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Output 3.3

Guideline for public administration to implement beneficial rainwater management

Version 4

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Activities from the Application form:

WP 3 Resilience to urban drought and urban floods in the face of climate change

Activity 3.4 Joint solutions for urban storm and rain water management with regard to climate change Partners LP1, PP2, PP4, PP5, PP8 and PP9 will jointly prepare draft of solutions (D 3.4.1) for municipalities for planning and implementing rainwater management to mitigate the effects of torrential rain (1st solution for run-off water retention and increased groundwater recharge under controlled conditions, avoiding sudden increases in underground flow) and to reduce the impact of drought (2nd solution for comprehensive use of rainwater as an alternative source of water for municipal purposes). Responsibility for preparation of the 1st solution is on LP1 and PP2, responsibility for preparation of the 2nd solution is on PP4 and PP5. The drafts will be tailored on common workshops organized on personnel or on-line basis.

Deliverable 3.4.2 Handbook for increasing the benefits of rainwater management - final version.

O3.3 - Guideline for public administration to implement beneficial rainwater management

Deliverable description: The results and solutions received in WP3 and verified in pilot actions will be developed by PL and CZ partners into draft methodological guidelines for public administration and designers. Drafts will be submitted for discussion and improvement to partners and associated partners at the workshop. Results of A.3.1 will be used by A.3.2 and A.3.3.

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1. Introduction

In the past, most European cities were built on the principle **of draining rainwater** from urban areas as quickly as possible. Rainwater was perceived as waste that had to be safely removed outside the built-up area. This was also reflected in the technical infrastructure – extensive sewage networks, in many cases single sewers where rainwater mixed with wastewater. This approach had serious reasons at the time: protection against floods, hygienic requirements for the health safety of surface water as a source of drinking water, and the technical simplicity of the solution.

However, due to increasing urbanization, the expansion of impervious surfaces, especially in cities, and climate change, this model is showing fundamental limitations. Sewerage systems are increasingly overloaded by torrential rainfall, and cities are losing a valuable water resource that could be used locally.

Table with rainwater balance in the territory of Novy Bydzov

item	m^3/year	%
annual drainage from the roofs of building	248 183	100
annual drainage from the roads and parking lots	142 632	
annual amount of rainwater flowing through relief channels (outside the wastewater treatment plant)	58 046	15

In recent decades, traditional drainage methods (sewage and rainwater drainage, or separate sewer systems) have proven to be unsustainable in the long term. The unsustainability of the current drainage method has two main reasons:

- the increase in paved areas exacerbated by rapid urbanization,
- changing climate.

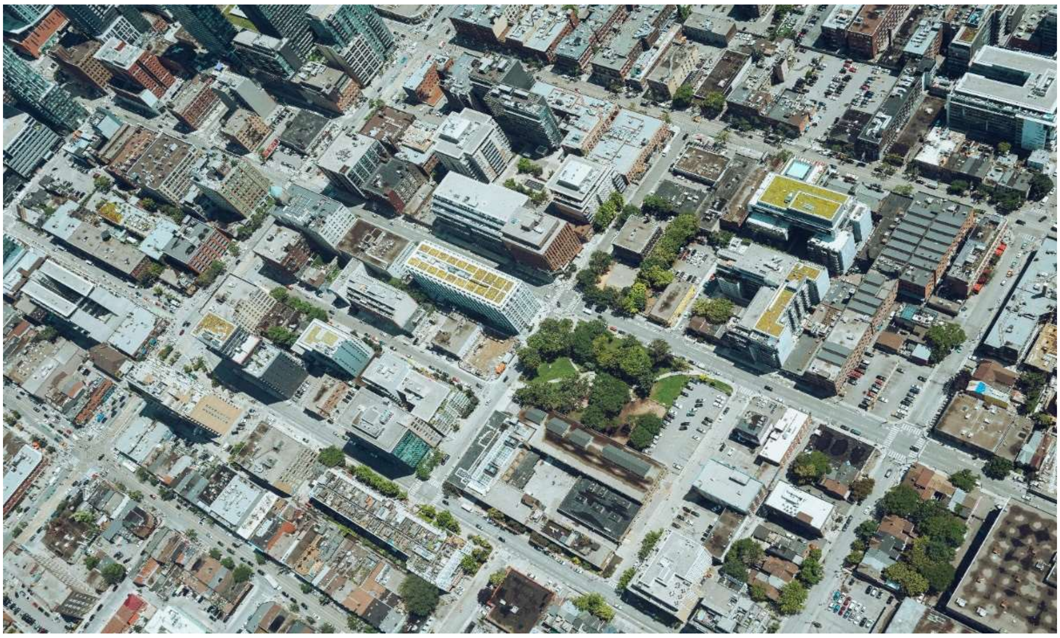

Figure 1: Urbanized areas are characterized by a high proportion of impervious surfaces

Urbanized areas – cities and towns are characterized by a high proportion of impervious surfaces (e.g. roads, sidewalks, parking lots, building roofs) in the total area of the catchment area. In the centers of urban agglomerations, this reaches 70 percent or more. Water falling on the surface of such catchments during rain cannot naturally infiltrate (seep) into the subsoil. The level of total evaporation is also reduced compared to natural conditions [Vítek et al., 2015]. In contrast, in catchments with natural vegetation cover, up to 50% of the volume of rainwater falling on the surface of the area infiltrates (approximately half of which supplies groundwater) and only 10% represents surface runoff (Figure 2).

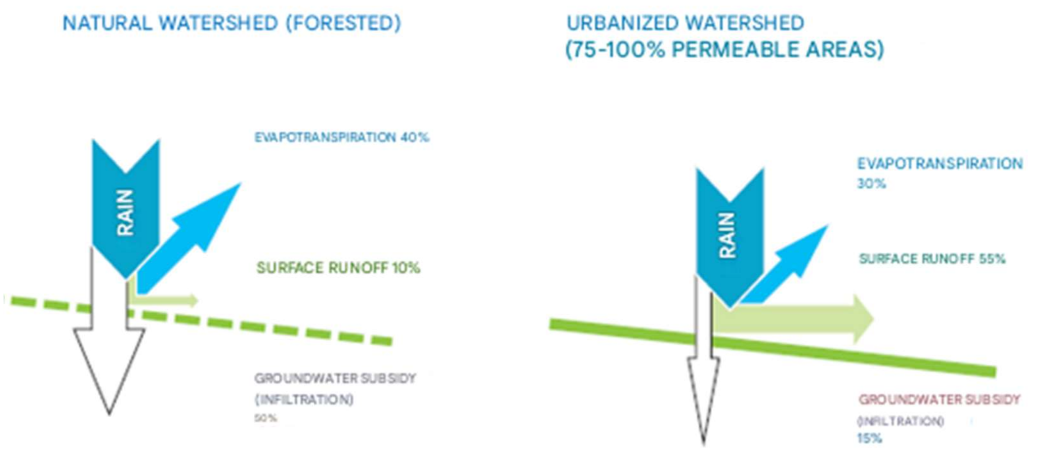

Figure 2: Comparison of rainwater runoff in a natural and urbanized catchment

In the central parts of urban agglomerations, surface runoff accounts for up to 55% of the rainfall volume. The greater part of the rainwater volume flows along the paved surface of the catchment into storm drains and is drained away from the urbanised catchments by the sewer network. In addition to the increase in volume, there is also a significant acceleration of surface runoff and suppression of the ability to transform (reduce) peak flows.

The consequence of the increased volume of surface runoff and its velocity is **a change in the hydrological regime** [Vítek et al., 2015], which is manifested by more frequent occurrence of local floods.

The impacts on the watercourse through overflows from **rainwater separators (relief sewer system)** of the combined sewer system and rainwater drainage are also significant. These include **hydraulic stress** and **the introduction of pollutants**. Both phenomena affect aquatic fauna and flora [Vítek et al., 2015]. The stream thus loses its aesthetic and ecological function.

The increased volume of surface runoff causes the capacity of the sewer system to be exceeded, transitioning to a pressure flow regime with water rising to the level of basements or directly flowing onto the terrain through inspection shafts or street drains and spilling into the surrounding area.

Figure 3: Overloaded sewer system during heavy rains (Kluck et al, 2005)

We cannot also forget the **negative impact of** increased surface runoff **on limiting groundwater recharge and replenishing its reserves.**

The change in the natural hydrological regime also threatens the environment **by disrupting the energy regime in large cities**. If solar energy falls on vegetation with insufficient water supply, the largest share of this energy cannot be consumed for water release by the plant (transpiration) as in vegetation with a good water supply (approx. 3-4 lm^{-2} per day). Urban greenery cannot therefore fulfill the role of the cheapest and most progressive climate device with an overall positive impact on the quality of life in an urban area [Vítek et al., 2015].

The ever-increasing sealing of urban surfaces, together with the pressure resulting from the impacts of climate change, is forcing public administrations in cities and municipalities to change their approach to rainwater management.

This part: GUIDELINE FOR PUBLIC ADMINISTRATION TO IMPLEMENT THE BENEFICIAL RAINWATER MANAGEMENT (RM) is intended for urban public administrations and aims to assist in the implementation of rainwater management and ensure sustainable urban water management that is resilient to the impacts of climate change.

2. Rainwater Management (RWM)

The development of rainwater management in European cities (in the last 3 centuries) can be summarized in three stages:

1. **Drain and drainage (19th-20th centuries):** The priority was to ensure hygiene and safety, so water was quickly drained away from the city.
2. **Control and regulation (second half of the 20th century):** The construction of retention tanks and separate sewers was intended to reduce the load on treatment plants and limit flood risks.
3. **Integrated management (21st century):** Rainwater is understood as part of the city's green infrastructure. The goal is to preserve or mimic the original hydrology and ecology of the area.

