SUSTAINABLE URBAN DRAINAGE SYSTEMS:

Stormwater management techniques suitable for Estonian climate conditions

UrbanStorm

The brochure was produced in 2021 within the **„Development of sustainable and climate resilient urban storm water management systems for Nordic municipalities – LIFE UrbanStorm"** project that is co-financed by the LIFE+ programme of the European Union and the Estonian Environmental Investment Centre.

The aim of the project is **to increase the capacity of Estonian municipalities to adapt to climate change, especially in managing the floods caused by torrential rains.** The project is being implemented by Viimsi Municipality (the lead partner), Baltic Environmental Forum Estonia, Estonian University of Life Sciences, and Tallinn Urban Environment and Public Works Department.

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For more information on the LIFE UrbanStorm project and sustainable urban drainage systems, visit urbanstorm.viimsivald.ee.

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Flooding after rain. Haabneeme, Estonia. Photo: Erki Tammleht.

Introduction

Viimsi Municipality together with partners from the Estonian University of Life Sciences, Tallinn Urban Environment and Public Works Department and the NGO Baltic Environmental Forum Estonia is **investigating and testing different sustainable urban drainage systems (SUDS)** under the LIFE UrbanStorm project. The aim of the project is to raise awareness and be prepared for the increase in precipitation and the frequency of torrential rains due to climate change. Project activities include study trips to other countries, compilation and analysis of information on sustainable urban drainage systems, testing of selected solutions in demonstration areas of Viimsi Municipality, trainings, seminars and various information activities.

The brochure has been compiled based on information obtained from study tours to Copenhagen, Malmö and Helsinki as well as literature sources and draws on the experience and knowledge of researchers of Estonian University of Life Sciences. The brochure briefly details the **causes of stormwater problems** in urban areas, introduces **sustainable urban drainage systems and their benefits** as well as gives an overview on sustainable **stormwater management techniques suitable for Estonian conditions.**

Stormwater problems affect almost **all Estonian municipalities.** That is why the LIFE UrbanStorm team wants to share the information and experience acquired during the project with all interested parties. You are welcome to visit **the website of the project**, where you can find all information materials produced during the project as well as information on established SUDS in pilot areas, trainings and other project activities: urbanstorm.viimsivald.ee.

Climate change and stormwater problems

Climate change has a direct impact on rainfall: warmer climates increase evaporation and raise the level of atmospheric humidity that in turn causes an increase in precipitation and the frequency of heavy rains. A statistically significant increase of the mean annual precipitation by 5%–15% has occurred in Estonia in the second half of the 20th century and scientists predict this growth pattern to continue into the future (10%–14% between 2041 and 2070, and 16%–19% in 2070–2100).* **Increased occurrence of heavy rains, rise of global sea level and more frequent storms** are also expected. This means that the frequency and extent of floods will increase. Such weather causes significant problems, especially in urban areas, where there are already difficulties with stormwater management at present.

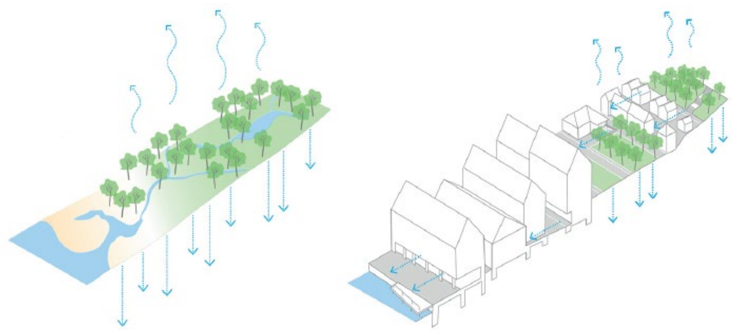


Figure 1. Changes in the water cycle as a result of urbanisation (right).

In the natural landscape, rainwater seeps into the ground, evaporates from surfaces and is absorbed and transpirated by plants, and part of it eventually reaches streams and rivers. Continued **urbanization** due to social and economic development, however, **causes major changes in the natural cycling of water.** The large share of impervious surfaces (rooftops, paved streets, parking lots etc.) in the urban environment causes increased volume of surface runoff but at the same time decrease of infiltration, evapotranspiration (total evaporation from surfaces and through vegetation) and the quality of water discharged into soil and water bodies **[Figure 1].**

* Estonian Environment Agency, 2014. Estonian Future Climate Scenarios until 2100.

