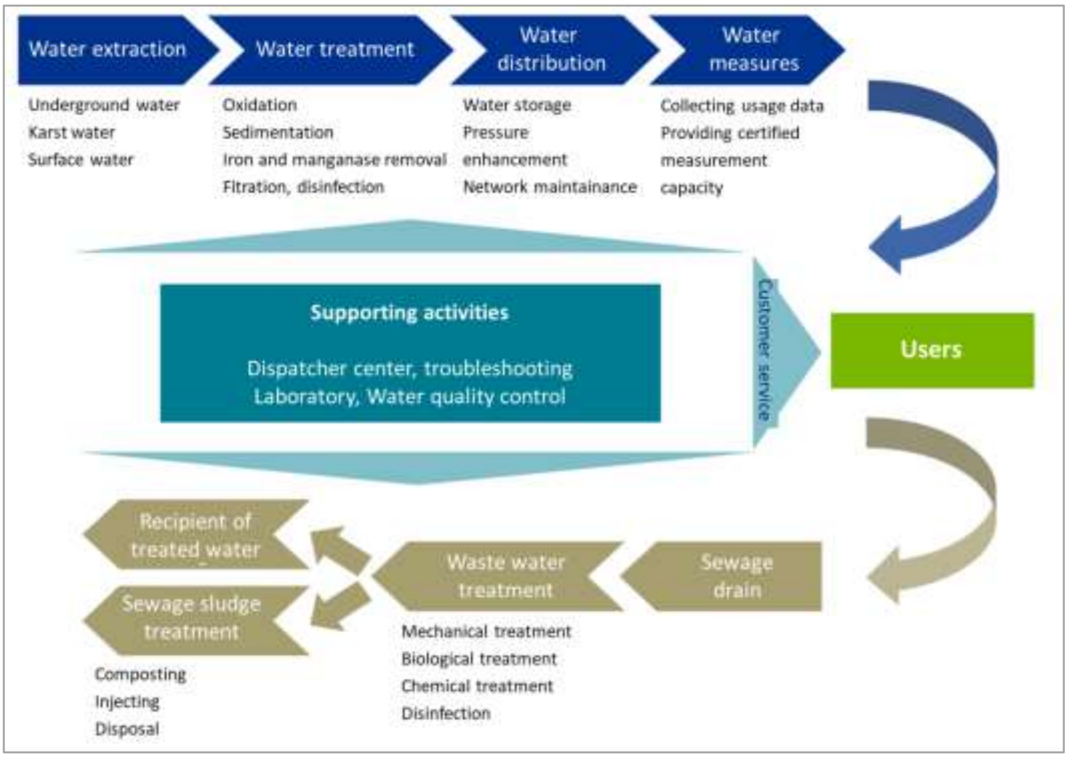

Figure 20. The supply chain of the water supply service[132]

The level of water supply is different in Tisza settlements (Figure 21). Generally, the consumption of drinking water per capita is declining in Eastern European countries, partly due to the pricing policy based on the Water Framework Directive. One of the aims of the Water Framework Directive is to eliminate wasteful water use.

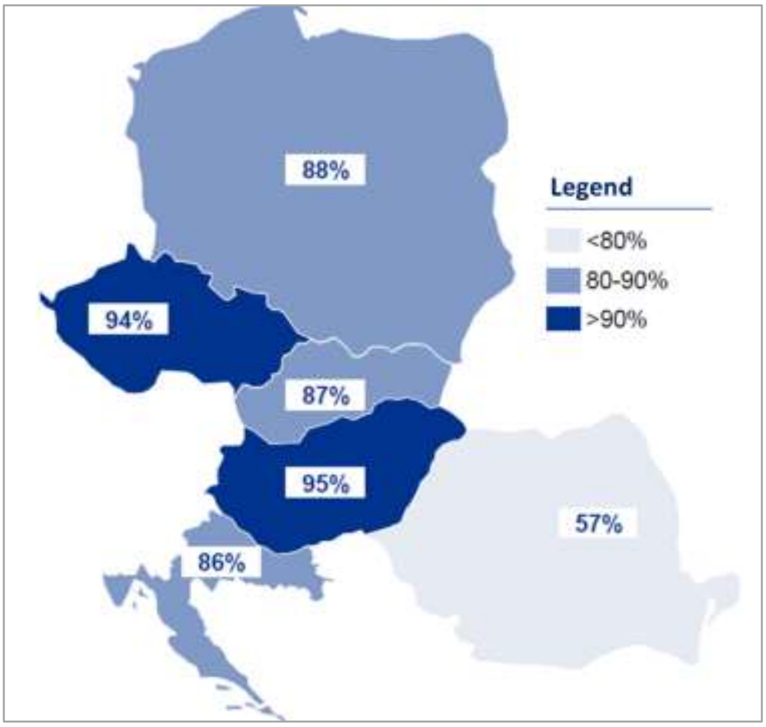

Figure 21. The proportion of people who joined the utility drinking water network in countries in the region in 2011[132]

Nonetheless, if a community considers the reuse of local water sources, the selection of a treatment train for a specific potable reuse scheme must be carefully evaluated by each community. Irrespective of which treatment combination is selected, safety will depend on meeting health-based targets identified for microbial, chemical and radiological quality through the application of multiple-barrier processes along with online or frequent operational monitoring to ensure consistent and reliable operation (Figure 22). The design of potable reuse schemes needs to consider waste water flows and loads as these can vary diurnally[133], from day to day and seasonally[134], so the following continuous scheme must be considered.

Figure 22. Framework for safe drinking water[135]

Risks need to be assessed and prioritized by determining the likelihood of occurrence at significant concentrations and the probability and severity of the consequences if inadequate control measures are applied. Health-based-targets provide the mechanism for defining significant concentrations.

Water lost from potable and sewer water distribution systems remains one of the key issues facing not only developing cities but developed urban areas throughout the Tisza watershed.

Within the same amount of drinking water loss (m³/year), the relative loss (%) can be strongly distorted by many factors such as weather: a dry, warm vegetation period is favourable due to enhanced irrigation water use, while a rainy spring and summer may have a negative impact on the relative loss. Likewise, a significant difference is caused by the drop in consumption due to increased water prices or the entry or exit of large consumers. The IWA Best Practice Report clearly states that "percentages by volume" are unsuitable for assessing the efficiency of the operational management of real losses (Figure 23). IWA Task Forces produced an international 'best practice' standard approach for Water Balance calculations, including definitions of all technical terms, as an essential first step in practical management of water losses.

<table>
<tr><td rowspan="10">System Input Volume</td><td rowspan="5">Authorised Consumption</td><td rowspan="3">Billed Authorised Consumption</td><td>Billed Water Exported</td><td rowspan="3">Revenue Water</td></tr>
<tr><td>Billed Metered Consumption</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Meter Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Meter</td></tr>
</table>

Figure 23. The IWA "best practice" standard water balance[136]

Several developments have been implemented, all of which will help to explain the leakage process and how it can be analysed and lowered:

- the burst and background estimate (BABE) procedures[137];
- the standardised water balance (IWA Performance Indicators and Water Losses)[138] (the information on the true network length is not always reliable[139])
- the use of key performance indicators to measure real losses [140];
- the fixed area variable area discharge (FAVAD) [141];
- the concept of unavoidable annual real losses (UARL)[142]
- ILI the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL). It has no measurement unit and thus it facilitates comparisons between countries that use different measurement units.

Water loss from the network system is mainly due to two reasons: pipe breaks and undefined leakage. These could be affected by the following factors: pipe material, the age of the pipeline, the type of pipe connections, pressure conditions, storage and transport conditions of the pipe material, laying conditions, laying depth, terrain and soil conditions around the pipe, regular or periodic presence of groundwater, operating conditions, traffic over the pipe network, damage caused by other construction, ground movements (caverns, hollow areas or earthquake zones).

Of the two forms of network water loss, undefined leakage plays a higher role in water loss. Due to the sudden, explosive destruction of the pipe, a large amount of water with high pressure breaks to the surface. The frequency of pipe breaks is low, their intensity large but short in duration. Hidden leaks are frequent, low intensity but durable. The frequency of undefined leakage is high, their intensity low but long in duration. Hidden leaks are frequent, low intensity but durable. The water flow of the leaks is smaller by two to three orders of magnitude than pipe breaks, but the water flow is four to five times higher, so the most significant loss is undefined leakage [143] (Table 8)

Table 8. The recommended acoustic monitoring period based on the specific (relative) water loss[144].

Waterloss categories	City	Small city $m^3/h/km$	Rural area	Monitoring period
low (<8%)	< 0.13	< 0.07	<0.05	optional
moderate (8-15%)	0.13-0.25	0.07-0.15	0.05-0.1	every 3 years
high (>15%)	> 0.25	> 0.15	> 0.1	annually

The basis of the economic damage of undefined leaks is primarily the cost of extracting, cleaning, networking (pumping, storing capacity, network capacity) of lost drinking water. There are other consequential damages such as paving collapses, interruptions, water in basements, building damages, pipe breaks. Technical damages are the damage to pipes, fittings, their repair, reconstruction costs, network operating problems (hydraulic changes, out-of-service circumstances for the period of reconstruction, etc.)

The persistent concern to citizens is chemical pollution by river and lake sediments in cities. After periods of heavy rain, water quality degradation in urban rivers and lakes can increase 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 the overloading of sewers and waste water treatment plants. After heavy rain, discharges from CSOs may impact the microbial quality of the water. There is a need to properly protect CSOs through upstream measures (e.g. nature-based retention basins) and to manage them to prevent flooding and minimise adverse impacts on the environment and public health[145].

Consumers generally assess the quality of their drinking water by appearance, taste and odour rather than by reviewing physical, chemical and biological data. Therefore, appearance, taste and odour of the drinking water must be acceptable to generate and maintain public perception of high-quality water. Drinking water produced by potable reuse schemes should match or exceed the acceptability characteristics of drinking water from conventional local sources to maintain public confidence. Unacceptable appearance, taste or odour in the drinking water supply augmented with potable reuse will exacerbate consumer unease associated with its origin. Consumers may perceive that recycled water is not adequately treated to remove waste water-derived contaminants if of objectionable or variable taste, of odour or colour are present, even when all health-based targets are met.

While traditional waste water treatment processes can reduce or remove many odour-producing chemicals, some aerobic and anaerobic biological processes employed for waste water treatment may contribute to odours by transforming larger natural or anthropogenic organic materials into smaller organic compounds with odorous functional groups, e.g. alkyl acids, ketones or phenols. Waste water processes such as trickling filters and activated sludge processes (ASPs) can support the growth of microorganisms including actinomycetes that produce geosmin and 2-methylisoborneol. These compounds produce earthy and musty/mouldy odours at very low concentrations (5–10 ng/l)[146].

Treatment processes used in potable reuse that reduce organic contaminants such as soil-aquifer treatment (SAT), reverse osmosis (RO), activated carbon and advanced oxidation processes (AOPs) can reduce most waste water odorants. While no single treatment process guarantees complete removal of taste and odour compounds from waste water, the combinations of processes typically used in potable reuse schemes should be effective[147].

Drinking water consumption has decreased in the Tisza basin by about 50% compared to the late 1980s. Today, consumption remains stable with an average daily use per person of about 100-110 litres of water at a national level. While in large cities the average daily consumption is 150-160 litres/person, in small villages it is as low as 50-70 litres.

d.) Sustainability objectives, measures and indicators for stormwater and excess water management - Increasing groundwater recharge, preserving base flow in streams, reducing impact of stormwater runoff

Flood risk means the combination of the probability of a flood event and the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event.

The Floods Directive, adopted in 2007, provides European countries with a common framework for identifying, evaluating and addressing flood risk. The first flood risk management plans focusing on prevention, protection and preparedness were to be drawn up by 2015. The aim of the Floods Directive is the development of urban areas resilient to changes that would otherwise cause an increased likelihood of flooding. Flood risk management plans shall address all aspects of flood risk management focusing on prevention, protection and preparedness, including flood forecasts and early warning systems and taking into account the characteristics of the particular river basin or sub-basin. Flood risk management plans may include the promotion of sustainable land use practices, the improvement of water retention as well as the controlled flooding of certain areas in the case of a flood event[148].

A literature review of vulnerability flood studies shows that vulnerability can be considered a combination of threshold capacity, coping capacity, recovery capacity and adaptive capacity[149, 150]. The threshold capacity domain applied as a result of dike construction or reservoir construction, where there will be some instances when the threshold is exceeded. Then, it is necessary to cope with hazard impacts and to recover from them. This is the coping and recovery domain, where damage reduction is the prime goal. Finally, there are very unlikely events with very high return periods where the expected damage is so extreme that recovery is neither feasible nor possible. These are the types of occasions we want to prevent by adapting. Therefore, this is the adaptive domain[151]. In flood risk management, when dealing with future uncertainties and general risk management, approaches that specifically address the likelihood of certain future trends are commonly used in spatial urban planning practice.

As severe floods in the past and the identification of floods and excess water as one water management issue for TRB (the first ITRBMP) that interlink water quality and quantity, adequate flood risk management is necessary in the Tisza watershed. In the past, the solution to the flood problem, offered by flood management and administration, was to drain the water downstream as quickly as possible by heightening the dikes along the riverbanks. However, experience showed that this solution was far from ideal. It has become clear that this method leads to higher water levels and a higher flood risk downstream. Moreover, the water defence infrastructure can collapse due to technical failure such as breaching, often creating more damage than would have occurred if no flood defence infrastructure had existed. The lower the investment in flood defence infrastructure, the higher the expected costs for damage. As investments in infrastructure increase, expected damage decreases, as does the total cost. At a certain point, however, higher investments no longer lead to major decreases in expected damages and the total cost begins to increase again. At this point, the total cost of investments and expected damage is minimal. The calculation of damage and risk consists of three steps: defining the probability and extent of flooding, determining expected damage and defining risk[152].

The mitigation of the adverse hydrological impacts of urbanization essentially requires a multidisciplinary approach through structural and non-structural measures[153]. Structural and non-structural measures must be integrated into the design and development of urban areas to avoid the need for an isolated approach to address urban drainage problems[154]. Flood monitoring activities can be divided into three broad sets, according to the stage of operations with respect to the event occurrence: the forecast of emergency monitoring and damage assessment. Remote sensing can play a key role in defining the spatial and temporal changes of the factors, which, in return, control flood generation and risk (Figure 24).