Modern Rainwater management (RWM) is a method of drainage of urban areas that mimics the natural hydrological regime of a river basin, mainly through decentralized facilities that aim **to retain, utilize, absorb and slow down the runoff of rainwater as much as possible directly at the point of impact**.

RWM is based on the principle: *"Water should stay as close as possible to where it falls."* This principle respects the original hydrology and ecology of urban areas before they were built up and contributes to the restoration of the natural water cycle.

The basic rules of rainwater management are...

1. REDUCTION AND TRANSFORMATION OF RAINWATER RUNOFF TAKES PLACE ON THE LAND, I.E. AT THE PLACE OF DEDUCTIONS AND AT THE EXPENSE OF THE OWNER OF THE PROPERTY FROM WHICH IT IS TO BE DEDUCTED (THE DEVICE THAT REDUCES RUNOFF IS AN INTEGRAL PART OF THE STRUCTURE BEING DRAINED);
2. RAINWATER IS NOT MIXED WITH WASTEWATER – THIS IS THE ONLY WAY IT CAN BE EFFECTIVELY EVAPORATED, INSECTED OR USED FOR HOME OPERATION;
3. THE AMOUNT OF RAINWATER RUNOFF FROM A BUILT-UP PLOT IS THE SAME AS THE AMOUNT THAT WOULD RUN OFF FROM THE NATURAL LAND SURFACE.

European cities are facing serious impacts of climate change, including:

1. **More frequent and intense torrential rainfall**, which overloads sewage systems and causes local flooding.
2. **Longer periods of drought and heat**, which worsen the availability of drinking water, reduce the quality of life of residents and lead to overheating of cities.

Rainwater management is one of the few measures that can **address both problems simultaneously**.

RWM can bring the following specific benefits in particular:

- **Reducing the risk of flooding and inundation:** Measures that retain or absorb rainwater, relieve the burden on sewer networks and reduce immediate runoff. In Germany (city of Hamburg), the introduction of a system of retention tanks and green roofs has reduced the number of local floods in densely built-up parts of the city by more than 40%.
- **Improving the availability of water resources:** Using rainwater for watering parks, cleaning roads, or flushing toilets can reduce drinking water consumption by up to 30%. Prague, for example, estimates that widespread use of rainwater could save up to 10 million m³ of drinking water annually.
- **Improving environmental quality:** Rainwater management and use contributes to groundwater recharge, promotes urban green spaces and increases biodiversity. In addition, constructed wetlands naturally purify water and improve the quality of surface streams.

- **Reducing the urban heat island effect:** Vegetated roofs and permeable surfaces retain water, which gradually evaporates and cools the surroundings. For example, a study from Copenhagen showed that the introduction of green infrastructure can reduce the temperature in the city by up to 2 °C during hot days.
- **Economic benefits:** The implementation of RWM measures creates jobs (design, construction, maintenance), reduces infrastructure renewal costs and brings long-term savings for municipalities and households. The European Commission (2020) states that the average economic benefit of investments in green infrastructure exceeds the costs by more than twice.
- **Social and health benefits:** More greenery and water in cities supports quality of life, improves microclimate, reduces dust and noise. WHO studies show that residents of cities with a higher proportion of green infrastructure suffer from lower levels of stress and respiratory diseases.

Modern rainwater management is based on several interconnected goals:

a) Water retention at the point of precipitation

The idea is to limit immediate runoff to the sewer and encourage infiltration or reuse of water. This reduces the risk of flooding and at the same time recharges groundwater.

b) Use of rainwater as a resource (rainwater harvesting)

Rainwater can be used for irrigation, flushing, road cleaning and technical use in industry. It is a cost-effective alternative to drinking water, which is irreplaceable and expensive to produce.

c) Improving the quality of the environment

Greenery and water features in urban areas contribute to reducing temperatures, improving air quality, increasing biodiversity and the attractiveness of public spaces. Also, limiting the flow of rainwater together with wastewater through relief channels directly into surface streams will reduce their contamination load and increase the quality of surface waters and life in them.

d) Relief of existing infrastructure

Every liter of rainwater that does not flow into the sewer system means less strain on the sewer network and treatment plants. This reduces operating costs and extends the life of the infrastructure.

It was found that after the application of RWM measures, 15 to 20 times less water flows away compared to conventional drainage of the design rainfall. RWM facilities and equipment thus contribute to reducing peak flows in the sewer network and, in the case of a unified sewerage system, also have a significant impact on reducing the total number of overflows from storm water separators into watercourses, which reduces their hydraulic and material load.

e) Strengthening the resilience of cities to climate change

RWM increases the city's ability to respond to extremes - on the one hand, it mitigates flood risks, and on the other hand, it ensures better water availability during dry periods.

RWM objects can very often be combined with lower or higher vegetation (green infrastructure). The connection of water management purposes with greenery has a synergistic effect and indirectly brings a number of positive effects, especially in the area of increased living comfort.

f) Citizen engagement and awareness raising

Rainwater management is not only the task of local governments, but also of citizens. When people use rainwater on their land, they contribute to the overall sustainability of the city. At the same time, their awareness of the value of water and the importance of climate adaptation is growing. Therefore, in many European countries, RWM measures are supported by subsidy titles - for example, for the installation of catchment facilities for collecting, accumulating and using rainwater (see Chapter 7).

It is crucial for city governments and state administrations to understand RWM as an investment in the future resilience of cities - similar to the case of transport or energy infrastructure.

3. Obstacles to RWM implementation and their solutions

Experience from European cities shows that rainwater management is not just a technical problem. The main obstacles often lie in the areas of legislation, finance, city administration, but also in public awareness. Identifying these barriers and proposing ways to overcome them is an essential part of every city's strategy.

Below are the main categories of barriers, with an outline of recommended solutions.

3.1. Political and strategic barriers

Obstacles

- **Outdated legislation:** Many building codes are still based on the principle of "rapid drainage" of rainwater into a unified sewer system.
- **Unclear ownership and operational relationships:** Who is responsible for public measures – blue-green infrastructure BGI (city, infrastructure manager, private investor)?
- **Lack of uniform technical standards:** It is not clearly defined how measures (BGI) should be designed and operated.

It cannot be argued that existing European Union directives or national legislative regulations generally do not support a water management policy that respects the principles of sustainable development.

Directive 2000/60/EC of 23 October 2000 on water states in paragraph 11: "*Environmental policy shall contribute to promoting the objectives of preserving, protecting and improving the quality of the environment, while making prudent and rational use of natural resources, and shall be based on the precautionary principle, on the principles of taking preventive measures, on the rectification of environmental damage at source and on the polluter-pays principle*." This definition makes it clear that the implementation of the framework directive does not mean the mere application of new technical standards, but requires a fundamental change in the approach to the management of water and water resources.

With the European Union directive on waste water management Urban Wastewater Treatment Directive (UWWTD) - **Directive (EU) 2024/3019** now includes the area **of rainwater management** within the broader urban wastewater management. It introduces key principles for rainwater management:

- Large cities are **required** to develop **integrated** rainwater management plans to reduce the risk of **urban flooding** and **water pollution** during heavy rainfall events. Smaller settlements must prepare such plans if there are such risks due to rainwater runoff. Environment .

- Plans must **prioritize nature-based measures,** such as green infrastructure (such as infiltration areas, green roofs, retention belts, etc.) that help to naturally retain, drain, or potentially use rainwater Environment .
- The directive **supports rainwater retention and reuse** as part of broader measures towards **circularity.** This means: collection, treatment and subsequent use of rainwater (e.g. for technical purposes, irrigation or other local needs) PreventionWeb .

In the legislation of national states, measures for nature-friendly rainwater management are generally enshrined in a number of regulations (Water Act, Building Act), however, legal regulations defining the rules for a new method of drainage are included in the laws and their implementing decrees in **an unsystematic and uncoordinated manner.** The current legislation requires the application of RWM principles only **in a restrictive form** and **does not motivate** owners of drained buildings with financial efficiency.

The individual **regulations are chaotic** as a result and **do not provide** the state administration with **clear and unambiguous rules** that would ensure their equal enforcement throughout the entire territory of the state. Since the state has in this regard fallen out of the role of organizer of its own water management policy, it leaves the public administration to solve the problem responsibly, incompetent and unprepared.

One of the obstacles is the lack of clarity regarding ownership and operational relations to the infrastructure forming the framework of the RWM. For example, who is responsible for blue-green infrastructure (city, infrastructure manager, private investor)?

Another problem is that rainwater management is not unified in the field of European and national technical standards. There is currently no single EN standard specifically for rainwater management, so a combination of different European standards must be used. The scope and level of national technical standards for RWM are different and some partner countries do not have technical standards for RWM and are adapting European standards. This issue has been developing particularly in the last 10 years. The largest base of technical standards and procedures for RWM in the partner countries can be found in the Czech Republic and Germany.

Possible solutions

- HARMONIZATION OF THE APPROACH TO LEGISLATION – unification of the approach of regional and local state administration;
- COORDINATION OF RWM PRINCIPLES – embedding a priority approach to RWM needs in city rules (standards) for the creation of land and transport structures;
- ENFORCEMENT OF RWM RULES – approval of uniform rules for rainwater drainage valid throughout the city;
- ACTIVE APPROACH TO PROMOTING THE WATER MANAGEMENT CONCEPT.