There are less surfaces enabling infiltration and less vegetation in urban areas as a result of developmental activities. Rainwater falling on impermeable surfaces turns into surface runoff a lot faster and in larger amounts, which may cause **floods, pollution and erosion problems.** In some places the differences with the natural environment can be up to five times **[Figure 2]**.

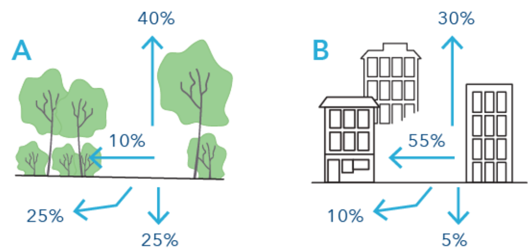


Figure 2. Stormwater infiltration, evaporation and flood-causing surface runoff in natural (A) and urban (B) environment in %.

Stormwater problems can be solved by increasing sewer reception capacity (if technically possible), i.e. by increasing the diameter and density of pipelines, but it is often more useful and cost-effective to use alternatives – **nature-based solutions.**

The use of alternative solutions can **improve the efficiency of water management, provide added value in the form of greenery, level the water regime** (especially in drier areas), **slow down the surface runoff, purify the water and add amenity** to the urban environment. As a whole, it gives new value to the entire urban environment and is also more sustainable in the long run than investing in sewerage infrastructure (re)construction.

Sustainable urban drainage systems and their benefits

Sustainable urban drainage systems (SUDS) are facilities that mimic natural ecosystems in stormwater drainage, enabling more **efficient and environmentally friendly stormwater management.**

The main aim of SUDS is to **reduce the volume and flow rate of surface runoff by dispersing, infiltrating and harvesting rainwater close to where it falls (the source) as much as possible.** For that, various rainwater harvesting systems, green roofs and green walls, infiltration trenches, swales, pervious pavements etc. can be used. SUDS also enables to remove pollutants from stormwater runoff.

Plant-based systems and landscape elements are used in sustainable urban drainage systems. Thus, sustainable stormwater management means integrated planning of the entire area and designing of green areas as well as increasing biodiversity, multifunctionality and aesthetic value of the urban space.

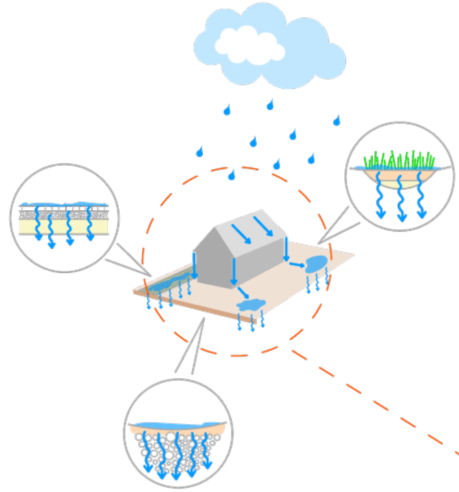
The benefits of SUDS can be divided into four categories: **regulating the volume of stormwater runoff, improving the water quality, creating a pleasant living environment and supporting biodiversity.** It is important to pay attention to all of those when designing a SUDS. Additionally the generic criteria of a good design should be taken into account, including constructability, maintainability, cost-effectiveness and safety. It is crucial to **engage all stakeholders early**, including those with responsibility for approving, adopting or maintaining the SUDS scheme, the environmental regulator, sewerage undertaker and roads authorities. Opportunities for SUDS will be maximised through collaboration between engineers, landscape architects, planners, architects and the local community that enables to achieve a good comprehensive solution as an end result [Figure 3].

Figure 3. The characteristics and benefits of a well-designed sustainable urban drainage system.

SUDS Management Train

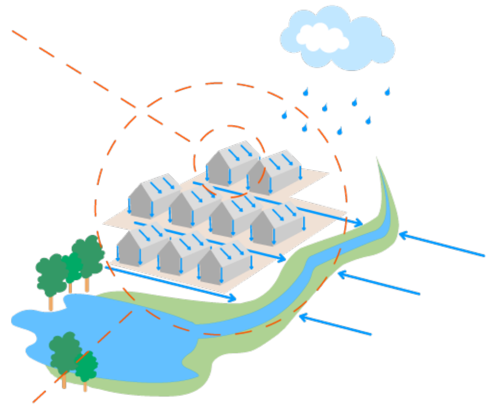
A central design concept for SUDS is the SUDS Management Train. This means **a sequence of SUDS components** that collectively provide the necessary processes to control the flow rates and runoff volumes, and to reduce concentrations of contaminants to acceptable levels. The principle of operation of the SUDS Management Train is similar to the natural water cycle process in the catchment area.