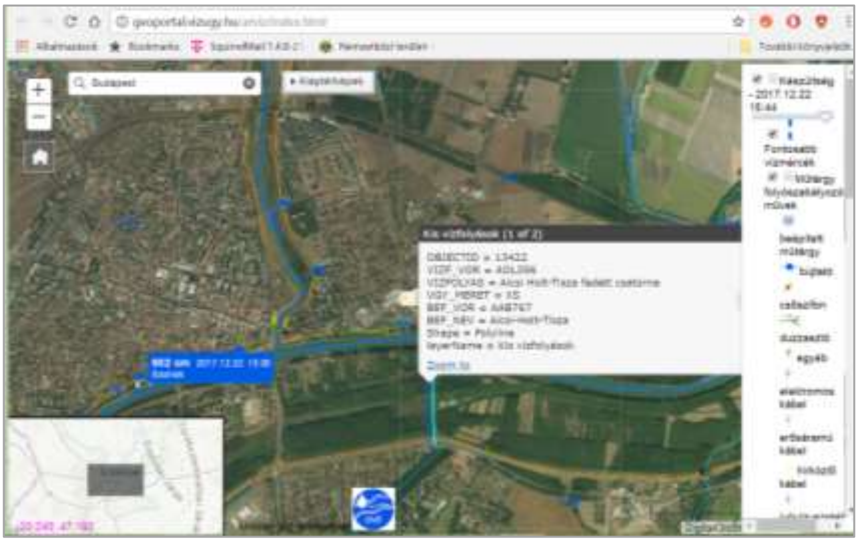

Figure 24. Real-digital webmap of flood risk in the Szolnok city[155]

Based on the experience of the projects implemented in the last decade, habitat developments in the Tisza area seem to directly serve the reduction of urban flood risk along the rivers by reducing the roughness of the flood basin and the floodplain, while simultaneously reducing the risk of drought through water retention and land use change. The renewal of water management requires the modification of urban land use, which is not possible without the coordination of local interests. The related technical tasks should be adapted to this consensus. Natural Water Retention Measures aim at restoring and maintaining water related ecosystems by natural means. They are Green Infrastructures intended to maintain and restore landscape, soils and aquifers in order to improve their natural properties, the environmental services they provide, and to favour climate change adaptation and reduced vulnerability to floods and droughts[156].

The 2013 EU Commission Communication on Green Infrastructure 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[157]. Blue-green cities may be the key to future resilience and the sustainability of urban environments and processes.

They aim to recreate a naturally oriented *Blue* water cycle, while contributing to the amenities of the city by bringing water management and green infrastructure together (Table 9).

Table 9. Blue and green assets and features in urban management[158]

Urban blue	Urban green
Waste water reuse and recycling	Green roofs
Rainwater harvesting and recycling	Green parks, streets, squares, parking lots, etc.
Stormwater management as a new resource	Living walls systems, urban agriculture

Source: Based on Blue Green Dream, 2012.

One example for Blue and green assets and features in urban management is eco-parking, which can significantly reduce runoff, increasing infiltration in correspondence with green policy.

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 surroundings. Urban blue networks, consisting of rivers, streams and other bodies of water in the city can complement green networks. The green network connects the green areas as a ring around the urban area, and the blue network is intended to improve the ecological conditions of the rivers and associated wetlands. The key element of these methods is to optimise water quality and quantity in time in the urban watershed. The critical issue of urban hydrology can be addressed with more alternative water recycling or/and locally stored water resources.

The immediate solution to reduce the impacts of stormwater runoff is to reduce the impervious surfaces of the city watershed in the control of Non-point Source Pollution (NSP). Research has shown that land development and the addition of impervious surfaces can increase stream-bank erosion. The loss of aquatic habitat and other changes are caused as the percentage of the total impervious area increases in the watershed.[159] “Impervious surface: A hard surface area that either prevents or retards the entry of water into the soil mantle or causes water to run off the surface in greater quantities or at an increased rate of flow. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving and gravel roads”[160].

As impervious surfaces emerged as an important indicator of water quality in the USA, researchers began to use numerous statistical, census-based and land-use mapping methods to estimate the total impervious area (TIA) of a given area. None of these techniques, however, had been tested rigorously for the fundamental mapping accuracy of the measurement. USGS-EPA published a report when six urban and suburban watersheds were selected for a study that represent a wide geographic distribution across the country[161]. High-resolution ortho-imagery (1 metre or better) and satellite images were obtained for each watershed and integrated into a GIS environment. The six classes of cover were roads, buildings, parking lots, driveways, sidewalks and other (such as sport courts). The report concluded that the component structure of the impervious area varied by region and differences appeared to be significant. Establishing a regional, economic and/or ecoregion-based approach to impervious surface and water quality issues could be extremely useful in understanding the spatial and trend context of impervious development in different parts of the country, but could also provide operational information on critical ecosystems and the potential benefit of mitigation efforts.

e.) Implementation of sustainable stormwater and excess water management measures and practices – green infrastructure

The manifold relationships between urban planning and water have structured and influenced the development of metropolitan areas, cities, towns, rural areas, villages and even neighbourhoods[162]. Local authorities can apply land use planning processes to make improvements to surface water bodies such as urban rivers and lakes. Multifunctional urban restoration can provide the strong links between restoration and flood risk management. It is also important to create spaces that allow citizens to experience nature. It is also clear that defining multiple benefits more accurately (both direct and indirect benefits in terms of ecosystem services) is often helpful in the decision-making process with regard to restoration projects in cities[163]. The creation of a more sustainable urban drainage system requires a change in the mentality for stormwater management. In practical terms, this can happen in a variety of ways, most notably by taking advantage of opportunities presented in the context of urban development and economic drivers. It should be ensured that new roads, housing projects, business complexes, industrial estates and other urban infrastructure are constructed with stormwater management measures that treat runoff and maintain a water balance close to the pre-development conditions. The cost of managing stormwater is often borne by property owners through their water and waste water service bills. Charging a separate fee for stormwater management (based on the area of impervious surface) provides a financial incentive to property owners, particularly businesses, to reduce the amount of stormwater runoff generated on their site. Natural vegetation and water features used for urban landscaping can easily be adapted to provide stormwater runoff attenuation and treatment. Due to its relationship with a range of other water and urban planning sectors, investments in sustainable stormwater measures can be applied to address issues in other urban sectors. Insufficient waste water treatment capacity, the restoration of natural habitats and water scarcity are all urban development issues that can be alleviated by the sustainable management of stormwater. The barriers to sustainable stormwater management must be carefully evaluated (Table 10).

Barriers are of course location-specific and tend to stem from a range of local political, economic and social factors. There are also important links between restoration activities and local and city authority strategies for open space, green infrastructure and green networks. These strategies often require that developments include a certain proportion of open space. If well designed, this open space can create green networks for morphological restoration, wildlife and people[164]. We also have to consider developing the pilot projects to demonstrate evidence of the results and the feasibility of maintenance. In several cases, it is useful to increase public engagement and institutional coordination. Changes to legislation may be necessary to ensure that alternative solutions are accepted as legal drainage options[165]. Stricter regulation, for example of building standards, can also ensure that planning permission for new development is dependent on the inclusion of measures that manage stormwater effectively. Promoting non-conventional solutions for stormwater management through, for example, the provision of subsidies for certain technologies creates a market for these products and increases competitiveness in comparison to conventional solutions. Gaining political support through, for example, the approval of alternative stormwater management policy by the city council provides a key driver for the widespread implementation of more sustainable solutions. Raising awareness of the problems (and costs) associated with conventional drainage approaches as well as the benefits of an alternative approach can present clear incentives for politicians to act[166].

Table 10. Examples of barriers to more sustainable stormwater management practices[167]

Barrier	Description	Consequences
Legislation and regulation	Much existing legislation, regulation and standards related to stormwater management have been developed for conventional, hard-engineered urban drainage systems.	Alternative stormwater management solutions can face legal challenges as they may fail to comply with conventional standards.
Institutional structures	The cross-cutting nature of non-conventional stormwater solutions is not necessarily compatible with the typical single functional organisational structures and planning responsibilities of water authorities and relevant municipal departments set up to provide conventional drainage services.	The relationship between urban drainage and other urban sectors such as land use planning is not reflected in existing institutional structures resulting in a fragmented management approach to aspects relating to stormwater.
Risk aversion	Opposition by decision-makers to adopting innovative solutions, due to the perception that the technologies are untested and the risk of failure and legal liability is unacceptably high.	Continued implementation of conventional stormwater infrastructure rather than investment in non-conventional solutions.
Perceived cost	The initial capital costs of replacing centralised drainage systems with non-conventional solutions, or including decentralised solutions in new developments, are considered too high to justify the investment.	Centralised drainage infrastructure continues to be repaired and extended despite high life cycle costs.
Professional resistance to change	Conservative attitudes to stormwater management and a desire to maintain a monopoly over drainage services	Reluctance of staff from municipalities and utilities to learn about and adopt new technologies.
Public acceptability	Public opposition to alternative stormwater options due to unfounded concerns and the lack of information and.	Non-conventional solutions are considered unacceptable and a waste of money by the local population, resulting in opposition and a lack of buy-in.
Space requirements	Land needs for non-conventional solutions are difficult and expensive to acquire in densely populated areas. The multi-purpose use of areas such as playing fields for temporary water storage may also be politically contentious.	The necessary land required to implement alternative solutions is unavailable or too expensive to acquire.

Water Sensitive Urban Design (WSUD) is a concept that aims to integrate urban water management, particularly stormwater, into modern urban design and landscape planning (Figure 25). Key principles for WSUD solutions should bring urban water management closer to the natural water cycle, provide aesthetic benefits and multi-purpose functions, with the flexibility to adapt to an uncertain future. Scenarios were selected in consultation and managed through interdisciplinary cooperation with all stakeholders based on the cost comparable to conventional solutions[168]. Naturally, landscaped stormwater drains can help filter out fine sediments through the action of vegetation, thus slowing down the flow and trapping solids. Pervious surfaces allow rainwater to percolate into the soil, thus treating the water in much the same manner as the land-based treatment of waste water and at the same time reducing the amount of runoff.

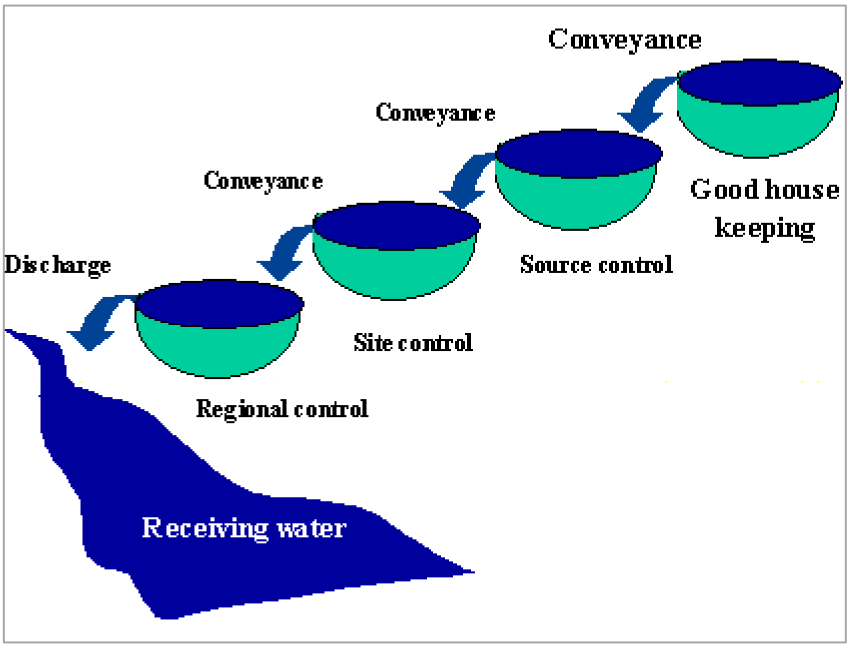

Figure 25. Cascade stormwater management at the local, sub-catchment and catchment levels[169]

In the next part, a short description of the solution is provided, but a great variety of options are available to implement more sustainable stormwater management.

Sustainable drainage aims to imitate the natural drainage of a site before development. Sustainable drainage systems (SuDS) give equal consideration to controlling water quantity, improving water quality and providing opportunities for amenity and improving biodiversity. Similarly to a natural catchment, a combination of drainage features work together in sequence to form a management train. The management train controls both flows and volumes, as well as treating surface runoff to improve water quality. The fundamental principle is to slow down the movement of surface water runoff, or encourage it to infiltrate into the ground and to reduce its impact further down the catchment.

Comprehensive *site planning* can be effective at maintaining a pre-development stormwater flow regime from the area. Where smart land-use planning and preventive measures are not sufficient to achieve this goal, the planning stage is also the ideal time to incorporate structural stormwater BMP solutions such as swales, ponds and constructed wetlands into the development as part of the landscaping. Information on rainfall data, topography, geology, soil types, vegetation, natural habitats, current hydrological parameters, etc. will all be needed if sustainable stormwater management practices are to be successfully incorporated into the site.

One of the largest impacts of increased urbanisation on stormwater management is the conversion of vegetation and soils to impervious roads, car parks, cycle paths, pavements and other paved surfaces. The change from a natural permeable surface to an impermeable one increases the volume and velocity of runoff flows from rainfall, which would otherwise be attenuated and absorbed by vegetation and infiltrate the ground.

The efficient hydraulic conveyance system reduces ponding time and the detention time of water, thus reducing infiltration. The groundwater recharge is therefore greatly reduced and the subsurface flow is reduced. As a result, streams will lose their potential source of water, and base flow from the catchment will also be reduced. Dry weather subsurface flow in an urbanized catchment depends not only on the base flow but on the contribution from waste water leakage and flows.

Urban drainage flow is expected to be discharged into streams after biological or chemical treatment. However, a certain percentage of urban drainage flows generated after consumptive use may be discharged without adequate water quality treatment. The water quality in the dry weather flow in urban areas can be very poor due to higher contribution from drainage flows. The poor water quality (mainly high phosphorus and potassium content) in urban streams during dry weather is a major issue in poor regions of the Tisza watershed.

Impervious cover (asphalt, concrete, glass etc.) increases air and soil water temperatures and can increase temperature in urban discharges. Drainage water temperature is an important parameter for aquatic habitats. Some of the indicators of the urbanization impact on water quality include increased stream temperature and pollutants.

Pollutants such as oils and sediment are also dispersed through such runoff, contaminating receiving water bodies. The local setting will play an important role in the type of system that is selected. Water infiltration with low infiltration rates may not be suitable for porous paving and attenuation tanks or drainage pipes may need to be fitted under the road instead. Porous paving needs to be strong enough to withstand the weight and volume of the traffic using the road. The main usage of the road will determine the type of pollutants that have to be managed and the risk that these will pose to underlying aquifers. Poorly maintained porous paving can become clogged with sediment resulting in poor drainage from road surfaces. The concentration of metals and oil can also build up in the soil that must be removed. The construction of the porous paving needs to be appropriate for the local weather. The volume and intensity of rainfall and variations in temperature will influence design specifications.