3.2. Economic and financial barriers

Obstacles

- **Higher initial investment costs** compared to classic sewage.
- **Limited budgets of cities and municipalities.**
- **Lack of economic motivation for citizens and developers.**

Support for decentralized approaches to rainwater management in cities is neglected, even though from the city's perspective they can bring a number of other positives in addition to flood protection (Chapter 2). Moreover, the vast majority of decentralized rainwater management measures are financed by private investors and can thus bring significant financial savings to public budgets.

A serious shortcoming in the possibilities of financing RWM is **the existence of a number of exceptions to the payment of fees for the drainage of rainwater from buildings and construction areas into the sewerage system** (e.g. in the Czech Republic, these fees do not apply to areas of motorways, roads, local roads and purpose-built publicly accessible roads, to areas of national and regional railways, including facilities necessary for the smooth and safe operation of rail transport, to zoos, hospitals and real estate intended for permanent housing and households). This neglects the principle of the Water Framework Directive, i.e. that the "polluter pays" and as a result, there is a lack of funds for the implementation of appropriate RWM measures. These measures are then perceived as unnecessarily expensive compared to the common practice of draining rainwater into the sewerage system.

Table with annual rainwater drained free of charge in sewer network in Novy Bydzov.

item	m^3/year	%
annual drainage in city area	390 816	100
annual amount of rainwater free of charge (excluded from law)	227 822	58

Possible solutions

- **Financial incentives and subsidy programs:** support for rainwater tanks in households, benefits for developers who apply RWM.
- **Introduction of the "you pay for the drain" principle:** the amount of the drain fee depends on the size of the impervious areas.
- **Economic arguments for politicians:** present savings associated with lower sewage load, improved microclimate and reduced flood damage.

3.3. Institutional and organizational barriers

Obstacles

- **Fragmentation of responsibilities:** RWM falls between multiple organizations (sewer system owner or sewer system administrator, technical services, investment department).
- **Lack of professional capacity in the authorities:** officials are not trained to assess RWM.
- **Lack of practical examples:** municipalities lack inspiration and hesitate to implement.

Ensuring the right procedures and decisions for drainage with the new RWM principles is such a complex process that individual officials who comment on the documentation are usually unable to handle it. In the case of larger territorial units and cities with a more complex organizational structure, it is therefore **necessary to introduce systematic measures to solve the problem by appointing a specific specialist or department, acting as the administrator of the city's water management concept,** who will be responsible for adhering to the new approach to rainwater and will actively promote it.

The administrator should communicate and cooperate with the relevant authorities and organizations in approving documentation and permitting construction. Based on the activities that appear in the builders' plans, the administrator should initiate necessary measures, the implementation of which will make it possible to comply with the principles of the city's drainage concept (e.g., area drainage studies or mathematical model calculations).

The administrator should cover the entire issue of water management in the city and be responsible for it.

Possible solutions

- **Establishment of interdepartmental working groups** for project coordination.
- **Training and education of officials and politicians** in the field of RWM.
- **Pilot projects and demonstration facilities** that will demonstrate feasibility and benefits.

3.4. Social and cultural barriers

Obstacles

- **Low citizen awareness:** Rainwater is often seen as a problem, not a resource.
- **Concerns about hygiene risks:** fear of mosquitoes, odors or contamination.
- **Limited willingness to change behavior:** People are used to drinking water "for everything."

For decades, rainwater has been perceived as a safety risk, bringing flooding and inundation. Therefore, citizens (also in connection with epidemics caused by insufficient wastewater infrastructure) see the classic solution of rapid rainwater drainage (using sewers) as the optimal measure to solve these problems. However, climate change and a high level of built-up areas require this familiar way of thinking to change and perceive rainwater as a valuable water source and look for ways to save drinking water sources for purposes where rainwater can be used as technological water (irrigation, toilet flushing, industrial use, etc.).

Possible solutions

- **Awareness campaigns and education:** clearly explain the benefits of rainwater management.
- **Citizen involvement in projects:** community gardens, participatory budgets.
- **Sample implementations in public buildings:** schools, kindergartens, offices as examples of good practice.

3.5. Technical and operational barriers

Obstacles

- **Geological and hydrogeological conditions:** unsuitable subsoil, high groundwater level.
- **Maintenance of measures:** concern about difficulty and cost.
- **Lack of data for dimensioning measures:** local monitoring of precipitation and runoff is missing.

In many cities, there may not be suitable geological and hydrogeological conditions for rainwater infiltration. However, as shown by expert studies and in many European cities, **unsuitable geological conditions for infiltration must not lead to the abandonment of the application of natural rainwater**

management. A detailed geological survey is necessary for each construction project **and based on it, identify the optimal solution** to reduce rainwater runoff at the point of origin.

When implementing blue-green infrastructure, designers often encounter concerns from owners about the future maintenance of these facilities and their economic demands. However, this area has also seen tremendous progress in recent years, and there are standard solutions that require only simple maintenance.

The fundamental problem **in dimensioning** blue-green infrastructure must be **sufficient and reliable data,** which should be based on high-quality local monitoring of precipitation, climate observations, knowledge of hydrogeological conditions, so that the implemented measures work. Cities should help builders and investors in implementing RWM by operating such monitoring and providing this data for building design.

Possible solutions

- **Detailed analysis of the site before implementation** (geology, hydrology).
- **Easy maintenance and clearly defined procedures:** administrator manuals.
- **Building databases and maps of RWM measures** at the city level.

3.6. Summary - recommendations for removing barriers to RWM implementation

The obstacles to the implementation of rainwater management need to be addressed at all levels - with the support of the European Union and its institutions, at the level of national parliaments and governments, at the regional and local levels. The following table summarizes the recommendations for each level.

<table>
<tr><th colspan="3">Level</th></tr>
<tr><th>European/national</th><th>regional</th><th>local</th></tr>
<tr><td colspan="3">political and strategic areas</td></tr>
<tr><td>creation of understandable and unambiguous rules of legislative rules</td><td rowspan="3">unification of the regional administration's approach to the interpretation of existing legislative regulations</td><td>unification of local government's approach to the interpretation of existing legislative regulations</td></tr>
<tr><td rowspan="2">development of European and national standards for RWM</td><td>active approach to promoting the water management concept</td></tr>
<tr><td>enforcement of RWM rules during construction and renovations</td></tr>
<tr><td colspan="3">economic and financial areas</td></tr>
<tr><td>financial incentives and subsidy programs</td><td rowspan="2">financial incentives and subsidy programs</td><td rowspan="2">financial incentives</td></tr>
<tr><td>cancellation of exemptions for payment for discharging rainwater into the sewer system</td></tr>
<tr><td colspan="3">institutional and organizational area</td></tr>
<tr><td rowspan="3">training and education of officials and politicians</td><td rowspan="3">training and education of officials and politicians</td><td>training and education of officials and politicians</td></tr>
<tr><td>establishment of interdepartmental working groups for the coordination of RWM projects</td></tr>
<tr><td>establishment of the position of administrator of the city's water management concept</td></tr>
<tr><td colspan="3">social and cultural area</td></tr>
<tr><td rowspan="2">awareness campaigns and education</td><td rowspan="2">awareness campaigns and education</td><td>awareness campaigns and education</td></tr>
<tr><td>citizen involvement in RWM projects</td></tr>
<tr><td>examples of good practice</td><td>examples of good practice</td><td>examples of good practice - exemplary implementations of RWM in public buildings</td></tr>
<tr><td colspan="3">technical and operational area</td></tr>
<tr><td rowspan="7">support local and regional authorities by providing sufficient and reliable data (free of charge data from government institutions)</td><td rowspan="7">support local authorities by providing sufficient and reliable data (free of charge data from regional institutions)</td><td>sufficient and reliable data for dimensioning RWM measures (analysis of climatic conditions and their variability)</td></tr>
<tr><td>Incorporating RWM principles into spatial planning, development documents and decision-making processes of urban administration</td></tr>
<tr><td>processing of analyses of rainwater runoff in individual parts of the city (hydrological analysis, hydraulic capacity of the sewerage system, analysis of the infiltration potential of the area, analysis of the possibilities of using rainwater in the city)</td></tr>
<tr><td>assessment of risks associated with managing rainfall in the city</td></tr>
<tr><td>setting general drainage limits</td></tr>
<tr><td>introduction of standards for the application of RWM for new and renovated buildings</td></tr>
<tr><td>consistent control and enforcement of RWM by public administration</td></tr>
</table>

4. Misconceptions often associated with RWM

When perceiving the concept of rainwater management, we often encounter misconceptions that are often associated with RWM. These include the following examples:

1. **RWM is not just the infiltration of rainwater into the subsoil.** The sentence: "There is nothing you can do about it, there is no infiltration there", is completely absurd from the point of view of RWM. Even though the possibility of infiltration is the first thing that must be checked when designing the drainage of a building, it is far from the only solution. **When rainwater cannot be safely infiltrated, its outflow from the building can almost always be delayed in the object,** which fulfills the purpose of sustainable development, just as when it is possible to infiltrate the water.

   Combination of retention and infiltration devices, or purely retention devices

2. **RWM does not represent a 100% protection of urban areas from flooding.** Just as street sewers are dimensioned for a certain design rainfall, so is the case with RWM facilities. When the design capacity is exceeded, they become overloaded. This is mainly due to the fact that from an economic point of view it is simply not possible to design such measures that have absolute reliability. For this reason, it is **necessary to pay maximum attention to the outlet of overflows from individual facilities, which should safely drain excess rainfall into the recipient.**
3. **RWM facilities,** like other water management facilities, are not **"maintenance-free".** Concerns that RWM facilities may become inoperable in the long term without proper maintenance are justified, but they are completely irrelevant as an argument excluding the introduction of RWM. This is because **when designing any technical work, it is necessary to consider a certain procedure for its maintenance and operation.** If it were assumed that the work would not be maintained after its completion, only structures that do not require any operational measures could be permitted.