The SUDS Management Train starts at the **source of the stormwater runoff** (in urban areas, this is mainly on the roofs of buildings and impermeable surfaces such as asphalt), where the primary management and prevention of stormwater runoff takes place. The surface runoff is then diverted to the **site level (e.g. street or block) SUDS components** receiving runoff from all roofs and paved surfaces of the site. The last stage before stormwater runoff reaches the sewer or water body is **regional (e.g. district or municipality) drainage system** where runoff from the whole region is managed. The further away from the source, the more water drainage solutions have to cope with, as the area to be controlled increases at each stage **[Figure 4]**.



1. Runoff control at the source (i.e. at each property) is very important to reduce the quantity of runoff. The more stormwater is attenuated at the source, the less of it reaches the downstream parts of the drainage system. Every property owner can contribute to this by reducing the proportion of impermeable surfaces and using sustainable drainage solutions on the property.

2. The residual stormwater flows from each source are conveyed to the **site (e.g. street or block) level runoff control** components of the drainage system where further attenuation and treatment of runoff takes place.



3. Regional runoff control components downstream at the end of the Management Train must manage surface runoff from the whole region (e.g. district or municipality). The more efficient is the drainage system upstream, the lower the runoff quantity, pollution and probability of flooding at the end of the Management Train.

Figure 4. Different levels of the SUDS Management Train.

Selecting SUDS components

The choice of SUDS components depends on the **amount of stormwater, relief, soil characteristics and land use.** Sustainable drainage system can be designed for any development or area (including private properties, appartment buildings, city quarters, public urban spaces). SUDS can be integrated in new developments as well as retrofitted in existing infrastructure, including places where there is very little space. A well-designed SUDS enables **efficient and multi-functional use of the existing space whilst also providing other functions in addition to drainage.** For example, areas with permeable pavement can be used for parking, rain gardens as traffic islands, detention/infiltration basins for recreation purposes and trees and green roofs contribute to temperature regulation of buildings.

The broad selection of SUDS techniques and possibility to combine different components enables the design of an **efficient drainage system for any conditions, including:**

- High-density development areas
- Steep slopes
- Flat sites
- Sites with high groundwater levels
- Sites in floodplain zones
- Contaminated sites
- Sites with low infiltration capacity
- Sites with unstable soils

The following principles must be kept in mind when selecting SUDS components:

- **Management of stormwater runoff should start at the source (i.e. close to where the rain falls)**

In the urban environment, the main runoff sources are **the roofs of buildings and other impermeable surfaces.** Even if infiltration into the ground is possible, it is recommended to direct the runoff away from the building or prevent its flowing under the foundation.

Suitable SUDS techniques for source control include green roofs, green walls, rainwater harvesting and use, and at a safe distance from the building also permeable pavements. The main aim of source control SUDS components is to **reduce the flow rate and volume of runoff**, so that the subsequent down-stream components can manage the residual flows.

- **Attenuation of stormwater runoff**

In case of light rain, the SUDS components at the source can manage the runoff but more extreme precipitation events require SUDS components that enable the **attenuation of stormwater runoff and its slow release to the next components of the Management Train.** The main cause of urban floods is the failure of the sewerage systems to meet increased levels of runoff.

- **Treatment of stormwater runoff**

When designing a sustainable urban drainage system, **reduction of pollution** must also be considered, as surface runoff absorbs litter and pollutants in its path. Low pollution stormwater runoff (e.g. coming directly from the roof) can easily be used for irrigation or domestic water. Surface runoff with medium or low pollution level can generally be safely infiltrated into the ground.

In case of land uses with different pollution potential it is recommended **to manage runoff separately that enables selecting appropriate treatment solutions according to the level of pollution.** The contamination of runoff can be prevented already on plots where sources of pollution can be easily identified and eliminated or properly managed.

SUDS techniques for runoff control at the source

One of the most important principles of SUDS is the **prevention of stormwater runoff** and problems related to it. SUDS components at the source – on and close to buildings – help to achieve this. It is important that the initial stormwater management (source control) takes place **upstream from ponds, wetlands and other SUDS components.** In case of light rainfall (5–10 mm), the source control components can usually manage the runoff.