Runoff from buildings, paths and roads can be attenuated and treated using *swales.* Swales are grassy ditches designed to infiltrate and treat collected runoff. As stormwater flows through the swale it is naturally treated by the vegetation and sub-soils as well as partially filtered through to the underlying soil. Compared with a concrete drainage channel, swales attenuate runoff and are capable of removing organic matter, sediment and suspended solids as well as, to a lesser extent, heavy metals. Swales infiltrate only some of the water that enters them and additional measures may be necessary to manage the discharge, particularly under heavy rainfall conditions. Overall, swales are an appropriate solution for the source management of stormwater at most sites. However, local conditions must be factored into the design of the swale to ensure that the performance is optimised and maintenance kept to a minimum[170]. Swales are unsuitable for large drainage areas as greater flow volumes and velocities cause erosion and reduce the attenuation and treatment capacity of the system. Swales are suitable for most soil types, although highly permeable sand and stony soils can pose a problem. In such cases, a fabricated soil bed and under-drain system can be added. An area that produces highly contaminated runoff may be unsuitable for the application of swales due to their limited treatment and buffer capabilities. This is particularly the case where there is a risk of groundwater contamination through infiltration. A high or highly undulated groundwater table can result in standing water in the swale and lead to runoff contaminants entering the groundwater untreated. This is the reason why swales are unsuitable on several urban sites on the flat plain of the Tisza watershed. On hilly sites, there is a limit to the steepness of the swale slopes and the surrounding topography. If these are too steep, runoff will enter the swale at a high velocity, causing erosion and reducing the natural treatment potential of the system. It is recommended to use more lower hydraulic capacity swales than fewer larger ones[171]. Typical challenges that can arise when constructing swales are related to the gradient of the banks being too steep, maintaining consistent falls along their length and ensuring that the vegetation is sufficiently established before being used as part of the drainage system. Any changes to the specified plants should be checked to ensure they are suitable for the type of swale proposed.

A *rainwater harvesting* systems can range from a simple water butt connected to a drainpipe (Figure 26), to a more complex system where the collected rainwater is pumped into the water supply network for domestic and productive uses. The purpose of reuse can be highly localised, such as domestic collection for toilet flushing, or on a much larger scale, such as for industrial processes and irrigation for parklands and urban agriculture.

Figure 26. Rainwater tank with a filtering system[172]

Rainwater harvesting is applicable wherever there are roof surfaces and a demand for the collected water (Figure 27). There are likely to be few issues with basic technologies where the only concerns will be whether the collection tank is secure against debris, mosquitoes and animals. More complex technologies that treat and distribute the collected water do, however, need to be selected, based on local circumstances and intentions of reuse. Systems that include basic treatment technologies and pumps require regular maintenance. Owners must be willing and able to carry out this maintenance if optimum performance is to be sustained.

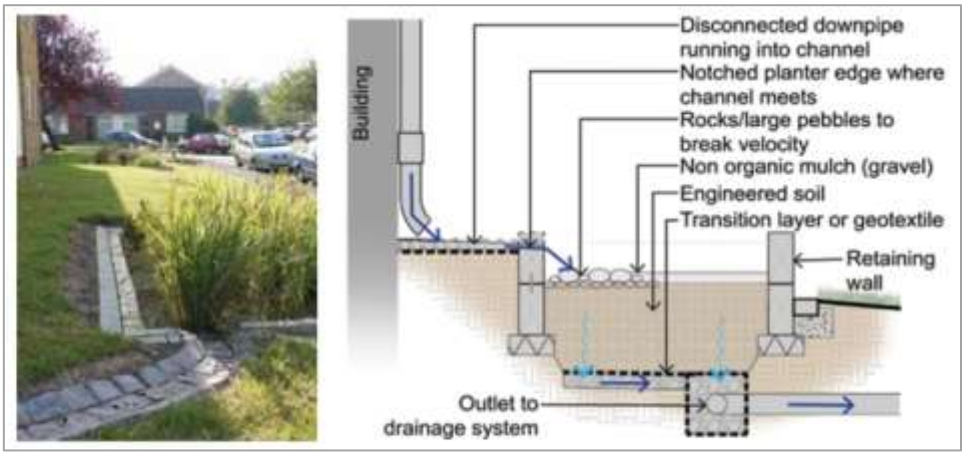

Figure 27. Small domestic rain garden and cross section through bioretention planter from disconnected downpipe[173]

The amount of water collected will depend on the roof area and rainfall rates. Investing in a complex harvesting system will only be worthwhile if supplies are sufficient to significantly replace the demand for potable mains water. Buildings that require large roof areas such as airports, railway stations, sports stadiums, arenas, shopping centres and municipal buildings are ideal for the technology. Collected rainwater is not necessarily clean and is not recommended for potable use. Contamination from air pollutants and toxic roof surfaces may result in the need of treatment for certain uses. An understanding of the pollutants contained in the collected rainwater will be necessary to ensure that the system includes appropriate treatment measures. Depending on the volume of storage available, rainwater harvesting is vulnerable to periods of low rainfall and drought. A backup mains supply is therefore required to cover shortages.

The cost of installing a complex rainwater harvesting system can be considerable. In cities where water bills are high, the capital and operational costs can be regained relatively quickly, leading to an attractive investment opportunity for businesses and households. However, where the price of water is low (and energy costs high) the return period will be much longer and subsidies to encourage investment may be necessary. Economies of scale can also be utilised such as constructing a larger system that covers an entire housing estate[174].

When combined with additional measures on the ground, a *green roof* can contribute to the complete disconnection of a roof area from a city's drainage network. An alternative brown roof is a type of green roof designed especially for the conservation of urban biodiversity. Although the potential for stormwater attenuation is less than other green roof designs, brown roofs do nevertheless reduce stormwater runoff intensity as well as removing pollutants found in precipitation[175].

Green roofs consist of layers of artificial membranes overlaid with a growing medium and vegetation. The vegetation may consist of a number of plant species selected due to their suitability for the local climate, the type of roof constructed and the desired aesthetic effect. Rainfall is retained in the soil thereby distributing stormwater runoff over longer periods and increasing opportunities for evapotranspiration. Depending on the design, contaminants contained in the rainfall may also be removed through natural treatment provided by the soils and vegetation[176].

The benefits of green roofs extend beyond the management of stormwater. The layer of vegetation provides effective insulation for the building, preventing the escape of heat during cold weather and keeping the interior cool under hot conditions. This reduces the building's energy consumption for heating and air conditioning. The existence of green roofs adds an attractive element to the urban environment through the extension of vegetated areas, reduces the urban heat island effect, enhances biodiversity and removes air pollutants. Green roofs are ideally suited for dense urban areas where there is limited space to implement alternative stormwater BMP options[177]. They provide multiple possible benefits, but it needs to be recognised that some of these are mutually exclusive and trade-offs are therefore necessary when selecting a design. Green roofs designed with the main objective of reducing stormwater runoff require high vegetation cover supported by a fertile soil[178]. This can lead to nitrate leaching, which compromises water quality in the runoff that flows from the roof. Depending on climatic conditions, green roofs may restrict the collection and reuse of rainwater from the roof surface, particularly where the objective is to attenuate stormwater in soils and plants. But designs that optimize reuse opportunities by providing natural treatment of the rainwater through soil filtration can be chosen, although such designs are unlikely to offer the same biodiversity and aesthetic benefits.

Green roofs need to be integrated with other stormwater BMP options such as infiltration basins and ponds. In comparison to regular roofing, green roofs may have high capital costs. However, a life cycle analysis of the technology will usually justify this cost through a greater life span and reliability in comparison to hard roofs as well as the additional energy savings and environmental gains they provide[179].

Infiltration systems are trenches or basins that collect stormwater and filter it into the soils below through a gravel and rock medium. Runoff is treated by the process of filtration through the stones and gravel that fill the trench or basin, and particularly by the underlying soils. Infiltration systems are capable of removing a range of pollutants, including almost all organic matter and sediment, suspended solids, heavy metals and nutrients. Unlike a swale, infiltration systems have no outlet so, if well designed, provide high attenuation rates as runoff seeps into the ground rather than being discharged to other drainage systems or directly into receiving water bodies. Infiltration systems are most effective when constructed in conjunction with source control options such as swales, sediment traps or certain types of green roof. Such a pre-treatment of stormwater before it enters the trench or basin helps prevent the clogging of the filter medium and reduces the risk of groundwater contamination. Local restrictions, particularly soil type and stormwater quality, must however be carefully considered to ensure that the solution is suitable and will not require excessive maintenance[180]. Infiltration systems are only suitable for use in soils with the appropriate infiltration capacity. Less permeable soils cause the clogging of the systems whereas soils that are too porous provide less treatment and increase the risk of groundwater contamination. Runoff containing high levels of pollutants can result in groundwater contamination, whereas high sediment loads cause the system to become clogged. Infiltration systems therefore require pre-treatment measures such as source control BMPs and sediment traps. Infiltration systems are not suitable in areas of high groundwater tables. A sufficient depth of soil between the bottom of the trench or basin is necessary to treat the infiltrated stormwater and avoid groundwater contamination[181]. Infiltration can be facilitated by fostering the application of permeable pavements (Figure 28).

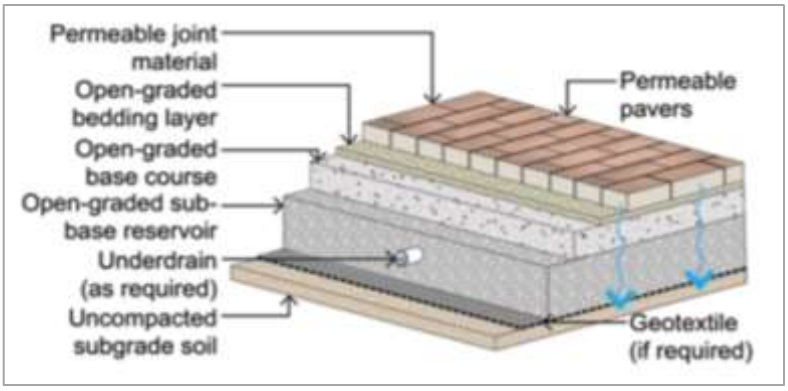

Figure 28. Infiltration by permeable pavement[182]

Detention ponds and basins are designed to provide temporary storage during heavy rainfall. Unlike infiltration basins and retention ponds, the detention equivalents do not necessarily lessen the volume of urban stormwater but rather are designed to smooth out high intensity peak flows through the gradual release of runoff. Multi-functional areas can therefore be designed, which combine storm water control with other urban uses such as recreation and transport - an advantage particularly attractive to dense urban areas where available land is in short supply[183].

Detention ponds and basins are constructed to collect runoff from wider areas such as a housing estate, car park or commercial development. The outlet is designed to control the release of water at a volume and velocity within the capacities of downstream infrastructural and natural drainage systems. Depending on the materials used and the desired detention time, some natural treatment of stormwater may occur in the ponds or basins, particularly the removal of sediment and suspended solids. However, due to the use of the site during dry weather for alternative purposes, this may be neither feasible nor desirable and therefore, the main objective will be quantity rather than quality-based. Detention ponds and basins are applicable to cities susceptible to combined sewer overflows, erosion as well as localised and downstream flooding during heavy rainfall. The design of the solution is, however, heavily dependent on a wide range of local factors, including climatic conditions, location of the site, use of the site during dry weather, protection of the infrastructure, etc. The design of the detention site is dependent on the local rainfall patterns and hydrology of the area being drained, as well as the characteristics of the stormwater entering the pond or basin (such as pollutant loads). The design must also be resilient enough to cope with future uncertainty in weather patterns. Densely populated urban areas are unlikely to have readily available space for the construction of a pond or basin with the sole purpose of stormwater detention. This option is therefore more typically used in areas where space is more readily available such as industrial estates and new housing developments. However, dense inner city areas can also be targeted if the solutions combine stormwater control with dry weather functions, such as sports facilities, playgrounds and car parking. Detention ponds and basins should rarely be stand-alone solutions and are likely to require supporting infrastructure both up and downstream of the site. Depending on the characteristics of the runoff entering the site, a combination of pollution and velocity control measures may be necessary to prevent, for example, siltation and erosion. Likewise, discharge from the site may require further management, particularly treatment, before entering natural water bodies. Ideally, detention ponds and basins are constructed as a site control measure within a stormwater facility.

Although a certain technological solution may theoretically help to achieve the targets associated with an objective, this does not necessarily mean that the solution itself is a sustainable one in the context under consideration, as costs, social implications, unwanted side effects and a range of other aspects need to be assessed. In reality, an option will never be entirely sustainable and trade-offs between benefits and costs are always necessary. Concessions are therefore inevitable, but what is imperative is that all sustainability criteria be considered during the selection process to ensure that these trade-offs are made with the confidence that the chosen option will, on balance, move the city towards increased sustainability.

Cost is always going to be a key factor in deciding which options to select. Rather than comparing implementation costs, a true economic value of an option, or group of options, is only obtained through a comprehensive life-cycle cost analysis. Besides construction costs, this includes operation and maintenance costs, the life span of the option and the period of investment. Ideally, the cost estimates should factor in the flexibility to change as well as environmental and social costs and benefits[184].

The most important input for all the above-mentioned solutions is the determination of the standard precipitation intensity. Intensity-duration-frequency (IDF) curves at a location are one way of presenting rainfall data available at a location by statistical analysis. Frequency refers to the probability that a storm of a given magnitude will be equalled or exceeded in a given year and is equal to the reciprocal of the return period in years. IDF curves provide average rainfall intensities corresponding to a particular return period for different durations.

Urban landscape irrigation Best Management Practices improve water use efficiency, protect water quality and are sensitive to the watershed and the environment. Landscape irrigation BMPs are economical, practical and sustainable. They will also maintain a healthy, functional landscape without exceeding the minimum water requirements of the plants or the maximum water allowance where applicable.

The American Irrigation Association and Society of Irrigation Consultant body suggest the considering of all sources of legally available water on-site that can be used for irrigation, and that will help minimize the amount of potable water to be used in irrigation:

- On-site developed water
- Rainwater harvesting
- Storm water capture
- Greywater
- Process water
- Foundation water

- Air-conditioning condensate[185]
- Municipally reclaimed water (abiding by local regulations)
- Groundwater
- Surface water such as lakes, streams, rivers or canals
- Potable water supply

5. Waste water – water recycling and alternative water sources

a.) The conventional approach to waste water management – waste water treatment

Water is consumed all over the urbanized area and released as waste water after use. Waste water is generated from residences, businesses, services (e.g. restaurants) and industries. These waste water sources are spatially distributed and the discharges are time-varying. The facility for waste water drainage from urban areas is generally provided in two ways: a separate sewer system for waste water from storm sewers or a combined sewer system. In separate sewer systems, waste water is collected and treated separately and treated water is sometimes discharged to surface water bodies. In combined sewer systems, waste water and stormwater are drained together and released to surface water bodies or main stormwater drains after treatment. Overflow under extreme conditions is, however, directed to main stormwater drains bypassing the treatment facilities.

The amount of waste water depends on the status of the sewerage, the level of water supply, the settlement characteristics, the habits of the citizens and the composition of the waste water dischargers.

As a result of investments funded by the EU, the annual waste water treatment capacity increased significantly between 2000 and 2013, and considerable new waste water treatment-related infrastructure was built in many settlements. However, the extended system works with lower utilization than before due to the following reasons:

- decrease in water consumption,
- low efficiency of the new treatment plants,
- connecting households to the treatment systems is a long process,
- the capacities of the new treatment plants are often significantly higher than the demands of the service area.

Waste water is not only discharged by residential and institutional consumers but also by industrial areas and, in the case of combined sewerage systems, also contains rainwater. The volume of domestic waste water is almost the same as the drinking water used in normal cases, but due to precipitation, the total amount of drained water can significantly exceed drinking water use.