5. Procedure for implementing rainwater management in cities

5.1. Concept for implementing rainwater management for the city as a whole

Rainwater management (RWM) cannot be seen as a set of individual technical measures, but as a long-term strategy for the entire city. Success is conditional on a conceptual approach – i.e. **the integration of RWM principles into spatial planning, development documents and decision-making processes of the city administration.** A strategic approach to rainwater management (RWM) at the city level requires that individual steps be interconnected, systematically managed and supported by current knowledge from hydrology, urban planning and landscape engineering. Professional literature clearly points out that **random and isolated measures** often **do not fulfill their purpose** and can lead to inefficient use of investments.

The steps below represent a methodological framework for developing a RWM concept in an urban environment.

5.1.1. Assessment of rainwater runoff in individual parts of the city

The assessment of rainwater runoff is a crucial step in planning rainwater management (RWM) measures in a city. Its aim is to comprehensively assess how rainwater behaves in individual parts of the city, what are the runoff volumes generated during design precipitation, what is the capacity of the existing sewerage infrastructure and what are the local conditions for infiltration or use of rainwater. The results of the assessment serve as a basis for the design of the most suitable RWM measures that respect the conditions and constraints of individual urban locations and support the principle of using rainwater at the point of impact.

The rainwater runoff assessment includes a detailed assessment of individual parts of the city in the following areas:

- ***Hydrological analysis***

Hydrological analysis is aimed at determining the amount of rainwater that flows from the assessed areas during defined rainfall episodes. The starting point of this assessment is the determination of the character of individual surfaces and their runoff coefficients. For each location, built-up, paved and permeable areas are identified, from which the overall ability of the area to absorb or retain rainwater is determined. Runoff coefficients are subsequently applied in the calculations of runoff quantities for design rainfall specified in technical standards.

For the needs of the conceptual document, short-term, intense rainfall is evaluated in particular, which is a critical factor for the load on the sewage system. At the same time, longer-term rainfall totals are also assessed, which can be decisive for the effectiveness of retention and infiltration measures. The result of the hydrological analysis is the quantification of runoff for individual parts of the city, their comparison with the capacity of the existing infrastructure and the identification of locations where the sewage network is or may be overloaded.

Hydrological analysis is usually carried out by specialized experts: Hydrologists, water management engineers, urban and spatial planning experts, environmental engineers, blue-green infrastructure specialists.

- ***Hydraulic capacity of the sewer system***

Hydraulic assessment of the sewerage system evaluates the ability of the existing infrastructure to discharge the runoff volume generated during design rainfall. The analysis collects available data on the dimensions and technical condition of the sewers, the shape and profile of the pipes, the capacity ratios of individual sections and their connections to recipients or wastewater treatment plants. Special attention is paid to parts of the city with a unified sewerage system, which experience significant overflow during rainfall.

Based on these data, a hydraulic model is developed that simulates the behavior of the system under various precipitation scenarios. The model allows identifying critical points in the sewer network, such as sections with insufficient profile, backflow points, point elements exposed to overflow or sections where the unified sewer system is relieved into recipients. This diagnosis creates a basis for decisions on places where it is appropriate to implement RWM measures in order to limit or slow down the runoff and reduce the load on the sewer infrastructure.

To solve the hydraulic assessment, it is advisable to cooperate with hydraulic engineers, sewerage designers, water management infrastructure operators, water management engineers, experts in modeling drainage systems, etc.

Figure 4: Historic sewer in Prague

- ***Infiltration potential of the territory***

Assessment of the infiltration potential of an area is crucial for deciding whether it is possible to effectively use infiltration as the basic method of rainwater management in individual locations of the city. The assessment is based on geological and hydrogeological information, which includes the grain size composition of soils, their permeability, the composition of the rock environment and available data on the groundwater level. In areas with sandy or gravelly soils, infiltration is usually well feasible, while areas with clayey or impermeable sediments have very limited potential.

It is necessary to identify zones with high, medium and low potential for infiltration within the city.

Within the framework **of spatial planning, these zones** need to be clearly defined and **the principles of rainwater management** defined and **their criteria established.**

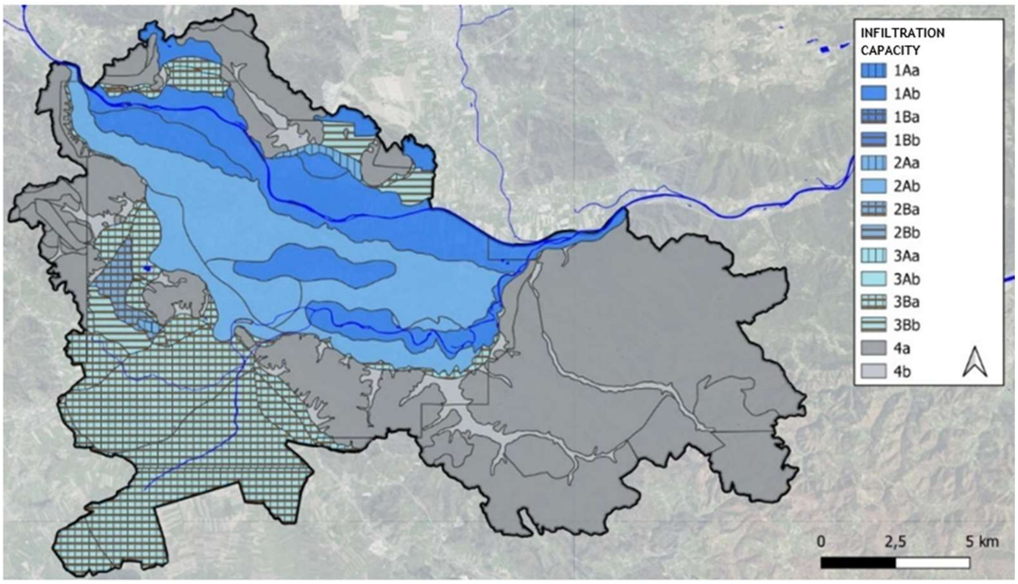

Figure 5: Graphic representation of the Infiltration Capacity Map for the Ljubljana example

The assessment also includes the identification of risks associated with possible groundwater contamination, especially in industrial zones or areas with historical burdens. If the groundwater level is located at a shallow depth below the terrain, it is necessary to consider measures to prevent its undesirable influence. The output of the infiltration assessment is the categorization of the area in terms of suitability for infiltration facilities, which becomes one of the basic inputs for the design of specific RWM measures.

Specialists dealing with this issue are geotechnicians, hydrogeologists, water management engineers, pedologists, and experts in ecology and groundwater protection.

❖ ***Rainwater use options***

The assessment of runoff also includes an evaluation of the possibilities for active use of rainwater (rainwater harvesting). The aim of this analysis is to determine in which locations it is appropriate to accumulate rainwater and subsequently use it, either for small-scale user purposes or on a larger scale. The evaluation is based on the nature of the development, its functional use and the technical capabilities of the buildings.

In residential areas with single-family homes, the use of rainwater is usually very promising, especially for garden irrigation, replenishment of retention elements around houses or as a source of domestic water. In commercial and industrial areas, rainwater can be used for technological purposes, cleaning paved areas, cooling or refilling fire tanks. In public areas, rainwater can be used for irrigation of urban greenery or refilling water features.

This type of assessment makes it possible to determine in which parts of the city the accumulation and use of rainwater is an appropriate part of RWM measures, and where, on the contrary, the main emphasis will be placed on retention, runoff slowdown or infiltration.

The hierarchy for choosing a drainage method must always be followed:

- **rainwater infiltration** should always be preferred,
- if it is not technically possible, **retention with regulated drainage follows**, or **the possibility of further use of rainwater**,
- **discharging it into the sewer should be a last resort.**

This hierarchical principle proves to be key and it is essential to reflect it in urban concepts.

Individual parts of the city can differ significantly in their hydrological behavior. The different character of the districts (historical center, housing estates, industrial zones, new residential complexes) requires a separate approach.

5.1.2. Assessment of climatic conditions and their variability

The basis of the conceptual preparation is the evaluation of the precipitation and temperature conditions of the given location and their changes over time. The concept should therefore be based not only on historical data, but also on predictions of future climate changes – for example, the expected increase in the frequency of torrential rains and dry periods. This information must form the basic framework for the dimensioning and selection of measures. An example of the evaluation of climatic conditions and their variability can be the water management study supporting the implementation of rainwater management prepared for the city of Novy Bydzov within the framework of the MAURICE project.

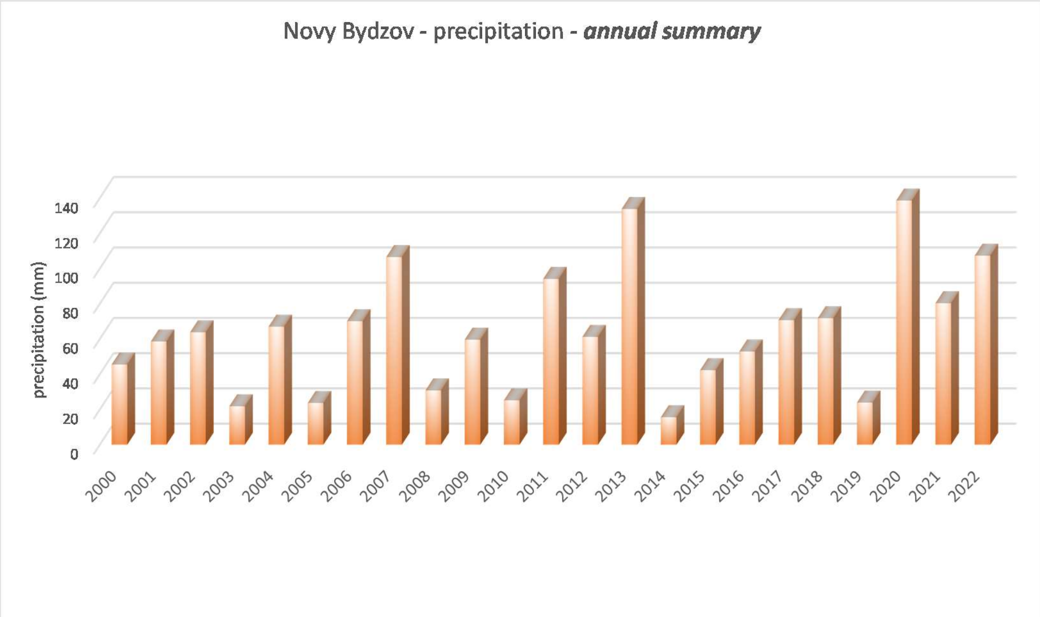

Figure 5: Annual precipitation summaries in Novy Bydzov (2000 - 2022)

5.1.3. Risk assessment associated with rainwater management in the city

City management must have a comprehensive assessment of the risks associated with rainwater management in the city.

These risks include primarily:

- overloading of the unified sewage network,
- local flooding and erosion phenomena,
- damage to surface flows due to pollution from relief channels,
- lack of water in the soil environment and a decrease in groundwater levels.

It is necessary to evaluate all risks in terms of their economic impacts, environmental impacts and quality of life in cities and **to set priorities and a concept for their solution**.

Risk assessment must therefore be part of every decision-making process and serves to determine priorities - whether to prefer measures to retain water, to absorb it, or to use it.

5.1.4. Setting general drainage limits

General drainage limits are one of the most important drainage parameters from the point of view of the application of RWM in existing and prospective urban development. These limits should be universally valid for any construction throughout the entire territory of the city or municipality - i.e. both for new construction and for reconstructions and reconstructions.

General drainage limits can be divided into two groups:

a. Key indicators that are essential for determining the maximum allowable runoff from the territory and for determining the dimensions (capacity) of RWM facilities and objects;
b. Mandatory requirements for technical solutions that will ensure appropriate operational reliability and economic independence for future property owners.

Drainage limits should be discussed and agreed upon by the relevant water management organizations (e.g. river basin manager, sewer network owner and operator, water authority, etc.) to create a unified approach to RWM that will be jointly promoted by all stakeholders.

- For each location, set runoff limits (l/s/ha) according to infiltration possibilities.
- These limits must be binding for new construction projects and renovations.
- The aim is to gradually reduce the load on the sewage network and wastewater treatment plant.

For example, the Prague *Standards for Rainwater Management* (2021) establish as a key principle **the limitation of maximum runoff into the sewer system** in both new and reconstructed buildings. This parameter must be considered **a binding tool for spatial planning.**

Its importance lies not only in the technical protection of the sewage network, but also in supporting the investor in finding solutions on the land (retention, infiltration, utilization).

Example of specific values for general building drainage limits (Czech Republic)

binding regulation	**binding rule**		**reference to a technical or legislative regulation**
	rule description	value, execution	
key indicator	specific rainwater runoff	max. 3 $l.s^{-1}.ha^{-1}$	TNV 75 9011 rainwater management
	frequency of BGI capacity exceedance	max. once every 5 years (p = 0,2 rok^{-1})	
	emptying time of BGI	max. 24 h	
binding requirement for technical solutions and initial design documents	safety overflow	the building must be connected to surface water or sewage	Decree No. 146/2024 Coll. on construction requirements
	ownership principle	BGI objects must be on the construction site	
	detailed hydrogeological survey	to demonstrate the quality of the rock environment and hydrogeological conditions in a timely manner	

5.1.5. Introduction of standards for new and renovated buildings

It is very practical for the construction of new buildings and for the reconstruction of buildings in the city to introduce clear rules (standards) for rainwater management. These should contain technical manuals, binding parameters, design principles, general drainage limits, recommended types of measures, etc. **for new and reconstructed buildings,** which the builder must comply with. The standards create a uniform procedure for designers and investors and at the same time define the requirements for operation and maintenance.
Without binding standards, there is a risk of implementing measures with very different quality and the result is **unsystematic management.** The introduction of binding standards is therefore one of the key pillars of the concept. A good example can be the standards for rainwater management for the capital

of the Czech Republic, Prague
(https://iprpraha.cz/assets/files/files/bddf4f520d27099cbc0f7a3609918e90.pdf)

5.1.6. Incorporating RWM into strategic documents

The conceptual framework for rainwater management must be **firmly anchored in** the city's strategic and spatial planning documents.

The principles of RWM must be reflected in:

- Zoning plan (runoff limits, requirements for infiltration areas).
- City climate strategies.
- Climate change adaptation action plans.

Inclusion in the spatial plan, climate change adaptation action plans and investment strategies ensures that RWM measures will have long-term support and funding and that RWM will not be just an isolated project, but part of the systemic development of the city.

As part of the MAURICE project, the partner Novy Bydzov prepared a water management study for the needs of implementing the RWM. The aim of the water management study was to examine the possible impacts of climate change on the water management of the city of Novy Bydzov in terms of risks to water supply (drinking, technical, utility) and to determine the benefits of using rainwater as a substitute for drinking water in facilities owned by the city.

5.2. Implementing rainwater management in undeveloped parts of the city

Undeveloped areas represent a unique opportunity to incorporate rainwater management (RWM) principles into the urban framework before construction. It is therefore necessary to apply a systematic and integrated approach that links spatial planning, legislative framework and nature-based measures.

5.2.1. Necessary studies for the given area

The basic step is to prepare hydrological and urban studies of the given area, which will determine the level of infiltration, retention and runoff in the area (listed in Chapter 5.1). The studies should also include **maps of impervious surfaces and infiltration capacities.** However, it is necessary to realize that these documents can only serve as a rough initial orientation and certainly cannot replace the function of a detailed hydrogeological survey in their details. The specific drainage solution depends on a well-evaluated and applied hydrogeological survey.

Additional European experience recommends applying the concept of **Water-Sensitive Urban Design (WSUD),** which integrates rainwater management into green infrastructure planning. This approach is also recommended by the European Environment Agency (EEA, 2020; climate-adapt.eea.europa.eu).

5.2.2. Access to the territory as a whole

Undeveloped areas must be understood as a whole, not as a collection of isolated plots. This corresponds to the principles of **the "sponge city"** applied in Vienna, Berlin or Copenhagen (EEA, 2022; time.com).

Although future development of the area may take place individually in different time stages, it is necessary to proceed conceptually in managing rainwater throughout the area and prevent RWM in one part from limiting the functionality of RWM in another part of the area and complicating RWM in the entire area as a whole.

Based on this approach, the costs of operating the sewer network and WWTP can be reduced, the material and hydraulic load on watercourses will be reduced, watercourses will be sufficiently supplemented with groundwater during periods of drought, and not overfilled during torrential rainfall. Life in cities will thus be of better quality and safer.

5.2.3. Selection and application of measures

It is always necessary to base oneself on the valid water legislation and technical standards. It is important that cities create clearly defined rules based on them and follow them in their territory.

Urban Wastewater Treatment Directive (2024), which also focuses on rainwater and supports the implementation of **nature-based solutions** (European Commission, 2024; environment.ec.europa.eu), is essential.

The set of recommended measures is briefly presented in Chapter 6 of this guideline.

5.3. Implementing rainwater management in built-up areas of the city

The implementation of rainwater management (RWM) in built-up areas is significantly more complex than in unbuilt areas. The reasons are spatial constraints, a high proportion of impervious surfaces and a complex structure of ownership relations. Nevertheless, significant benefits for the urban environment and the quality of life of residents can be achieved by applying appropriate technical and organizational measures. A suitable means for the implementation of RWM is an analysis of the potential of existing development in terms of bringing rainfall-runoff conditions closer to natural conditions. On its basis, **it may be possible to disconnect certain parts of paved areas from the sewerage system within a defined area of existing development.**

Unfortunately, it must be stated that **until the exemptions from the obligation to pay fees for rainwater drainage (valid in many European countries) are abolished, no major changes can be expected in this area - rainwater is still largely drained in a conventional way.** However, public administration in cities should pay attention to buildings owned by the city and located on city land in existing developments. Redevelopment of drainage of city properties also has a positive effect on other property owners (examples of "good practice").

The most common barriers to implementing RWM in built-up areas include:

- **Lack of space** – densely built-up areas lack areas for retention and infiltration elements.
- **Ownership relations** – complex property rights complicate the implementation of area-wide measures.
- **Technical infrastructure** - existing sewerage networks are not designed for torrential rainfall (Vítek et al., 2015).
- **Insufficient awareness and motivation of investors** – absence of legislative incentives and pressures.

The city's first step should be **to analyze the potential of existing development** in terms of bringing rainfall and runoff conditions closer to natural conditions - a necessary part of the spatial plan, which is one of the main goals of the general drainage plan.

The methodological procedure for analyzing the potential of existing development can be divided into three parts:

1. **Categorization of existing development** – in this phase, the area of interest is divided into individual areas according to ownership relations and spatial parameters. The output of the categorization of existing development is the definition of several coherent locations in the city, for which a more detailed survey of the watershed is subsequently carried out.