Wear and tear, maintenance and, occasionally, more expensive chemical use can increase costs. 80% of the water service relies on fixed costs and fees, since network investment costs and built-in cleaning and handling costs are very high. In this way, the decrease in consumption and waste water production only slightly reduces the actual costs

The main parts of the sewerage system are the following: the connections at the site where the waste water is produced, the structures and facilities of the collecting and drainage network as well as the waste water treatment plant. Depending on the type of waste water to be drained, there are several types of sewerage systems: combined, separate, mixed and improved mixed sewerage systems.

In the combined sewerage system, the waste water and the precipitation falling onto the area are collected and transported in common channels. Thus, in this system, the amount of waste water and rain water has a common capacity threshold. If the amount exceeds its limit (e.g. due to extreme precipitation), the excess water is led directly into the recipient through pouring outlets so as to relieve the network. The benefits of the system are greater water drainage safety due to the larger cross-section, only single connections are needed, network registration is easier, smaller space requirements, vertical and horizontal alignment is simpler. The disadvantages: due to higher alteration in water quality and quantity, the sewage treatment technology must be flexible and the overload may cause an overcharge to the treatment system.

In the case of a separated sewerage system, the produced waste water is collected by sewage channels and rainwater is collected by precipitation drainage channels in a certain area. The waste water is transported to the treatment plant and the precipitation water is immediately transferred to the recipient. Benefits of the system: economical cross-section sizes are applied, the waste water treatment plant has steady loads, with low fluctuation in quantity and quality, drainage better due to higher possible slopes. The disadvantages are: two networks are needed, the networks have a larger space requirement, thus it is more difficult to install and the cost is higher.

The variation in waste water quantity is mainly due to the water usage patterns, which often differ during weekdays and weekends. The seasonal variations in urban waste water flows are related to changes in climatic variables, such as temperature and precipitation, also the changing habits of customers, such as travel and other activities occurring in the summer. Higher drainage flows are evident in summer compared to winter.

Waste water entering a conventionally activated sludge treatment plant usually passes through a bar screen to remove gross materials, which may damage mechanical equipment further down the treatment plant. The bar screen consists of vertical bars separated by a distance of about 1 cm. Screened solids are continually scraped off the bars. The screenings can be landfilled or incinerated. The conventional approach to urban waste water management is based on a centralised system that collects and treats a combined flow of most or all the waste water elements (Figure 29).

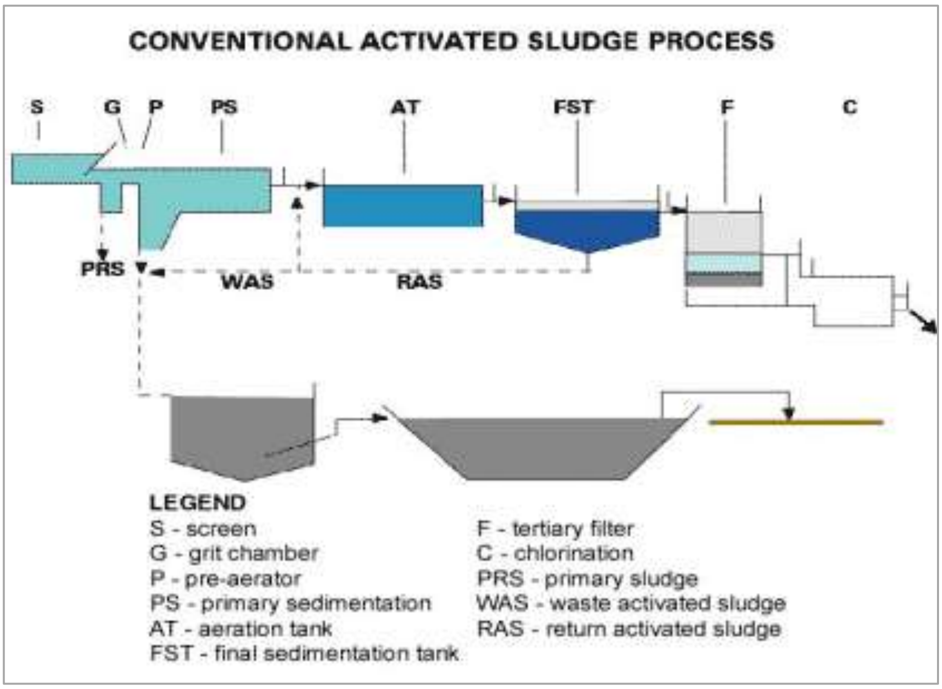

Figure 29. The scheme of conventional waste water treatment plant[186]

Next, sand and heavy particles are removed in a grit chamber. This chamber can be aerated to separate these particles from other suspended solids. The waste water spends a relatively short time in the grit chamber (in the order of minutes). The sedimented sand and grit is usually landfilled.

The finer solids are removed in a settling or sedimentation tank, where the waste water spends about an hour to allow the solids to settle or float. The mechanical removal of solids as described above is usually called 'primary treatment', the sedimentation tank is called primary sedimentation tank; the overflow from the sedimentation tank is called primary-treated waste water (primary effluent) and the produced sludge is called primary sludge.

The primary-treated waste water is then passed to an aeration chamber. Aeration provides oxygen to the activated sludge and at the same time thoroughly mixes the sludge and the waste water. Aeration occurs either by bubbling air through diffusers at the bottom of the aeration tank or mechanically agitating the surface of the water.

In the aeration tank, the bacteria in the activated sludge consume the organic substances in the waste water. The organic substances are utilised by the bacteria for energy, growth and reproduction. The waste water spends a few hours in the aeration chamber before entering a second sedimentation tank to separate the activated sludge from the treated waste water. The activated sludge is then returned to the aeration tank. There is an increase in the amount of activated sludge because of the growth and reproduction of the bacteria.

The excess sludge is disposed of to maintain a desired amount of sludge in the system. This part of the treatment process is called 'secondary treatment', the sedimentation tank is the secondary sedimentation tank, the overflow from the sedimentation tank is called secondary-treated waste water (secondary effluent) and the excess activated sludge is called secondary sludge.

Depending on the flow rate of the waste water, several parallel trains of primary and secondary stages can be employed. There are several ways to operate an activated sludge process. In a 'high rate' process, a relatively high volume of waste water is treated per unit volume of activated sludge. The high amount of organic waste consumed by the activated sludge produces a high amount of excess sludge. The opposite condition holds in an 'extended aeration' mode of operation.. A relatively low amount of organic waste is treated per unit volume of sludge with little excess sludge to be removed. The removal of BOD is higher in the extended aeration mode than in the high rate mode, but more waste water can be treated with the latter mode.

An activated sludge treatment plant is a highly mechanised plant, and is suited to automated operation. The capital cost for building such a plant is relatively high. The energy requirement, particularly for providing air to the aeration tank, is also relatively high. There is a need for the regular maintenance of the mechanical equipment, which requires skilled technical personnel and suitable spare parts. The operation and maintenance costs of an activated sludge treatment plant are therefore relatively high.

An activated sludge treatment process can be operated in batches rather than continuously. One tank is allowed to fill with waste water. It is then aerated to satisfy the oxygen demand of the waste water, after which the activated sludge is allowed to settle. The treated waste water is then decanted, and the tank is filled with a new batch of waste water. At least two tanks are needed for the batch mode of operation, constituting what is called a ‘sequential batch reactor (SBR)'. SBRs are suited to smaller flows, because the size of each tank is determined by the volume of waste water produced during the treatment period in the other tank

Waste water treatment plants typically include primary and secondary treatment processes and may include advanced treatment (sometimes identified as tertiary treatment) due to the developments during the previous decade.

Primary treatment is essentially a physical treatment process which removes suspended solids. It removes some organic nitrogen, phosphorus and heavy metals but only provides limited removal of microbial pathogens. Secondary treatment involves biological digestion and is commonly based on some form of ASP or trickling filters. It removes organic materials by digestion and should reduce biochemical oxygen demand and suspended solids by 85% or more. Particle-bound chemicals are removed and the concentrations of microbial pathogens are reduced. Targeted nutrient reduction processes are often included in the design of ASPs, e.g. biological nutrient reduction (BNR). Nitrification and denitrification processes, in particular, can greatly improve water quality for downstream processes such as advanced oxidation and chlorination by removing ammonia and nitrate, respectively. Maintaining longer retention times of solids in activated sludge-based processes can provide the attenuation of many trace organic contaminants. In recent years, secondary treatment has seen an increased use of MBRs, where membrane filtration (MF or UF) is integrated with biological treatment in the form of a suspended growth bioreactor. The membranes are used to reject the solids generated by the biological process, resulting in the production of clarified secondary effluent. The membrane filters provide the enhanced removal of microbial pathogens with the extent of removal depending on pore size. This removal is enhanced by the formation of a cake layer on the surface of the membranes during operation. This effectively reduces pore sizes and increases the removal of small particles such as viruses. Advanced treatment can include a range of processes of the type used in drinking water treatment plants. These include oxidation, adsorption, media filtration, membrane filtration and disinfection[187] (Figure 30).

Figure 30. Examples of potable reuse schemes[187]

Regarding chemical aspects, the chemical hazards in waste water can include a wide range of substances that are naturally-occurring or of anthropogenic origin. They include industrial chemicals, chemicals used in households, chemicals excreted by people and chemicals used or formed during waste water and drinking water treatment processes. Depending on the type of chemical hazard, concentrations may range from <1 ng to mg per l[188]. Metals and inorganic chemicals are generally present in higher concentrations (µg to mg per l) while pharmaceuticals and personal care products, when detected, are generally present in lower concentrations (ng to µg per l)[189]. While the list of chemical hazards in waste water can be long, studies have shown that typically detected concentrations typically are well below those that would represent a risk to public health[190]. Depending on the management and control of industrial discharges, waste water can have significant industry-related chemical contributions (Table 11). [191]

Table 11. Chemicals potentially present in waste water or produced during treatment

Type of chemical	Examples	Potential sources
Heavy metals	Cadmium, copper, chromium, lead, mercury, nickel, silver,	Industrial discharges, natural sources, water/waste water, arsenic (metalloid) pipes and fittings
Inorganic chemicals	Fluoride, nitrate, nitrite, ammonia	Mains water, natural sources, human waste
Synthetic industrial chemicals	Plasticizers, biocides, epoxy resins, degreasers, dyes, chelating agents, polymers, poly-aromatic hydrocarbon, polychlorinated biphenyls, phthalates	Widespread commercial use, industrial discharges
Volatile organic compounds	Petrochemical products, industrial solvents, halogenated hydrocarbons	Industrial discharges, mains water (e.g. trihalomethanes) DBPs
Pesticides	Household, garden and agricultural pesticides	Domestic agricultural and industrial discharges
Pharmaceuticals	Non-steroidal anti-inflammatories, antibiotics, anti-hypertensives, statins, veterinary pharmaceuticals	Pharmaceuticals and metabolites excreted by people and animals, domestic disposal of unused pharmaceuticals, discharges from manufacturing sites
Steroidal hormones (estrogenic and androgenic)	Estradiol, estrone, testosterone	Human and animal waste (particularly from feedlots); can include the excretion of natural hormones and contraceptive medication
Personal care products	Fragrances, cosmetics, antiperspirants, moisturizers, soaps, creams, whitening agents, dyes and shampoos	Human waste
Antiseptics	Triclosan, triclocarban	Household use and commercial use
Per- and polyfluoroalkyl substances	Perfluorooctanoic acid, perfluorooctane sulfonate	Household products (e.g. water and stain resistant compounds including furnishings and non-stick coatings for cookware), firefighting foams
Flame retardants	Brominated flame retardants, fyrol FR 2 (tri(dichlorisopropyl) phosphate), tris(2-chloroethyl) phosphate	Household products, e.g. furnishings, clothing, electrical devices
Dioxins and polychlorinated biphenyls	Octachlorodibenzo-p-dioxin, 2,3',4,4',5-pentachlorobiphenyl	Industrial discharges
Nanomaterials	Silver, titanium-oxide, zinc-oxides	Used in consumer products, e.g. personal care products, food storage containers, cleaning supplies, bandages, clothing and detergents
Cyanobacterial toxins	Microcystin, cylindrospermopsin, anatoxins, saxitoxins	Growth of cyanobacteria in waste water treatment plants, waste water lagoons and surface waters used as environmental buffers
Disinfection by-products	Trihalomethanes, haloacetic acids, bromate, chlorate, chlorite, N-nitrosodimethylamine	Reaction between disinfectants and organic material in waste water and drinking water; types produced dependent on source water and nature of disinfectant

Sources: NRMMC-EPHC-NHMRC (2008), NRC (2012), USEPA (2012), TWOB (2015), WHO (2017a),

There are millions of chemical formulations commercially available and the number of chemicals synthesized has grown tremendously over the past few decades. Although only a small proportion of these chemicals will be in commercial or industrial use at any one time, the nature of municipal waste water systems dictates that nearly all commercial products in use have some propensity to be collected and delivered to municipal WWTPs. Hence, waste water can present a continually evolving composition of chemicals in complex mixtures. It is likely that chemical constituents will vary widely among regions depending on local circumstances and industrial activities. Industrial discharges can be a source of heavy metals, synthetic industrial chemicals, manufactured pesticides and pharmaceuticals, volatile organic carbons (VOCs), dioxins and polychlorinated biphenyls (PCBs)[192] .

Regarding microbiological aspects, the pathogens that can be found in waste water are diverse in characteristics and behaviour. They include bacteria, viruses, protozoa and helminths. The greatest risk from exposure to waste water is gastrointestinal disease, following the ingestion of enteric pathogens; but other routes of transmission such as the inhalation of aerosols or dermal contact can also lead to disease.

Table 12. Examples of water/waste water-borne enteric pathogens[193]

Pathogen	Type species	Illness
Bacteria		
Burkhoideria	*B. pseudomallei*	Melioidosis
Campylobacter	*C. coli, C. jejuni*	Gastroenteritis, Guillain—Barre syndrome
Escherichia coli - diarrhoeagenic		Gastroenteritis
Escherichia coli - enterohaemorrhagic emorrhag ic	*E. coli* 0157	Gastroenteritis, haemolytic uremic syndrome
Legionella spp.	*L. pneumophila*	Respiratory illness (pneumonia, Pontiac fever)
Mycobacteria (non-tuberculous)	*M. avium complex*	Respiratory illness (hypersensitivity pneumonitis), skin infections
Salmonella Typhi		Typhoid
Other *Salmonella*	*S. enterica, S. bongori*	Gastroenteritis, reactive arthritis
Shigella	*S. dysenteriae*	Dysentery
Vibrio cholerae	*V. cholera*	Cholera
Viruses		
Adenoviridae	Adenoviruses	Gastroenteritis, respiratory illness, eye infections
Astroviridae	Astroviruses	Gastroenteritis
Calicviridae	Norovimses, sapovirsus	Gastroenteritis
Hepevirldae	Hepatitis E virus	Infectious hepatitis
Picornaviridae	Enteroviruses Parechoviruses	Gastroenteritis, respiratory illness, nervous disorders, myocarditis Gastroenteritis, respiratory illness
Reoviridae	Rotavirus	Gastroenteritis
Protozoa		
Acanthamoeba	*A. culbertsoni*	Granulomatous amoebic encephalitis
Cryptosporidium	*C. hominis/parvum*	Gastroenteritis
Cyclospora	*C. cayetanensis*	Gastroenteritis
Entamoeba histolytica	*E. histolytica*	Amoebic dysentery
Giardia	*G. intestinalis*	Gastroenteritis
Naegleria fowleri	*N. fowled*	Amoebic meningitis
Helminths		
Ascaris	*A. lumbricoides* (roundworm)	Abdominal pain, intestinal blockage
Taenia	*T. saginata* (tapeworm)	Abdominal pain
Trichuris	*T. trichura* (whipworm)	Abdominal pain, diarrhea

Sources: Adapted from WHO {2006; 2017a).

As a general note, care should be taken in interpreting microbial data, since reported pathogen concentrations can be obtained by using different methods, such as microscopy, culture and detection of genetic material using polymerase chain reaction (PCR), and next generation sequencing. Culture-based methods tend to be time-consuming and not available for all pathogens. However, they have the advantage of detecting living organisms. Tests using PCR and next generation sequencing are much quicker and are powerful tools for detecting the physical presence of microbial pathogens or components of pathogens. However, they do not generally determine viability or infectivity.

Concern has also been raised about the potential for the selection and development of antibiotic-resistant microorganisms in treated waste water. Antibiotic-resistant bacteria (ARB) and antibiotic-resistant genes (ARG) are a substantial worldwide public health issue and concerns have also been raised about exposure to ARB and ARG in water[194] . However, as the level of treatment applied in potable reuse schemes will generally exceed that used in existing drinking water treatment plants, after treatment, concentrations of ARB and ARG in potable reuse schemes are likely to be lower than those found in conventional drinking water supplies[195].

Regarding the radiological aspect, the occurrence, fate and transportation of radionuclides in waste water are reasonably well understood. Most radionuclides are naturally-occurring and estimates of worldwide average annual exposures to radiation from cosmic rays, terrestrial radiation, inhalation, food and drinking water are about 2.4 mSv, and the typical average dose is 1 to 13 mSv. The dominant source of radiation is the inhalation of radon[196]. Potential sources of radionuclides in waste water include nuclear power plants and other facilities that use radioactive material for manufacturing. Such radionuclide releases are usually strictly regulated and exposures from artificial sources are minimal relative to natural background radiation. Medical facilities and patients discharging clinically-used radionuclides can also be a source. Medical applications for radioisotopes include iodine-131 (half-life ~8 days) contrast media and technetium-99m (half-life ~6 hours). The short half-lives reduce the persistence of these radioisotopes, following shedding from outpatients or patients discharged from hospitals. Discharges from medical facilities to waste water systems should be prevented. Standard treatment technologies and processes used in potable reuse are effective in removing radionuclides.

b.) The challenges facing the conventional approach to waste water management and options for sustainable waste water management

Although a well-designed and maintained system protects public health and has few environmental hazards, not all urban settings are compatible with conventional designs and, even in the ones that are, a range of limitations raise the question of sustainability in the long run. When functioning poorly or combined with stormwater collection, waste water transportation networks may leak or overflow, causing untreated waste water risk to be dispersed into the environment. Conventional centralised waste water treatment is energy intensive and therefore requires a reliable and affordable power supply to operate effectively. Large waste water treatment plants have a capacity based on forecast volumes of waste water and, in combined systems, the predicted stormwater runoff rates. These systems are not easily adapted if design specifications prove to be too high or too low due to population growth, migration or change in climate patterns. Centralised systems fail to exploit the valuable resources in human excreta and greywater, such as the nutrients and energy they contain, and the potential for reclaimed water use or agricultural disposal. The cost of constructing, operating and maintaining centralised waste water collection and treatment infrastructure is high, as well as the constant cost ratio. Conventional waste water management is a rigid solution and this lack of flexibility makes it difficult to adapt to unexpected future climate and other change.

An alternative approach to waste water management views waste water not as a problem that needs to be disposed of, but rather as a variety of resources that, when managed correctly, can be reused (Figure 31).

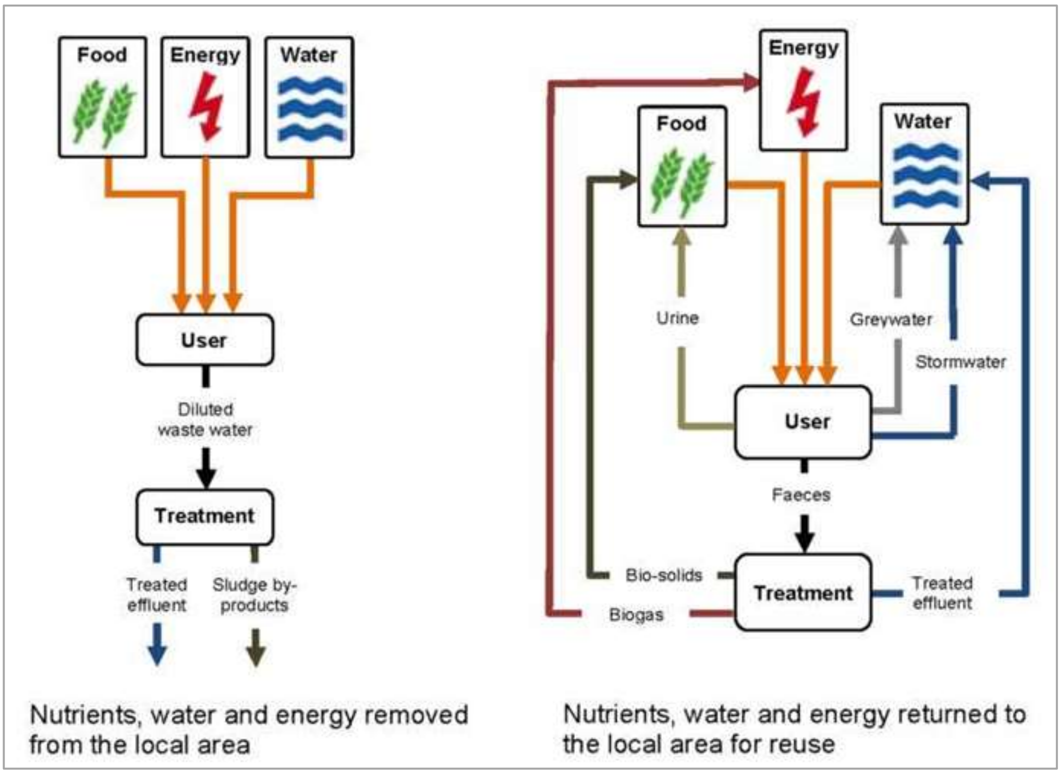

Figure 31. The traditional linear and circular economy based WWTP

Conventional waste water management can be considered a linear process with inputs (combined waste water flows) at one end and outputs (downstream discharge of treated effluent and disposal of sludge) at the other. In contrast, an integrated approach based on the cyclical processes observed in nature encourages the separate collection, treatment and reuse of urine, faeces, greywater and stormwater. With this approach, more sustainable solutions can be applied, which improve treatment performance at less cost and enable resources to be recycled more efficiently (Table 13).

Decentralised systems can provide recycled greywater, stormwater and treated blackwater (water containing urine and faeces) for irrigation and other non-potable uses, which reduces demands on the water supply network. In addition, recycled waste water can be used to recharge aquifers during dry periods (Figure 50). Urban population growth challenges the design capacity of centralised sewers, while decentralised treatment facilities can be flexible.

A decentralised system infrastructure can prevent overload by separating greywater and stormwater as well as the management of human waste at the household and community level. Urine and biosolids from faeces provide a cheap and environmentally friendly source of fertiliser and soil conditioner for agriculture and urban greening. The extraction and reuse of nitrogen and phosphorus also prevents nutrient overload in local water bodies. Savings are made through reduced energy and chemical costs. Additional revenue can be gained from the reuse of waste water and the nutrients and energy it contains. The separation of waste water flows and the confinement of specific pollutants allow for the application of the most effective and cost-efficient treatment techniques.

Pathogens, heavy metals and micro-pollutants such as hormones, metabolites of pharmaceuticals can therefore be isolated and removed more easily than possible in diluted flows. The construction of wetlands and other natural systems for waste water treatment provides habitats that support biodiversity and increases green areas in a city. The sustainable management of waste water is closely linked with other areas of the urban water cycle as well as urban planning as a whole. Rather than selecting options based on narrowly-defined problems and objectives, a more sustainable approach can identify multi-purpose solutions that provide urban benefits within and beyond the sanitation sector.

The greater integration of the urban water cycle therefore leads to decisions being taken, which are more likely to result in more sustainable urban water management as a whole.

Table 13. The differences between a conventional and an integrated approach to waste water management

Aspect of waste water management	Conventional approach (waste water management as a linear process)	Integrated approach (waste water management as a cyclical process)
Collection	Faeces, urine, greywater and stormwater are combined and conveyed through an expensive sewer network to a centralised treatment facility.	Faeces, urine, greywater and stormwater are collected separately and managed close to the source.
Treatment	Centralised treatment of combined waste water elements based on energy- and chemical-intensive infrastructure and technology.	Separate waste water elements are treated using innovative, decentralised technologies and natural systems.
Treated effluent	Treated effluent is discharged downstream to receiving water bodies such as rivers, lakes and estuaries.	Treated effluent is reused locally for non- potable water supply purposes.
Nutrients	Nutrients are disposed of in the environment through discharged effluent and sludge.	Nutrients are recycled and reused locally through the recycling of urine and the creation of biosolids from faecal sludge.
Sludge by-product	The sludge by-product is disposed of in landfills or by incineration.	Sludge is digested to create biogas and converted to biosolids for use as fertiliser and soil conditioner.
Energy consumption	Large amounts of energy are used for treatment and pumping.	Energy consumption is minimised by the use of natural treatment processes.

c.) Waste water management and urban agriculture utilizing greywater and treated water

Population growth, increased urbanization, catchment pressures, expanding areas of water scarcity and the impacts of climate change on water availability are all increasing pressures on existing drinking water resources, resulting in the need to identify new or alternative sources of drinking water supply[197].

Nutrients such as nitrogen and phosphorus contained in waste water can be recycled as fertiliser for farming purposes. If safely managed, treated effluent can also be used as a source of irrigation for crops. Moreover, the application of sewage sludge to agriculture improves the quality and moisture retention ability of soils.

The Council of the EU adopted its Conclusions on 'sustainable water management' in October 2016. It emphasizes that well-treated urban waste water can be reused for a variety of purposes in the agricultural sector, for industrial applications, sustainable urban development and the protection of ecosystems[198].

Greywater is the term used to describe water segregated from a domestic waste water collection system and reused on site. This water can come from a variety of sources such as showers, bathtubs, washing machines and bathroom sinks. It contains some soap and detergent, but is clean enough for non-potable uses. Water from toilets or wash water from diapers is not considered to be greywater. Kitchen sink water is not considered greywater in many countries. Many buildings or individual houses have systems that capture, treat and distribute greywater for irrigation or other non-potable uses. Recycled greywater and treated effluent can be used as a cheap and reliable source for the irrigation of parks, gardens, golf courses and sports fields.

Urban agriculture is the practice of growing plants and raising animals within and around cities, along with the related input provisions, processing and marketing activities and services. Farming in cities is varied and can consist of individual gardens, formal and informal allotments, as well as the use of other available urban green space such as parks, riverbanks, rooftops and public grounds. The products grown are wide-ranging and depend largely on the local environment and market demands.

The role of urban agriculture in sustainable urban development is being increasingly recognised through its contribution to poverty alleviation, food security and nutrition, employment generation, urban environment management and climate change adaptation. Urban agriculture, including urban greening, creates a market for the reuse of waste water and the nutrients within it. This is particularly the case where decentralised waste water collection and treatment systems are implemented. The demand from urban agriculture for cheap fertiliser, irrigation water and soil conditioner creates a market and incentive for waste water reuse. The economic value of these products helps to redefine waste water as a resource rather than a problem – a crucial requirement to generate a cyclical process for managing it. In addition, productive use of waste water for urban agriculture will help to reduce the demand for freshwater supply as well as to reduce the volume of discharged waste water.

The uncontrolled collection, transportation and reuse of waste water products leads to health risks, especially through human contact with pathogens. Although containing few high-risk pollutants, greywater is still unsafe for human consumption. Extra care must be taken based on chain management to ensure that cross-connections between potable water and greywater networks are avoided. Depending on the source and user behaviour, greywater may contain traces of pathogens. Although the impact on human health is likely to be minimal, appropriate treatment of greywater may be necessary prior to reuse in locations where the risk of contamination with faecal coliforms exists. The cost of greywater collection and reuse systems are dependent on the system chosen and the purpose of reuse. However, even sophisticated systems with high capital costs can have a short payback period when reduced potable water consumption and waste water treatment charges are considered.

d.) Sustainability objectives and indicators for waste water, water recycling and alternative water sources

The practical solutions associated with a more sustainable approach to waste water management are often non-standard. Infrastructure, legislation, regulations and social attitudes related to sanitation are established in most cities on the basis of a long-held conception of waste water as a single waste product rather than a multi-faceted resource. Due to these factors and the resistance they cause, it may be difficult to implement non-standard and innovative solutions (Table 14).

Table 14. The limitations to alternative urban waste water management

Barrier	Description	Consequences
Public acceptance	In many cultures, the reuse of human waste, even when safely treated, is taboo.	No market for recycled products.
Legal restrictions	The assumption that the reuse of waste water poses a risk to human health prevents the development of accommodating legislation and the necessary regulation.	Limitations on the use of waste water as a resource preventing its reuse.
Institutional aspects	Conflicting objectives and poor coordination between authorities whose responsibilities are relevant to waste water management, including its reuse.	Lack of an integrated framework through which more sustainable options could be identified and implemented.
Political motivation	The benefits (and health risk reduction) of good waste water management are not widely known so there is little political mileage to be gained from an improved service.	Lack of political support for more sustainable waste water management options.
Technical norms	Local engineers and planners have preconceived ideas concerning waste water solutions based solely on conventional infrastructure.	Alternatively, more sustainable solutions are not considered during the planning stage.
Land rights	Unclear land rights in certain urban areas such as informal settlements restricting investments in sanitation facilities.	Inability to construct sustainable waste water infrastructure in urban areas that may be in need of it most.
Perceived risk	New approaches and technologies are perceived as having a high risk of failure as they have yet to be tested on a large scale.	Decision makers, politicians and funders are unwilling to invest in non-conventional solutions.