2. **Terrain reconnaissance** – the aim of terrain reconnaissance is to collect additional data on the existing development in terms of its possibilities and prerequisites for the introduction of RWM. The reconnaissance is not carried out across the entire territory, but only for locations selected during the process of categorizing the existing development.

3. **Determining the potential of RWM in existing development** – the last step in analyzing the potential of existing development is to assess the impact of "disconnecting" specific impermeable paved areas from the sewer network using a mathematical model. Based on this, it is then possible to evaluate the return on the proposed measures or, alternatively, to solve problems with overloading of non-capacity sections of the sewerage system and watercourses. In the case of an intention to introduce RWM in existing development on a large scale, it is appropriate to evaluate the impact of this step on the introduction and transport of sediments (undissolved substances) in the sewer system. This applies in particular to sections where sedimentation problems already occur in the current state.

Despite the obstacles, the benefits of implementing RWM in built-up areas can be significant:

- **Reduction of flood risk** due to relief of the sewage network (Vítek et al., 2015).
- **Improving the microclimate and reducing heat islands** – e.g. using rain gardens and green roofs (Water in the City, 2018).
- **Increasing the quality of public space** – more greenery and water supports social interactions and the health of residents.
- **Economic efficiency** – EEA (2021) states that blue-green infrastructure is cheaper than sewer expansion in the medium term (eea.europa.eu).

Example: **Enghaveparken in Copenhagen** combines parkland with retention functions and can hold up to 24,000 m^3 of water during heavy rainfall.

RWM is best applied in built-up areas to the following types of structures:

- **Public buildings and spaces** – schools, offices, parks, squares (Vítek et al., 2015).
- **New housing construction and reconstruction** - where RWM can be incorporated into the project (RWM Standards Prague, 2021).
- **Industrial areas** – often have large roof areas suitable for retention tanks or water recycling.

Foreign practice shows that **the public sector** is often the pioneer in the development of RWM. **Cities should first pay attention to buildings owned by the city and located on city land in existing developments. Rebuilding the drainage of city properties also has a positive effect on other property owners (examples of "good practice").** For example, in Amsterdam, the city invested in the *RESILIO project*, where over 10,000 m^2 of blue-green roofs were built (wired.com).

The introduction of RWM in built-up areas must be consistently applied:

- **In new buildings** – integration from the beginning (e.g. obligation to design retention elements).
- **During reconstructions** - an opportunity to renew roofs, yards or parking lots (Water in the City, 2018).
- **When revitalizing public spaces** – street trees, rain gardens, infiltration strips.

The EEA (2020) recommends a strategy of **"no-regret solutions",** i.e. measures that are always beneficial – even with uncertainty in climate scenarios.

The following measures are most often applied in built-up areas:

- **Rain gardens and bioswales** – effective even in limited street space.
- **Infiltration strips and drainage ditches** – use green areas along roads.
- **Green roofs and facades** – multifunctional measures that retain water and cool the microclimate.
- **Permeable surfaces of sidewalks and parking lots** - also recommended in *the RWM Prague Standards* (2021).
- **Multifunctional retention parks** – such as Enghaveparken (Copenhagen) or Seeliger Park (Berlin).

According to the European Commission (2021), **nature-based solutions** in urban spaces are key to climate resilience (environment.ec.europa.eu).

The following figure (Fig. 6) highlights flat roofs with an area greater than 100 m^2 in the built-up area of Novy Bydzov, which would be suitable for the implementation of green roofs.

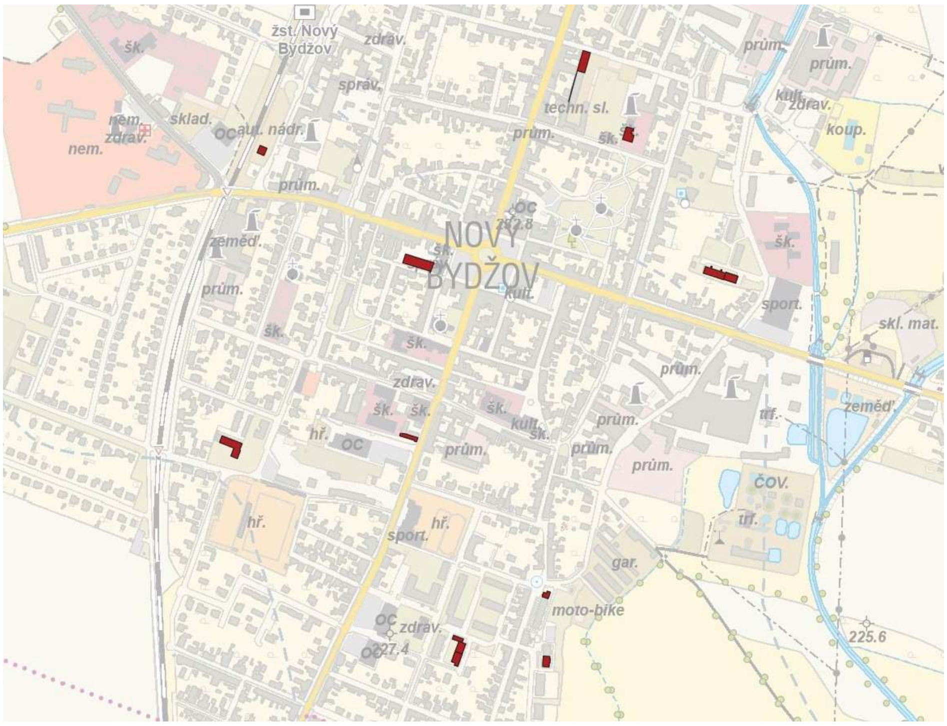

Figure 6: Flat roofs on buildings owned by the City of Novy Bydzov with floating roofs larger than 100 m^2

5.4. Implementation of rainwater management for specific buildings (projects)

The implementation of the principles of rainwater management (RWM) at the level of individual buildings is a key step towards the comprehensive implementation of the city concept. In this phase, legislation, methodological guidelines and technical standards are applied, which must be respected by the builder and consistently enforced by the public administration. In contrast to a comprehensive strategy or solutions for entire urban areas, the focus here is on individual buildings and their construction and technical conditions, ownership relationships and the construction process.

Rainwater management (RWM) at the level of individual buildings represents the most concrete level of implementation. While strategic documents and spatial planning determine the general framework, it is only at the level **of building permits and project documentation** that decisions are made as to whether and how the RWM principles will actually be implemented.

5.4.1. Legislative framework and documents at the city level

For specific projects, it is necessary to clearly require the application of relevant legislation and binding standards:

- **Water Act** – establishes the obligation to manage rainwater in such a way as to prevent its pollution and to prefer its disposal on the land.
- **The Building Act** – emphasizes the obligation to respect the principles of sustainable development of the territory and allows the inclusion of requirements for RWM directly into the spatial planning documentation.
- **Technical standards** – provide a methodology for the design and assessment of infiltration devices and retention structures.
- **Municipal standards** – an example is *the Standards for Rainwater Management in the Capital City of Prague* (ČVUT, 2021), which specify technical and procedural requirements and recommendations that can be considered a model for other cities.

To effectively enforce these requirements, it is appropriate for the city to adopt its own **methodological regulation or decree,** which sets out uniform rules for developers in advance. According to European practice (European Commission, 2021; CIRIA, 2015), it is crucial that the rules are clear, transparent and binding already at the stage of zoning and construction procedures.

According to *the RWM Prague Standards* (2021), it is necessary for cities to adopt clear methodological regulations that specify to builders:

- **requirement for infiltration or retention of rainwater on the property,**
- **limits on maximum discharge into the sewer system** (e.g. in Prague max. 2 l/s/ha for new construction),
- **obligation to assess water recycling options,** especially for larger projects.

The legislation of EU countries currently only sets out general frameworks for RWM, which is why **the role of urban standards** and **territorial regulations** is crucial.

European cities (e.g. Berlin, Hamburg) have introduced **"rainwater fees"** to incentivise developers to implement RWM. These fees can be reduced if the project includes retention tanks, green roofs or infiltration systems (EEA, 2020; climate-adapt.eea.europa.eu).

5.4.2. Control and enforcement of RWM by public administration

A control mechanism is essential for the effective implementation of RWM:

- **The building authority** requires documentation of a hydrotechnical calculation and a draft measure.
- **The Water Authority** assesses whether the solution is in accordance with the Water Act.
- **A municipal authority** (e.g. the environmental department) checks whether the measure corresponds to the city's strategy.

The role of building authorities and water authorities is crucial. The inspection focuses on:

- **completeness and quality of the submitted documentation,**
- **compliance of the design with binding regulations and standards,**
- **implementation of the construction in accordance with the project** (inspection during the final approval),
- **setting conditions for maintenance and operation of the device.**

Abroad (e.g. in Copenhagen), controls are reinforced by **monitoring the real behavior of systems,** which allows the city to monitor the effectiveness of measures even after construction is complete (EEA, 2020).

Experience shows that without consistent control, RWM principles are circumvented – e.g., a formal design of a seepage device, which is not technically feasible or remains unmaintained (CIRIA, 2015; VÍTEK et al., 2015).

5.4.3. Procedure of the investor, builder and designer

Every investor (builder) should be obliged to submit and prove the following when approving a construction project:

- Evaluation of **the possibility of infiltration and retention** on the land.
- Assessment of **rainwater use in the building** (flushing, irrigation).
- Compliance with the specified **maximum discharge into the sewer.**
- Ensuring **maintenance of the proposed measures** (e.g. regular cleaning of retention tanks).

European practice shows that in many cities (e.g. Malmö, Vienna) the investor is obliged **to submit a rainwater audit** (rainwater plan), which systematically evaluates all options for managing rainfall (EEA, 2021).