Just as the barriers to more sustainable waste water management are location-specific, so are the measures by which they can be overcome. A more sustainable, cyclical approach to waste water management requires the buy-in of many more stakeholders, unlike in a conventional, linear approach. Waste water management cuts across a wide range of local government mandates and responsibilities, so the efficiency of institutional coordination is important. The recycling of waste water and the nutrients and energy it contains is a key aspect of increased sustainability. However, to do so there must be a market for the products generated. If the use of these resources is financially competitive with alternatives then a market will be created that supports the economic sustainability of the waste water management system. One of the biggest barriers to more sustainable waste water management is the public perception of waste water as a waste product rather than a resource. Public education can change this mind-set, allowing solutions such as waste water reuse and nutrient recovery to become more widely practiced and politically acceptable.

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In a sustainable waste water management system, nutrients in the waste water are reused to grow food by closing local biogeochemical cycles. In this way, there is no need to use as much chemical fertiliser and at the same time, there is much less of a nutrient discharge into rivers.

The problem of resource depletion and the pollution of the river is overcome by closing the material cycles (Figure 32)[199].

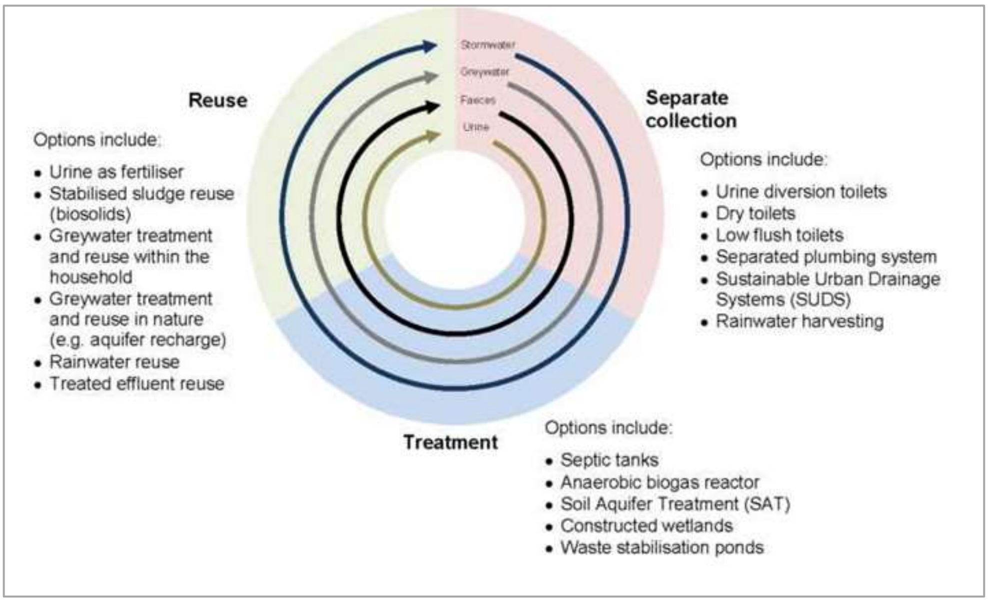

Figure 32. Examples of options that complement a closed loop waste water cycle[199]

In some urban settings, the design of a waste water management system and the options selected will be most efficient when serving large numbers of people. This allows for economies of scale, integration with existing infrastructure and the production of large quantities of resources such as fertiliser and biogas.

The urine diversion toilet is a possible solution. Urine is a pathogen-free substance rich in nutrients. In its pure form or mixed with water, urine can be applied safely as a fertiliser with no prior treatment and is therefore a cheap and highly effective replacement for its chemical equivalents. However, in most systems, urine is mixed with faeces, flush water and other waste water streams during collection, causing dilution and contamination with pathogens and other pollutants. The urine is collected without water in the front while faecal matter is removed, either with or without water, through the standard procedure at the back. Along with the installation of a new toilet, a collection and storage system for urine is necessary on larger scales.

As opposed to the centralised treatment of combined waste water streams from toilets, showers, sinks, washing machines and rooftops, a Decentralised Sanitation and Reuse (DeSAR) system is based on the separate collection of blackwater, greywater, stormwater and kitchen waste at the household level (Figure 33). The decentralised system allows the waste to be treated on site and maximises the possibilities of reusing the resources contained within it locally. The DeSAR system makes use of low flush vacuum toilets to maintain a concentrated flow of faecal matter and urine. Together with separated organic kitchen waste, the excreta is digested to produce biogas, which is recycled as an energy source within the household. The digested material that remains from the biogas generation process is pathogen-free, rich in nutrients and can be used as agricultural fertiliser. Greywater and stormwater are also collected separately in order to apply appropriate decentralised treatment on site.

The use of the natural environment in waste water management is typically to the detriment of the health of ecosystems. There are many examples throughout the world where rivers and lakes have been used as conveyors and diluters of waste water, resulting in the complete destruction of aquatic life within them.

Natural treatment is based on the ability of soils, vegetation and sunlight to treat water through physical, chemical and biological processes. These techniques are particularly effective for removing pollutants from greywater and stormwater as well as nutrients, pathogens and certain micro-pollutants standard blackwater treatment techniques are unable to capture.

Ponding or lagooning is effective in treating waste water and can reduce BOD and SS to the same levels as mechanical treatment plants (e.g. Activated Sludge Treatment). In addition, because of the longer residence time of the waste water in the lagoon (in the order of days), the removal of pathogenic bacteria and viruses by natural die-off is greater than in an activated sludge treatment plant (residence time in the order of hours). Cysts of parasites and helminth eggs are also usually removed through sedimentation in the lagoons.

A lagoon is a shallow excavation in the ground (1 to 2 m deep). It is generally unlined and the waste water percolates into the soil and groundwater. With time, the percolation rate will be reduced because of the formation of a sediment layer. Evaporation loss of water can be significant in arid climate regions. The soil itself is, however, not involved in the physical and biochemical waste water treatment processes taking place in the lagoon. A lagoon can therefore be lined with a layer of clay or with an impermeable plastic membrane if the protection of groundwater is desired, without affecting the performance of the lagoon. Waste water lagoons are also called 'waste stabilisation lagoons', because the organic substances in the waste water are converted to more stable (less degradable) forms.

The following processes take place in a lagoon. As waste water enters the lagoon, the sedimentation of solids occurs. Because of the long residence time of the waste water in the lagoon system, much of the solids in the original waste water are removed. Aeration of the water from the atmosphere occurs by a process of diffusion, by turbulence caused by wind movement on the water surface.

Oxygen is also supplied by algae living in the lagoon, which thrive on the nutrients (nitrogen and phosphorus) released by the decomposition of organic waste. The photosynthetic activity of algae, however, only takes place when there is sunlight. Thus, oxygen produced by photosynthesis is only available during this period. There is a symbiotic relationship between the bacteria and the algae. Bacteria take up oxygen and release carbon-dioxide, while algae take up carbon-dioxide released by the bacteria and produce oxygen for the bacteria.

Anaerobic lagoon: The oxygen demand of the bacteria exceeds the amount of oxygen supplied by surface aeration and algal photosynthesis. The biodegradation of the organic waste is carried out by anaerobic bacteria. Methane gas is generated in the process as a by-product. Odorous gases are produced, but the impact is reduced when a layer of scum forms on the water surface.

Facultative lagoon: The oxygen demand of the bacteria is met by surface aeration and algal photosynthesis, but is not met when the latter is not active. The water environment is aerobic during the day but becomes anaerobic at night. The biodegradation of the organic waste is performed by facultative bacteria, which can operate under both aerobic and anaerobic conditions.

Aerobic lagoon: The oxygen demand of the bacteria is met by surface aeration and algal photosynthesis.

It is common to have a series of lagoons with the first one or two being anaerobic lagoons, the middle ones facultative lagoons and the last few aerobic lagoons. The sediment at the bottom of the lagoons is anaerobic and undergoes anaerobic bacterial decomposition. The first lagoon in a series will eventually be filled with solids. The sludge produced can be removed and treated for reuse or disposal (Section 2 (6)) or allowed to undergo further biodegradation in the lagoon prior to reuse. Anaerobic lagoons can be deepened so that more sludge can be accommodated and the need to remove sludge is less frequent.

Lagoon performance is affected by temperature. At a higher ambient temperature (e.g. in the tropics), a shorter residence time of waste water in the lagoon is required to achieve the same level of treatment as when the temperature is lower. Because algae are present in treatment lagoons, they leave with the treated effluent. One way of harvesting algae is through aquaculture. Lagoons can be constructed and operated cheaply by using local materials and skills. If a number of anaerobic ponds have been constructed at the end of the series, the last of these can also be used for fish farming. Not only does this generate local income but the fish provide additional treatment by feeding on the remaining nutrients within the effluent. Similar benefits can be achieved by the use of the ponds for the cultivation of floating plants. The sludge collected at the bottom of the ponds has to be removed and safely disposed of, although this is not required on a regular basis. Vegetation must also be removed from the ponds to ensure that they do not become breeding grounds for mosquitoes.

Constructed wetlands are in-between lagoons and land-based treatment systems. A constructed wetland consists of a gravel bed in which wetland species, such as reeds, are planted. Waste water (usually after the settling of solids) passes through the gravel bed and organic substances are degraded by bacteria attached to the surfaces of the bed and plant roots. The removal of BOD and SS in beds with and without plants does not appear to differ very much. Wetland plants take up nutrients (nitrogen and phosphorus) when water residence time is long. Long-term nutrient removal requires the harvesting of the plants. Constructed wetlands consist of a range of designs that vary according to the way the flow is directed (i.e. horizontal or vertical) and the water level within the system (i.e. inundation vs. percolation systems). The appropriateness of the system depends on the type of pollutants to be removed, the volume of water to be treated, the possibility of inconvenience to nearby residents (for example, through odour and mosquitoes) and the amount of space available. Wetlands are effective at capturing most pollutants contained in greywater and stormwater runoff as well as removing pathogens, nutrients and micro-pollutants from septic tank outflows and conventional waste water treatment discharges. The systems can therefore be used as a decentralised solution to treat separated waste water flows as well as an addition to existing centralised waste water infrastructure in order to improve the quality of effluent discharges. The maintenance requirements of constructed wetlands are quite high, particularly to prevent the clogging of the filter media. Wetlands require a large land area, which is not always available in densely populated urban areas. Different designs, such as vertical flow wetlands and combinations with other treatment techniques do exist however, and greatly reduce the amount of space required.

The outlet of treated waste water effluent is potentially a valuable resource for the augmentation of the urban water supply. This is particularly the case in water scarce cities where an increasing water demand is causing the overexploitation of available supplies. Soil Aquifer Treatment (SAT) is a low cost technology for the advanced treatment, storage and reuse of mixed waste water flows. Secondary treated effluent is infiltrated through a soil percolation zone into an aquifer, where it mixes with existing groundwater. Contaminants (chemicals and microbes) are removed by physical, chemical and biological processes that occur in the soil matrix and aquifer itself. The water is then extracted for reuse through boreholes outside the aquifer treatment zone.

The quality of the influent waste water, soil types and the purpose of reuse will all determine the feasibility of the technology and the level of pre- and post-treatment required. Detailed site investigations and pilot studies are therefore required. The suitability of SAT depends on the characteristics of the local groundwater. The use of aquifers of good quality can cause the deterioration of the groundwater and environmental damage elsewhere in connected aquatic systems. SAT may also increase the risk of flooding in areas where groundwater levels are high.

Waste water sludge is a potential source of energy, which can be digested to create biogas for cooking, electricity, heat and transportation fuel. The generation of biogas can be carried out on a large scale, using the sludge by-product derived from primary and secondary waste water treatment processes; or on a neighbourhood or household scale through the digestion of untreated human and kitchen waste derived directly from the buildings. Depending on the size of the biogas reactor and the use of the gas generated, the capital costs to construct the reactor itself and accompanying infrastructure can be high. However, the long life span of the infrastructure and the value of the energy generated means that the payback period tends to be short.

Most waste water treatment processes generate a sludge by-product that needs to be either disposed of or reused. The quantity and quality of the sludge varies depending on the treatment process used and the variety of the treated pollutants in the waste water. Typically, much of this sludge is finally incinerated despite the fact that, if treated to sufficient standards, it can be used as biosolids for a range of productive purposes. Biosolids are widely used in agriculture due to the nutrients they contain and as a soil conditioner, because the organic matter they are comprised of helps soils to retain moisture and nutrients. They are also valued for the same reasons for forestry use and the landscaping of parks, energy plantations, golf courses, etc.

The main concern regards the use of biosolids centres on those derived from the treatment of waste water mixed with industrial and stormwater flows. In such cases, there is a risk that traces of heavy metals and chemicals the waste water treatment process is unable to remove will be transferred to the grown food products. These health concerns, together with potential public opposition to the use of a human waste product for agricultural purposes, have resulted in banning the practice altogether in some countries. The extent of this threat depends on the quality of the waste water prior to treatment. The risk is therefore considerably reduced if stormwater and industrial waste have not been mixed with human waste during the treatment process. Where this is the case, or their impact is minimal, the use of biosolids for agriculture is generally considered a sustainable use of sludge. The use of biosolids for agricultural purposes should take into account the quantity of nutrients that these contain, mainly on nitrate sensitive areas of the Tisza watershed. This allows them to be applied at an efficient rate without causing nutrient pollution. In areas where there is less demand for the use of biosolids for land application, alternatives include the incineration of sludge for energy recovery and the conversion to alcohol and other fuels. These options provide a useful source of renewable energy for a city, although fail to recycle the nutrients contained within the sludge.

The benefits of natural systems for managing waste water are more than a cheap and low energy treatment method. Systems such as wetlands, ponds and reed beds, which can be incorporated into parks or garden landscapes, provide additional benefits to the urban environment. The construction of natural treatment systems provide urban habitats for flora and fauna. In addition, with increased green space and aquatic environments in the city, the inhabitants' quality of life is also improved. Plants, such as reeds, used to absorb nutrients from waste water, can be harvested and reused as a source of fertiliser. An increased water and vegetation surface in the city can reduce the heat island effect. Natural systems such as wetlands and ponds can attenuate stormwater runoff during heavy rainfall, reducing the risk of local and downstream flooding.

In line with an integrated approach to urban water management, the selection of objectives and associated indicators for waste water should ideally not be carried out separately but rather as part of a larger IUWM strategic planning process, in which an overall vision for the city has been agreed upon and priority issues, such as improved sanitation, have been identified (Table 15).

Table 15. The objectives, indicators and targets for urban waste water management

Examples of integrated waste water management objectives	Examples of associated indicators	Examples of associated targets	Relevant urban management sectors
Eliminate the threat of human contamination and disease	Number of reported cases of diseases caused by contact with human waste Faecal coliform content of effluent discharges	Zero cases of disease caused by inadequate waste water management by the year X Zero releases of effluent with a faecal coliform count of X per X	Waste water services Health
Minimise non-renewable energy consumption in the management of waste water while maintaining levels of service	Measured non-renewable energy consumption for pumping and treatment Energy expenditure by waste water utility	X% reduction of carbon emissions for pumping and treatment by year X X% of financial savings in non-renewable energy bills by year X	Waste water services Energy Climate change mitigation
Recycle nutrients from waste water for use as fertiliser for municipal purposes	Municipal expenditure on chemical fertiliser Quantity of phosphorus produced from waste water	X% reduction in municipal expenditure on chemical fertiliser by year X X kg of phosphorus produced per year	Waste water services Parks and recreation Environmental management
Disconnect stormwater flows from the waste water sewage system	Area of roof space disconnected from combined sewer systems Actual volumes of waste water treated in relation to measured rainfall rates	X% of roof area disconnected from the sewer system by year X X% reduction in volumes of waste water treated during heavy rainfall compared with past events of equal magnitude by year X	Waste water services Drainage services Housing Environmental management
Increase removal of environmentally damaging pollutants through the waste water treatment process prior to discharge to the environment	Quantities of target pollutants present in discharged effluent Change in population numbers of key species in a specified area affected by target pollutants	Reduction of target pollutants to X amount per unit of treated effluent by year X X number of specie X counted by year X in specified area	Waste water services Environmental management
Save water supplies through the reuse of waste water for the irrigation of municipal gardens and playing fields	Quantity of potable water used for municipal irrigation purposes Quantity of treated waste water discharged with no reuse purpose	X% reduction of potable water used for municipal irrigation X% decrease in the volume of treated effluent discharged with no reuse purpose	Waste water services Water supply Parks and recreation

Any sustainability assessment of WWTP needs to be backed up by multi-stakeholder engagement. This ensures that the actions, opinions and needs of all who have an influence on and are influenced by the waste water management are taken into consideration. The involvement of utilities, user groups, relevant authorities, NGOs, agriculture, the private sector, etc. is therefore essential for designing solutions that stakeholders can identify with and for the direct and indirect impacts of management decisions to be truly understood.

6. IT of IUWM (Smart City, data sources, SDSS)

a.) Critical knowledge on physical data on the availability and characteristics – (technical, design, operational and performance) of the various equipment, devices, GIS and RS technologies and systems used in the urban water management cycle

Current urban drainage master plans/systems have been designed using historic rainfall data but as a result of predicted changes in rainfall frequency, intensity and duration (although the precise direction and magnitude of these changes are uncertain), this approach will no longer be reliable in the long run. Raised river levels during heavy rainfall may mean that runoff drainage cannot discharge to a watercourse and increasing impervious areas within cities can only exacerbate this problem. Assessing the social, economic and environmental implications over the space and time of a potential solution is not easy. A comprehensive assessment should test the robustness of an option against a long list of relevant factors. These include future climate scenarios, life-cycle costs, associated risk, integration with existing infrastructure and interaction with the urban environment. This can be a complex task and will often require the assistance of modelling software and detailed comparative analysis. Using generic and locally specific sustainability criteria, these tools can manage data in a way that enables a range of different implications, scenarios and combinations of options to be assessed. Urban systems have increased in complexity as never seen before in history. Cities evolve based on the characteristics of emergence, self-similarity, self-organization and the non-linear behaviour of land use changes with time[200]. For the modelling of land use changes and urban planning, some interesting aspects used in this technique are the representation of the environment. This can be performed in two or three dimensions, the integration with GIS-Remote sensing, the combination of temporal-spatial variables and the interaction between agents and with their surrounding environment.

Smart City has been in operation for several years to encourage a new way of thinking about the urban environment by means of a “smart” organisation of services and human interactions designed to increase sustainability, efficiency and the quality of life[201].

Diagnostic tests focusing on loss reduction can be effective if they are based on accurate measurements of water losses. The amount of leakage can be identified for pipe sections, and diagnostics is limited to pipe sections with high water loss if economically important.

The most effective method of water loss analysis is the so-called "zero-consumption" loss measurement, which continuously registers and processes the data coming from high precision pressure and flow meters. Measurement takes place in low-consumption night hours, by disconnecting part of the water network to be tested and by measuring the amount of input and output water with flow meters. Thus, testing can be performed without disturbing consumers.

During short measurement periods, in the case of identifying appropriate area sizes, it is possible to register regular zero or equally minimum values within the constantly changing water consumption. Zero values identify perfect water network conditions, while regular minimum, but not zero values indicate leakage, damages in the pipe network system representing constant “water use” as water loss. (The presence of a continuous consumer should be excluded before the measurement by arrangement with the operator or an on-the-spot check.) These measurements could be continuous with built-in networked instruments or periodic with mobile meters or measuring vehicles. In the case of periodic measurements, if the leakage occurs between two test times, the damage will not be diagnosed immediately. Thus, the water loss remains hidden until the next diagnostic measurement, resulting in a higher amount of water loss. The amount and rate of water loss are possible to decrease with the proper designation of the measurement periods, and/or with the increase in the network reconstruction rate. The periodic water loss measurement method is an efficient, easy-to-use method to distinguish undamaged and damaged line sections and provide accurate information on the loss rate of the damaged pipe sections. This allows for the precise localization of the leakage on the damaged pipe section.

The basis for the electroacoustic research of leakage is the generation and the properties of leakage noise. The leakage curve of the leakage noise is an irregular, rapidly changing acoustic signal, in correspondence with the random and continuous movement of the joint vibration of the leaking water, the damaged pipe wall and the surrounding soil particles. Acoustic leakage research has evolved in two ways in recent decades; based on a) the measurement of noise intensity and b) the transmission velocity of the noise.

Other methods such as thermo-graphical surveys can also be promising. Thermography is based on detecting the temperature change in the water-saturated soil around the damaged pipe section. Thermographic surveys can be applied on homogeneous, uncovered surfaces, mainly in the case of main pipelines and well connecting networks, but not in a built, urban environment. The most appropriate way of surveying is airborne imaging, mostly at low altitudes (10-20 metres above ground).

The primary field of application of soil radar is in the detection of the pipelines. The location of the damaged pipe section is only possible in the case of extensive overflow[202].

Smart metering

Smart water meters are similar to conventional mechanical water meters, except that they are connected to a data logger for the continuous monitoring of water consumption. Smart water meters provide real-time information or sufficient data points, which allow consumers to understand and monitor water consumption. They also help utilities manage water networks efficiently and provide better customer service as peak periods of water usage can be accurately determined by the data provided by smart water meters. Pulses are created in the smart water meter by the water consumption event; for instance, the use of a washing machine is logged by the data logger at a pre-defined frequency. Several user-defined parameters such as flow rate, time, and volume are used to disaggregate the information provided by these pulses and assign them to different water use events.

Implementing smart metering can also have many benefits for operators and users; for example, in remote reading, pre-payment of consumption, service restriction, verification of water meters, localization of pipe breaks and congestion. The provision of fast, on-line delivery of metering data to the customer service and billing system, on-line user information, fast, cost-effective use of different consumer restrictions and the use of pay-per-view meters are beneficial for service providers.

However, in order to attain the benefits, it is important to find solutions to the following major challenges:

1. Where the service provider does not own the meter, it may be problematic to have the smart meter obligatorily installed.
2. Electronic meters do not measure in case of power failures, but battery meters have a shorter life span and are more vulnerable.
3. The communication link between the water meter and the data acquisition unit may be difficult due to distance and energy consumption.
4. Water meters of detached houses are housed in pits, often under water, and the signal must be transmitted safely from the measurement point to the data collection unit. To do this, a different meter type is needed, like those in blocks of flats.

5. As regards the prepaid system, it may be problematic to provide the power supply needed to control the solenoid valve.
6. The purchase cost of a smart meter is over twice as high as that of a conventional one.
7. The installation, operation and regular verification of smart meters cannot be considered a real choice in the short term, as the regular verification of conventional water meters is already a significant cost to service providers.

Therefore, smart measurement cannot be introduced in the short term due to significant costs. With multi-utility installation, the installation and operating costs of smart metering can potentially be divided[203].

b.) Urban Mapping - Vertical/Horizontal Spatial borders - GIS framework

In modern industrial cities, the pattern of land use has become more complex and diverse. The increased commercial activity in the city centre has led to the gradual drift of residential population away from central business areas. Land use plans and zoning codes are prepared by the appropriate authorities. These are then subjected to public consultation and participation prescribed by law. A Geographical Information System (GIS) is a computer system designed to capture, store, manipulate, analyse, manage and present a variety of spatial and geographical data. GIS data enable multiple viewpoints to be considered and provide the capability for dynamic query and display of information as well as more understandable space/time representation. Automated mapping in GIS allows for efficient handling and dissemination of thematic information, enabling quick map-making for planning and decision-making. Remote Sensing (RS) data are an important input into GIS. RS acquires information about objects without touching them.

The terms "land use" and "land cover" are not synonymous. Land cover is used to describe the physical state of the land surface: the physical, chemical, or biological description of the terrestrial surface, e.g. grassland, forest or concrete. There are two types of land cover change: conversion and modification. Land cover conversion involves a change from one cover type to another. Land cover modification involves alterations of structure or function without a wholesale change from one type to another.

There are many different ways of understanding or defining a 'city'. These may refer to an administrative unit or to socio-economic agglomerations. The expansion of *de facto* cities into suburban areas has led to the traditional delimitation of urban and rural areas becoming less clear, a pattern that has been reinforced by complex, overlapping urban systems.

In order to classify the degree of urbanization by local administrative units (LAU) based on the grid cell approach, the following criteria are employed in the EUROSTAT method. An urban centre is defined as contiguous (in other words, neighbouring or adjoining) grid cells of 1 km² with a population density of at least 1,500 inhabitants per km²; these clusters are used to identify all cities with urban centres of at least 50,000 inhabitants. An urban cluster is defined as contiguous grid cells of 1 km² with a population density of at least 300 inhabitants per km² and a minimum population of 5,000inhabitants. Rural grid cells are defined as those grid cells outside of high-density and urban clusters. The typology for metropolitan regions is based on NUTS level 3 regions, divided into metropolitan and non-metropolitan regions. Metropolitan regions are approximations of functional urban areas (cities and their commuting zones) of 250,000 or more inhabitants. Eurostat online data codes, such as urb_cpop1, provide easy access to the most recent data available[204].

Land cover is a key indicator of anthropogenic environmental activities. The EU's CORINE Land Cover (CLC, Coordination of Information on the Environment) programme provides harmonized and thus comparable land cover and land use information for/about all EU member states. The Urban Atlas programme was started in the framework of CLC. CORINE Land Cover data are generated by remote sensing technologies based on satellite images. The European Urban Atlas provides reliable, inter-comparable, high-resolution land use maps for 305 Large Urban Zones and their surroundings (more than 100,000 inhabitants as defined by the Urban Audit) for the reference year 2006 in EU member states and for 695 Functional Urban Areas (FUA) and their surroundings (more than 50,000 inhabitants) for the reference year 2012 in EU and EFTA countries. Change layers were produced in 2012 only for all FUAs covered both in 2006 and 2012 reference years.

The Urban Atlas service offers a high-resolution land use map of urban areas. The product described in this mapping guide is adapted to European needs (discussed and agreed with DG Regional and Urban Policy (REGIO)) and contains information that can be derived mainly from Earth Observation (EO) data, backed by other reference data, such as Commercial Off-The-Shelf (COTS) or Open Street Map (OSM) navigation data and topographic maps. The EO data are the basis for interpretation. Automated image segmentation and classification was applied to achieve an initial differentiation between basic land cover classes (urban vs. forest vs. water vs. other land cover) is possible following a decision of service providers.

A given area should be interpreted with a minimum of 100 m extension (100 m buffer) to ensure accuracy and the continuity of polygons. A subset with the spatial extent of the final product will be generated during the post-processing phase. At the borders of this subset (i.e. the final product), polygons smaller than the Minimum Mapping Unit may be present (Table 16).

Table 16. Accuracies of Urban Map Product

	CORINE Classes [Lev. I, No.]	Levels provided	MMU	Thematic Accuracy	Positional Pixel Accuracy
Urban	1	I -IV	0.25 ha	>= 85%	<+/- 5 m
Rural	2-5	I-II	1 ha	>= 80%	<+/- 5 m
Overall accuracy				>= 80%	

Scale 1:10,000. Mapping scale on screen 1: 5,000. Minimum Mapping Unit (MinMU) = 0.25 ha. Positional accuracy + / - 5 m.

When interpreting urban area patterns, it is important to distinguish these different densities and randomness properties, for example, from Continuous urban fabric (S. L. > 80%) to Discontinuous Urban Fabric (S. L. 10% - 80%) (Figure 33).

The main water-related land use categories are the following: industrial, commercial, public, military and private units (water treatment plants, sewage-treatment plants, seawater desalination plants); Artificial, non-agricultural vegetated areas (such as public green areas, suburban natural areas, forests or green areas extending from the surroundings into urban areas are mapped as green, urban areas, when at least two sides are bordered by urban areas and structures, and traces of recreational use are visible). Categories not included are: private gardens within housing areas, cemeteries, buildings within parks, such as castles or museums, patches of natural vegetation or agricultural areas enclosed by built-up areas without being managed as green urban areas.

Direct water land use categories with a visible water surface area are also delineated on the EO data. EO MinMU 1 ha data should be considered as a primary (guiding) data source: sea, lakes, fishponds (natural or artificial), rivers including channelled rivers and canals.

The default source for delineation is the EO data. If no clear delineation is possible using EO data, other reference datasets may be used. For example, reservoirs; water courses or ponds with a strongly variable surface level. All water bodies and water courses visible in the imagery are mapped as long as they exceed an extent of 1 ha. Water courses are also mapped continuously when the water surface is covered by vegetation. If the water is partly obscured, e.g. by vegetation, the delineation shall be oriented on other parts of the water where it is not obscured[205].

The urban map and similar land cover maps can be important starting points in complex urban hydro modelling (Figure 34). When geospatial data are used in hydrologic modelling, important issues arise such as the necessary resolution to capture essential variability, or the derivation and regionalization of model parameters representative of the urban watershed[206]. The goal of the reclassification of a land use/cover map is to represent the location of hydraulically rough-versus-smooth land use types for watershed simulation.

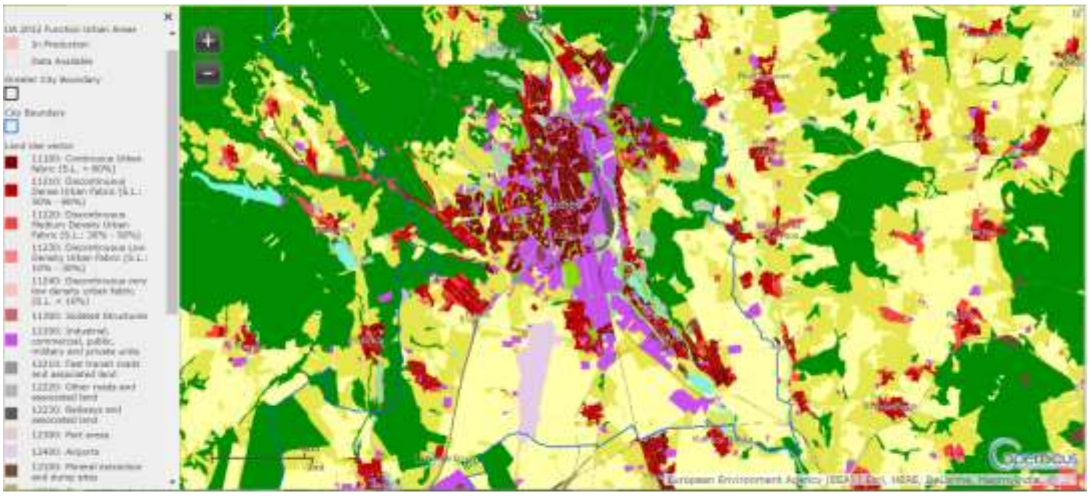

Figure 34. Digital urban map of Košice (SK) on the Map server of the EU Environmental Agency[207]

The velocity of surface runoff is controlled by hydraulic roughness. The Darcy-Weisbach and Manning equations have been widely used to describe surface flow characteristics and they contain a hydraulic roughness coefficient. Also, Chézy and Engelund-Hansen attempted to relate the flow depth in a canal to its velocity where the hydraulic roughness coefficient was also a critical parameter[208]. The detailed measurement of hydraulic roughness over any large spatial extent is impractical. Hydraulic roughness maps can be obtained from a variety of sources, including aerial photography, generally available land use/cover maps and satellite remote sensing. Limited field tests do exist, where measurements of runoff depth and velocity are used to calculate hydraulic roughness coefficients for overland flow areas[209]. Assigning hydraulic roughness to general land use/cover classifications is difficult, because these classifications are rarely made according to hydrologic characteristics (Table 17).