In a number of European countries (e.g. Germany, the Netherlands), such a procedure is firmly enshrined in legislation and the builder cannot obtain a building permit without documenting the measures (EEA, 2020).

5.4.4. Solving inadequate infiltration conditions

Infiltration is not always possible – e.g. due to **low soil permeability, high groundwater levels or subsoil contamination** (Vítek et al., 2015). If infiltration is completely impossible, it is necessary to demonstrate that all alternative measures have been considered and that runoff to the sewer is effectively minimized.

In such cases, it is necessary to choose alternative measures:

- **Retention tanks with regulated outflow** – water is used for irrigation or flushing.
- **Green roofs** – retain up to 50-80% of precipitation (Water in the City, 2018).
- **Permeable surfaces** – allow partial infiltration and slow down runoff.
- **Relief facilities** – multi-chamber tanks with the possibility of gradual discharge.

The European Commission (2021) highlights that **nature-based solutions** are a suitable alternative to technical measures where direct infiltration is not possible (environment.ec.europa.eu).

5.4.5. Practical examples

Procedure for the builder when applying the principles of rainwater management (RWM)

STEP 1 - Preliminary land analysis

- Assess **hydrogeological conditions** (soil infiltration capacity, groundwater level, risk of contamination)
- Evaluate **area ratios** (proportion of impervious surfaces, greenery)
- Take into account **climatic conditions and precipitation intensity** (VÍTEK et al., 2015; EEA, 2020)

STEP 2 - Drafting a water management concept

- Determine **the maximum permissible discharge into the sewer** according to city standards (e.g. Prague: 2 l/s/ha – RWM Prague Standards, 2021)
- Examine the possibilities **of using rainwater** in the building (flushing, irrigation, technical purposes)
- Design a combination **of technical and nature-based measures** (retention tanks, green roofs, permeable surfaces, ditches, rain gardens)

STEP 3 - Choosing the right solution

- **Prefer infiltration** if conditions allow
- If infiltration is not possible, choose **retention with controlled drainage** or **water recycling**
- In the case of large-scale constructions, require **a comprehensive rainwater audit** (rainwater plan – practice from Vienna, Malmö; EEA, 2021)

STEP 4 - Submission of documentation

- The project documentation must include:
    - Hydrotechnical calculation (precipitation, runoff and retention balance)
    - Proposal of measures in accordance with city standards
    - Investor's declaration on ensuring maintenance of measures

STEP 5 - Review and approval

- **The building authority** verifies the completeness of the documentation
- **The Water Authority** assesses compliance with the Water Act
- **The city's environmental department** ensures compliance with city standards and the zoning plan

STEP 6 - Implementation and acceptance

- The investor must prove that the measures were implemented according to the project
- For larger buildings, **monitoring of the system's function may be required** (practice from Copenhagen and Hamburg)

- **a regular maintenance** system (cleaning retention tanks, checking the function of infiltration facilities, caring for vegetation on green roofs)
- It is recommended to establish **a registry of measures** at city level for long-term monitoring (EEA, 2020)

6. Technical measures and equipment in rainwater management

Modern rainwater management uses a wide range of technical measures. All measures have a common goal – **to retain, slow down or use rainwater as close as possible to its point of impact,** thereby approaching natural hydrological processes.

Technical measures form the practical backbone of rainwater management. Each city can choose a combination of solutions according to its conditions and create Standards for RWM in the city area for its needs. It is important to understand that the greatest effect is achieved by a combination of multiple measures - from small individual solutions (tanks at homes) to large urban projects (retention reservoirs, wetlands).

The introduction of RWM measures is technically feasible, economically beneficial and proven by many European examples. **However, political will, clear legislation and systemic support are necessary for success.**

The main groups of blue-green infrastructure are listed below. For each group and subgroup, the principle, meaning and typical use are described. Detailed specifications and possible uses of blue-green infrastructure are elaborated in a separate guideline: **GUIDELINES FOR DESIGNING BLUE-GREEN INFRASTRUCTURE FOR RAINWATER RETENTION AND GROUNDWATER RECHARGE**, elaborated within the MAURICE project.

6.1. Reduction or prevention of precipitation runoff at the source

The purpose of these technical measures is to reduce or completely minimize the occurrence of rainwater runoff at the source. Therefore, when designing a rainwater drainage system, it is necessary **to preserve permeable unpaved surfaces as much as possible,** preferably with vegetation cover in low-lying terrain and with natural drainage. When designing drainage, it is also advisable to minimize the number of impermeable paved areas.

The technical measures to achieve this goal are described below.

6.1.1. Unpaved surfaces

- **Description:** Grasslands, parks, gardens, tree-lined avenues and other vegetation elements.
- **Meaning:** They soak up water directly on site, support groundwater recharge and improve the microclimate.
- **Example of use:** Establishing parks instead of paved parking lots, restoring front gardens of apartment buildings.

6.1.2. Permeable paved surfaces

- **Description:** Surfaces made of grass tiles, gravel or permeable paving.
- **Meaning:** They allow water to seep into areas that are functionally used (e.g. parking lots, sidewalks).
- **Example of use:** Parking for residents, pedestrian zones, cycle paths.

6.1.3. Vegetation and gravel roofs

- **Description:** Roofs that are planted with vegetation or covered with gravel.
- **Meaning:** They retain and evaporate water, reduce the load on sewers and cool buildings.
- **Example of use:** Administrative and public buildings, new apartment buildings.

6.2. Accumulation and use of rainwater

Accumulated rainwater can be used primarily as a source of water for watering city parks or green infrastructure, cooling city surfaces by sprinkling or cleaning them. In city buildings, it can also be used as a source of utility water for flushing toilets or cleaning (usually it is necessary to build a separate utility water distribution system). Rainwater can also be used for other purposes.

In Novy Bydzov, a complete technical solution was developed for the Winter Stadium location as part of the MAURICE project, which replaced drinking water for the production of ice for the ice rink with rainwater from the roof of the winter stadium.

A brief description of the accumulation and use of rainwater is given below.

- **Description:** Systems that collect rainwater in tanks and allow its further use.
- **Meaning:** It saves drinking water and ensures a supply for drier periods.
- **Example of use:** Underground or above-ground tanks near family houses, reservoirs near schools and public buildings, accumulations in industrial areas.

6.3. Infiltration device without regulated drain

These devices are generally usable for all types of common areas. Their feasibility is limited by hydrogeological conditions, i.e. the absorption capacity of the subsoil, the height of the groundwater level (maximum groundwater level at least 1 m below the foundation joint of the building/RWM facility), the slope of the terrain (if there is a risk of landslide). Feasibility must be confirmed by a detailed hydrogeological survey. Their application is unsuitable in cases where there is a risk of groundwater or soil contamination, i.e. unsuitable for areas from which highly polluted rainwater can flow (e.g. areas where hazardous substances are stored) or in cases where there is an unremediated ecological burden.

Individual examples of technical measures in this category are characterized in the following text.

6.3.1. Surface infiltration without retention - surface infiltration

- **Description:** Unpaved areas where water spills and the infiltration area is large enough.
- **Meaning:** The simplest method, suitable for smaller plots of land.

6.3.2. Surface infiltration with retention - infiltration gap

- **Description:** A depression in the terrain covered with grass or planted with vegetation.
- **Meaning:** It captures a larger amount of water, which gradually soaks in.

6.3.3. Surface infiltration with retention - infiltration tank

- **Description:** A reservoir in the field without a permanent water level.
- **Meaning:** It serves to temporarily retain water and gradually absorb it.

6.3.4. Underground infiltration with retention - infiltration trench

- **Description:** Underground gravel or block element.
- **Meaning:** Allows for absorption even where there is no free surface area.

6.3.5. Underground spaces filled with gravel or blocks

- **Description:** Prefabricated box or gravel bed systems.
- **Meaning:** High retention capacity, suitable for larger paved areas.

6.3.6. Infiltration shaft

- **Description:** A vertical element leading into deeper soil layers.
- **Meaning:** Usable where surface infiltration is limited.

6.4. Infiltration device with regulated drainage

These devices are generally usable for all types of common areas. In contrast to infiltration without regulated drainage, they can be used in conditions with poorer permeability of soil layers. They are also limited by the availability (distance) of the recipient (i.e. surface water or sewage system) into which the regulated drainage and water from the safety overflow will flow. The use of infiltration devices with regulated drainage is inappropriate in cases where there is a risk of groundwater or soil contamination.

Individual examples of technical measures in this category are characterized in the following text.

6.4.1. Infiltration trench with regulated drainage

- **Description:** Combination of a spillway and a controlled discharge.
- **Meaning:** Provides both infiltration and controlled discharge into the sewer.

6.4.2. Soaking tank with regulated drain

- **Description:** A tank that gradually releases water.
- **Meaning:** Reduces sewer overload during heavy rains.

6.4.3. Infiltration trench or underground spaces with regulated drainage

- **Description:** A variant of underground infiltration devices supplemented with a control element.
- **Meaning:** Allows for better runoff management during extreme rainfall events.

6.5. Retention facilities with regulated outflow

When discharging rainwater into surface waters, it is necessary to delay the outflow by means of a retention facility. Each retention facility must be equipped with an outflow regulator that regulates the outflow from the facility to a value that must be lower than the prescribed permissible outflow. Each retention facility must be equipped with a safety overflow that is hydraulically and structurally designed to safely transfer the flow caused by a rainfall higher than the design rainfall.

The feasibility of measures in this category is limited by the availability of surface water or sewage into which the regulated drain and water from the safety spillway will flow.

Individual examples of technical measures in this category are characterized in the following text.