The hydrologist must exercise some judgment in assigning hydraulic roughness parameters to these classification schemes. Moreover, it often requires interpretation of what a particular land use/cover classification may indicate in terms of overland flow roughness[210]. Field observation or experience is usually required to assign appropriate values of hydraulic roughness to channels and overland flow areas. Impervious areas mapped by land use/cover maps can be used for assigning hydraulic roughness to such areas, besides the obvious implications for infiltration modelling. Infiltration is a major hydrologic process controlling the amount of runoff at different urban scales. Measurements of infiltration and soil characteristics are usually performed at point locations but applied remote sensing methods help us to extend these parameters. A raster Digital Elevation Model (DEM) contains topographic information as a regular array of elevation data. Other data structures such as the Triangular Irregular Network (TIN) or grid can also be effective tools for urban modelling[211]. The basic geoprocessing in extracting hydrologic features from a DEM involve the next steps: depressions correction; flow direction; flow accumulation; delineation of drainage network; watershed of isolated boundaries. Using larger DEM cell sizes also ‘short-circuits’ streams or river meandering, causing an overall shortening of the drainage network. Drainage length shortening and slope flattening often have competing effects on distributed simulations of hydrographs[212]. Extracted hydrographic features depend on the raster pixel resolution of the DEM and terrain characteristics may have a significant influence on urban hydrologic model calibration and performance.

Table 17. Watershed scale hydraulic roughness based on US Land Use Classification (NLCD) classification[213]

Landcover	Description	Manning's *n*
21	Developed, open space	0.0404
22	Developed, low intensity	0.0678
23	Developed, medium intensity	0.0678
24	Developed, high intensity	0.0404
31	Barren land	0.0113
41	Deciduous forest	0.36
42	Evergreen forest	0.32
43	Mixed forest	0.40
52	Shrub/scrub	0.40
71	Grassland/herbaceous	0.368
81	Pasture/hay	0.325
90	Woody wetlands	0.086
95	Emergent herbaceous wetlands	0.1825

Satellite images are usually used for Earth observation, and many remote sensing applications are devoted to urbanization, especially in the following areas: urban structure and urban planning, green vegetation vigour and drought stress monitoring, water management, disaster management and emergency situations, traffic control and monitoring, property mapping, mapping of disturbances and land use/land cover (LULC) changes.

The new-generation Remote Sensing data (visible, infrared, microwave, laser spectra) give more opportunities for use and allow new applications in urban hydrology fields. In the case of flood monitoring, high-resolution, multi-temporal data provide the results to significantly improve the performances of the forecast, alert and post-event monitoring of inundation events.

Multi-temporal and multi-sensor remote sensing data allow the temporal and spatial reconstruction of flood inundation, from the beginning until the end, when all the inundated areas become dry again. Erosion and sedimentary features mainly focus on the post-flood investigation. The sediment transfer processes, such as erosion and the deposition of hyper-concentrated mud, debris flows, etc. on slopes and in riverbeds constitute an indicator of local runoff generation[214].

Several authors have explored the integration of remote sensing with hydrological modelling, covering several aspects especially useful in the following areas[215, 216]:

1. The use of remote sensing data to retrieve and evaluate flood-runoff hydrology information, such as flood area extent, water stage, discharge, etc.;
2. The use of remote sensing imagery to retrieve hydro-geomorphic parameters (e.g. roughness parameters, river cross-section geometries, detailed floodplain topography), which can be used to build model structures and enhance process representation in the model;
3. The use of remote sensing observations to calibrate and validate hydrodynamic models;

4. The use of remote sensing information to compare existing data with the models.

Roughness and elevation are the parameters that strongly influence model results and are usually poorly constrained. LiDAR-derived DEM and DSM height have also been used to derive roughness estimates, to be included as floodplain, runoff friction parameterization or evapotranspiration. However, the choice of the method depends on the details of the model, the type and nature of the data acquisition and the integration and calibration or validation methods[217].

HidroGIS modelling integrates GIS and hydrological models, which can help developers to optimize different scenarios of urban hydrology.

MIKE URBAN DHI professional software can cover all water networks in the city, including water distribution systems, stormwater drainage systems and sewer collection in separate and combined systems. MIKE URBAN is the urban water modelling software of choice when the important parameters for model selection are stability, workflow, openness, flexibility, GIS integration and physical soundness (Figure 35).

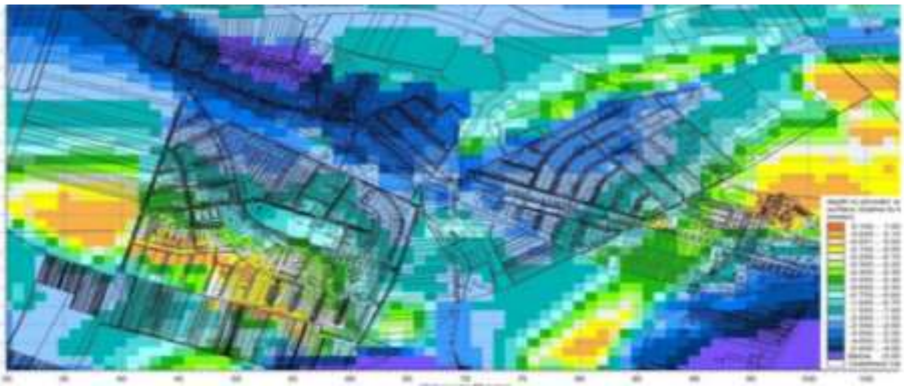

Figure 35. Sewer network delinearization based on simulated groundwater level [218]

HEC-RAS is a computer programme that models the hydraulics of water flow through natural rivers and other channels. GeoHECRAS is a2D/3D visualization and editing data wrapper to the HEC-RAS software. GeoHECRAS can use AutoCAD and MicroStation drawings, import GIS data, cut cross sections and produce flood maps[219].

Arc Hydro is a GIS data structure that links hydrologic data to water resource modelling and decision-making methods. Using Arc Hydro helps you build a dataset that can be integrated with water resource models. The Arc Hydro data model standardizes water data structures so that data can be used consistently and efficiently to solve water resource problems at any spatial scale[220].

SWAT is an open source model that can be used with GIS data to simulate hydrological processes in basins. The SWAT complement is a tool to evaluate soil, water and basin management. The QGIS interface is called QSWAT. This model is used to predict the effects of land use and management in water flow, the amount and chemistry of sediments in basins, primarily in basins that do not have previous monitoring information. It is also used in big and complex basins that have a variety of soils as well as management practices[221].

7. Abbreviations

AMD	acid mine drainage
AOP	advanced oxidation process
AOPs	Activated Carbon and Advanced Oxidation Processes
ARB	Antibiotic Resistant Bacteria
ARG	Antibiotic Resistant Genes
ASP	activated sludge process
AWRP	advanced water recycling plant
BAC	biological activated carbon
BMD	benchmark dose
BMDL	lower confidence limit on the benchmark dose
BNR	biological nutrient reduction/removal
CBF	City Blueprint Framework
CCP	critical control point
CECs	chemicals/contaminants of emerging concern
CFU	colony-forming unit
CRMWD	Colorado River Municipal Water District (USA)
Ct	product of disinfectant concentration and contact time
CSF	cancer slope factor
DALYs	disability-adjusted life years
DBPs	disinfection by-products
DEM	Digital Elevation Model
DOC	dissolved organic carbon
DPR	Direct Potable Reuse
DPR	direct potable reuse
EO	Earth Observation
ESB	engineered storage buffer
GAC	granular activated carbon
GCF	Governance Capacity Framework
GDWQ	Guidelines for Drinking water Quality (WHO)
GI	Geographical Information System
GL	gigalitre
GWR	groundwater replenishment
H2O2	hydrogen peroxide
IBL	Internal Boundary Layer
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
IPCC	Intergovernmental Panel on Climate Change
IPR	Indirect Potable Reuse
IUHM	Integrated Urban Hydrology Management
IUWM	Integrated Urban Water Management
IWA	International Water Association
LAU	local administrative units

LMWD	Laguna Madre Water District (USA)
LOAEL	lowest-observed-adverse-effect level
LRV	log10 reduction value
LULC	Land Use / Land Cover
MBR	membrane bioreactor
MF	microfiltration
MGD	million gallons per day
MinMU	Minimum Mapping Unit
MLD	million litres per day
NDMA	N-nitrosodimethylamine
NF	nanofiltration
NIWR	National Institute for Water Research (South Africa)
NOAEL	no-observed-adverse-effect level
NRW	non-revenue water
NSP	Nonpoint Source Pollution
NTU	nephelometric turbidity unit
NWRI	National Water Research Institute (USA)
OCWD	Orange County Water District (USA)
OCSD	Orange County Sanitation District (USA)
OSM	Open Street Map
OWMP	Occoquan Watershed Monitoring Program (USA)
ozone-BAC	ozone-biological activated carbon
PCBs	polychlorinated biphenyls
PCR	polymerase chain reaction
PDU	PCR detectable units
pppy	per person per year
PRM	Preventive Risk Management
PUB	Public Utilities Board - National Water Agency (Singapore)
RO	Reverse Osmosis
RO	reverse osmosis
RS	Remote Sensing
SAT	Soil-Aquifer Treatment
SAT	soil-aquifer treatment
SCADA	supervisory control and data acquisition
SDG6	Sustainable Development Goals – Clean Water and Sanitation
SSP	sanitation safety plan
TDI	tolerable daily intake
TDS	total dissolved solids
TIA	total impervious area
TIN	Triangular Irregular Network
TOC	total organic carbon
TPF	Trends and Pressures Framework
UBL	Urban Boundary Layer
UCL	Urban Canopy Layer

UF	ultrafiltration
UHI	Urban Heat Islands
UML	Urban Mixed Layer
UMZ	Urban Morphological Zones
UOSA	Upper Occoquan Service Authority (USA)
USA	United States of America
USEPA	United States Environmental Protection Agency
USL	Urban Surface Layer
UV	ultraviolet
UWCS	Urban Water Cycle System
VOC	volatile organic compound
WHO	World Health Organization
WRP	water reclamation plant
WRRF	WateReuse Research Foundation
WSP	Water Safety Plan
WSP	water safety plan
WSUD	Water Sensitive Urban Design
WWTP	waste water treatment plant

References

Lists of applied internet browser sites and recommended software sites, books, journals, web sites and software

c, Different search engines were used to find the most relevant studies on these topics, in particular Google Scholar, Digital libraries of ScienceDirect, SpringerLink, ResearchGate and Open Access. Each list of references was also thoroughly examined for every study that proved to be useful material for this urban hydrology literature practice and research-oriented paper.

List of applied internet browser sites:

DEENK University of Debrecen, Digital library
http://www.lib.unideb.hu/config.proxy
EIP-WATER
http://www.eip-water.eu/leeuwarden-declaration-why-and-how-drive-water-innovation-europe
European Soil Data Centre (ESDAC)
http://esdac.jrc.ec.europa.eu/resource-type/datasets
GREEN SURGE consortium
http://greensurge.eu/
Google Scholar
http://scholar.google.hu/
IEEE Xplore digital library
http://ieeexplore.ieee.org/Xplore/login.jsp?url=/Xplore/accessinfo.jsp&reason=fromWhatCanIAccessMenu
Open Access -Theses and Dissertations
https://oatd.org/
ResearchGate
https://www.researchgate.net/
Science direct
http://www.sciencedirect.com
Springer Link
http://link.springer.com/
SWITCH Managing Water for the City of the Future
http://www.switchurbanwater.eu/index.php
Urban morphological zones (UMZ)
https://www.google.hu/search?q=UMZ_v15_2006+Urban+Morphological+Zones+2006+(EEA&oq=UMZ_v15_2006+Urban+Morphological+Zones+2006+(EEA&aqs=chrome..69i57.1560j0j7&sourceid=chrome&ie=UTF-8
Urban Audit Database (Eurostat)
http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/introduction
Urban Atlas (EEA)
https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-urban-atlas
Use of freshwater resources (EEA)
https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-2/assessment-2
Wiley online library

http://onlinelibrary.wiley.com/

List of recommended software sites:

ALADIN-Climate as atmospheric forcing model by Hungarian Meteorological Service.
http://www.cnrm-game.fr/spip.php?article145&lang=en
ENSEMBLE model RT2B Production of seasonal to decadal climate change scenarios
http://ensembles-eu.metoffice.com
EnviMet A holistic urban microclimate model
http://www.model.envi-met.com/hg2e/doku.php?id=files:downloadv4
eWater Toolkit free tools for river and catchment management, urban water, environmental flows, and water quality and quantity
https://toolkit.ewater.org.au/Tools/Source%20-%20public%20version/downloads?id=1000117
Flodlog - Flood modelling and logistic model development for urban flood crisis management
http://www.uni-miskolc.hu/~floodlog/index.html
Meteora weather alert app
http://meteora.met.hu/meteora.html
MIKE URBAN DHI -Integrated urban water modelling.
https://www.mikepoweredbydhi.com/download/mike-2016/mike-urban?ref={181C63FF-2342-4C41-9F84-F93884595EF3}
RayMan urban climate model
http://www.mif.uni-freiburg.de/rayman/intro.htm
REMO regional climate model
http://www.remo-rcm.de)
SUB-URBAN TOOLBOX - COST EU
http://rotterdam.maps.arcgis.com/apps/MapJournal/index.html?appid=5f495157aae84a2780b5e7d87dcd66f2
WaterReuse
https://watereuse.org/water-reuse-101/videos/how-reuse-works/
Weather Research and Forecasting (WRF) Model Source Codes and Graphics Software
http://www2.mmm.ucar.edu/wrf/users/download/get_source.html

List of recommended mapservers:
Geologic Institute of Serbia
http://geoliss.ekoplan.gov.rs
Hydrogeological Maps, State Geological Institute of Dionýz Štúr (SGIDŠ) Slovakia
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