6.5.1. Dry rainwater retention basins (polders)

- **Description:** A space that is dry most of the time and only fills up during precipitation events.
- **Meaning:** Flood protection, suitable for larger urban areas.

6.5.2. Underground rainwater retention tanks

- **Description:** Tanks located below the surface, often under parking lots or squares.
- **Meaning:** They enable efficient farming in cramped urban conditions.

6.5.3. Rainwater retention tanks with storage space

- **Description:** They combine a retention function with the possibility of accumulation for water use.
- **Meaning:** Double effect – protection against sewer overload and water supply.

6.5.4. Artificial wetlands

- **Description:** Ecological elements simulating a natural wetland.
- **Significance:** They retain and purify water, support biodiversity and recreational functions.

7. Identifying financing for rainwater management

Currently (probably due to the existence of a number of exceptions to the charging of rainwater discharge into the sewerage system and often also due to the inconsistency of administrative authorities in promoting environmentally friendly RWM) financing a new concept of rainwater management is relatively complex. The EU and a number of Member States are aware of the importance of RWM for the sustainability of water management and the quality of life in urban environments, therefore they allocate various subsidy titles for its successful implementation. The following chapters summarize some of the subsidy sources in the EU and the partner countries of the MAURICE project.

7.1. European resources

7.1.1. European Regional Development Fund (ERDF) & Cohesion Fund (CF)

- *For what*: blue-green infrastructure in cities, SUDS, flood and drought measures, modernisation of water management (mostly through national/regional operational programmes).
- *Examples of use*: streets with infiltration, retention parks, compartments/sewerages, smart rainwater management.
- *Where to watch*: national portals "EU Funds" and calls for OP Environment/OP Environment, etc. (see countries below).
- *Note*: in the period 2021-2027 often under the priorities "Climate adaptation", "Environment" or "Sustainable cities". funduszeeuropejskie.gov.pl

7.1.2. EU Mission "Climate Change Adaptation" (Horizon Europe, Mission 3)

- *For what*: pilot and demonstration projects of cities/regions for adaptation – including rainwater management, blue-green infrastructure, resilience plans.
- *Who*: municipalities, city associations, regions, research + partners.
- *Note*: emphasis on "mission cities/regions", joint learning and replication.

7.1.3. LIFE program (Environment/Climate sub-programme)

- *For what*: innovative nature-based solutions (NBS), SUDS, watercourse renaturation, urban wetlands, green roofs/walls, water quality measures.
- *Past/current projects*: a number of urban SUDS/LID applications across the EU.
- *Who*: municipalities, public enterprises, universities, NGOs.

7.1.4. Interreg (Cross-border, Transnational - e.g. Central Europe, Europe)

- *For what*: cross-border planning, pilots and exchange of know-how (storm risk mapping, SUDS catalogues, common standards).
- *Who*: cities, regions, universities, water managers.

Note: Until 2020, similar projects were typically financed from OPs 2007–2013 and 2014–2020 (ERDF/CF), LIFE and Interreg; 2021–2027 they continue, "Mission" calls have been added.

7.2. Examples of funding opportunities in the partner countries of the MAURICE project

7.2.1. Czech Republic

<u>European/national operations (ERDF/CF implementation):</u>

- **Operational Programme Environment (OPŽP) 2007-2013, 2014-2020, 2021-2027** *What for*: comprehensive adaptation measures, SUDS, retention and infiltration, separate sewerage, improvement of water quality, urban greenery with retention function. Beneficiaries: municipalities, urban companies, SVS/VK, SVJ, NGOs (according to the call).

<u>National programs (ME/SEF):</u>

- **"Rainwater" (SEF, 2017-present - waves opened several times)** *What*: retention and use of rainwater in households (retention, use in toilets/flush, grey water). Recipients: individuals - family houses.
- **New Green for Savings (NZÚ)** - selected sub-programmes support rainwater utilization systems in family homes/residential buildings (in combination with energy/savings).

<u>Regional/municipal:</u>

- **Capital City of Prague - Rainwater Management Standards** - the standard is not a grant, but is key to the eligibility of projects in urban investments and development areas (often connected to urban/OPE resources).

7.2.2. Germany

<u>Federal framework:</u>

- **"National Program for Natural Climate Protection" (Aktionsprogramm Natürlicher Klimaschutz, BMUV/ZUG)** - support for renaturation, blue-green infrastructure, natural water retention in municipalities (grants to municipalities/states/NGOs).
- **"Klimaanpassung in Kommunen" (BMUV/ZUG)** – investments and planning for climate adaptation (including rainwater, heat islands, blue-green networks).

<u>Provincial/municipal programs (examples):</u>

- **Berlin - "GründachPLUS / Regenwasseragentur"** – subsidies for green roofs, retention measures for buildings; methodological and project support for the municipality.
- **Hamburg – Support for Green Roofs and Retention Measures (BUKEA)** – long-term city grant program for "Schwammstadt" projects.
- **North Rhine-Westphalia (NRW) – "Directive on the granting of grants for climate adaptation in municipalities"** – finances concepts and investments (SUDS, retention parks, blue-green corridors).

7.2.3. Poland

<u>European/national:</u>

- **The Operational Programme Infrastructure and Environment (POIiŚ) 2014-2020 - Priority "Adaptation"** – included urban rainwater management systems (separate sewers, retention facilities, SUDS). Its successor is **FEnIKS 2021-2027** (adaptation, small retention).
- **NFOŚiGW – "Moja Woda" (2020-2024, continuously opened waves through regional WFOŚiGW)** – subsidies to households for small retention systems (tanks, infiltrations, rainwater utilization). Beneficiaries: individuals with RD.
- **NFOŚiGW - "Adaptation to climate change" programs** – support for cities (over 100 thousand inhabitants) and smaller municipalities for infrastructure and nature-friendly solutions; in the past co-financing from POIiŚ, now from FEnIKS.

7.2.4. Italy

<u>National/European – PNRR (National Recovery and Resilience Plan, NGEU):</u>

- **M2C4 – "Protection of the territory and water resources"** – investments in water infrastructure and adaptation, financed in a number of metropolitan cities by "Città Spugna" (SUDS, invarianza idraulica). Beneficiaries: cities/metropolitan areas, water ATOs, road administrations.

<u>Thematic national initiatives:</u>

- **Strategia Nazionale del Verde Urbano (MASE)** – framework for urban green infrastructures; follows up on urban/afforestation planting programmes (including metropolitan cities).

<u>Regional/municipal (examples):</u>

- **Milan – BE2 grants** (municipal energy subsidies + *tetti/pareti verdi* and depavimentazione as rain measures). Beneficiaries: private owners and SVJ; can be combined with regional FESR calls.
- **Regional Rural Development Programmes (PSR/FEADR 2021-2027)** – some regions (e.g. Emilia-Romagna) allow the use of green/retention at the urban-rural interface (through agricultural entities – e.g. agroforestry, water retaining landscape elements).

7.2.5. Slovenia

<u>National/municipal:</u>

- **Eko sklad - subsidies for "zbiralnik deževnice" (rainwater retention tanks for households)** – regularly opened calls; can be combined with municipal support (e.g. for reconstructions).
- **City programs (e.g. Ljubljana)** – have long-term support for green roofs and blue-green infrastructure interventions (mostly from city budgets and ERDF). (Background information, check in the city's current budget calls.)

7.2.6. Croatia

<u>European/national:</u>

- **Competitiveness and Cohesion Programme (ERDF/CF) 2014-2020, 2021-2027** – finances water management and adaptation projects (including drainage with rainwater retention, green infrastructure in cities). Beneficiaries: LGUs (local self-government units), municipal enterprises.
- **NPOO/PNRR Croatia** – investments in water and adaptation infrastructure, part of projects with a rainwater management component (according to calls).
- **FZOEU - Fond za zaštitu okoliši i energetsku utvoriti** – ongoing national calls for municipalities/citizens; annual allocation plan includes environment, energy and selected adaptation interventions (it is recommended to follow "eFZOEU" and annual call plan).

7.3. Recommendations for using subsidy programs

7.3.1. Practical notes on requests and resource combinations

1. **Start with a strategy and standards** – city "rain plan" and standards (Prague, Berlin…) increase the chance of funding and make it easier to assess the benefits (retention, water quality, heat islands).
2. **Connect energy, greenery and water** – combinations (e.g. Milan: energy + green roofs + depaving) are often subsidized.
3. **Community and "pilot" components** – LIFE/Interreg often require measurable pilots and sharing of results.
4. **Phase your investments** – EU funds like to see "packages": concept (runoff/infiltration studies) → fast pilots → large investments (OP / PNRR).
5. **Follow the annual plans of the funds** - some national funds issue calls cyclically (NFOŚiGW, FZOEU; for municipalities/countries in DE often spring/autumn rounds).

7.3.2. Recommended procedure for your city hall (checklist)

1. **Map "what I want to fund" vs. source** (investment × study × pilot).
2. **Verify eligibility** (type of applicant, territory, publicity, sustainability).
3. **Prepare the package** :
    - *Concept & data* (map of impervious areas, infiltration maps, runoff limits).
    - *Quick interventions* (permeable parking lot near the school, infiltration ditch near the road).
    - *Flagship project* (retention park / "mushroom district").
4. **Fill in the co-financing** (municipal budget + national fund + EU).
5. **Keep track of time** (ETŘ calls: OP/ERDF, national funds, LIFE/Interreg – various calendars).
6. **Consider a partnership project** (metropolitan areas/ATOs, water utilities, universities).
7. **Keep an eye on operating costs** (from the city/municipal corporation budget; some programs recognize 5 years of O&M as eligible to a lesser extent).

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