SUDS techniques for runoff control at the source:

- Green roof
- Green wall
- Rainwater harvesting and use

Green roof

Green roof or grass roof is a roof partially or completely covered with vegetation. Green roofs can be divided into **two main categories:**

- **Intensive green roof or roof garden** – green roof with thick (20–60 cm) substrate layer and high vegetation (including trees and bushes).
- **Extensive green roof or grass roof** – green roof with thin (5–15 cm) substrate layer and low vegetation.

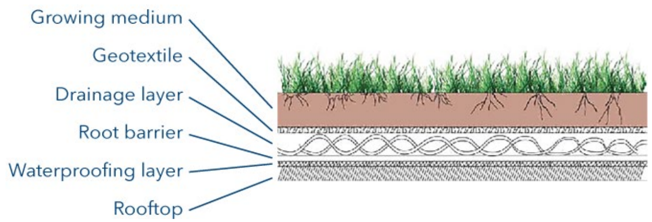


Figure 5. Cross-section of a green roof.

Advantages

- Can be used in densely built areas as no additional land is required
- Reduces, attenuates and treats stormwater runoff
- Acts as a thermal insulation and a cooler
- Reduces the energy consumption of the building
- Cleans air
- Reduces noise
- Helps avoid the heat island effect
- Adds greenery to the urban environment
- Provides habitats for birds, insects and other small animals
- Can be used as roof garden and/or recreation area

Disadvantages

- Many aspects must be accounted for in the design, including the load-bearing capacity of the building and roof (taking into account the wet weight of the green roof and the additional load due to maintenance and snow cover), maintenance needs, accessibility during construction and subsequent maintenance and safety (leakage, fire and wind resistance)
- Cannot be installed on roofs with a very large (over 30°) slope
- Higher price compared to the construction cost of a normal roof

Maintenance requirements

- Removal of fallen leaves and debris and maintenance of vegetation – twice a year or as required
- Stabilisation and repair actions – as required
- Inspection of all components (including soil substrate and its potential erosion, vegetation, drains, irrigation systems (if applicable), membranes and roof structure) – annually and after severe storms

Extensive green roof. Vantaa, Finland. Photo: Gen Mandre.

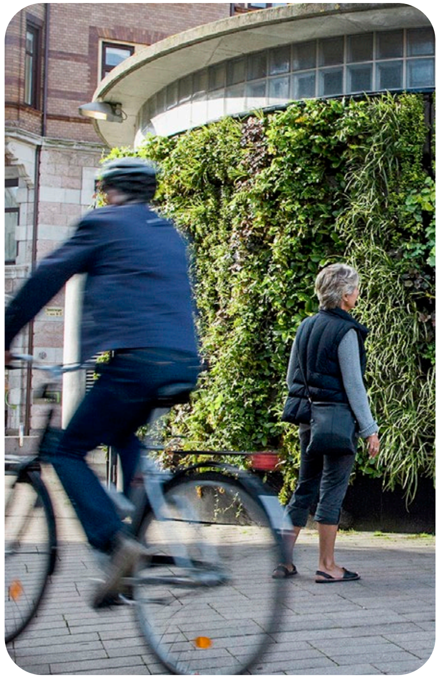
Intensive green roof. Malmö, Sweden. Photo: Gen Mandre.

Green roof with container gardening. Malmö, Sweden. Photo: Gen Mandre.

Extensive green roof on a sloping surface. Malmö, Sweden. Photo: Jolanda Lipu.

Green wall

Green wall or living wall or vertical garden or green facade is a vertically built structure intentionally covered by vegetation, where the plants grow on wall-mounted structures in small containers or in growth medium at the base of the wall. **Support frames, trusses, arches, etc.** are also used to allow the plants to grow up or hang down.



Left: Green wall at Pumphuset. Helsingborg, Sweden. Photo: Eva Lie.
Right: Green wall. London, United Kingdom. Photo: Valdo Kuusemets.

Advantages

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- Provides habitats for birds, insects and other small animals

Disadvantages

- Needs maintenance and is relatively costly (structures, plants, maintenance)
- Can damage the wall of the building if improperly installed (moisture, plant roots)

Maintenance requirements

- Regular watering and fertilisation (which is easiest to do with an integrated irrigation system)
- Replacement of dead plants
- Removal of dried leaves
- Pruning of plants – as required

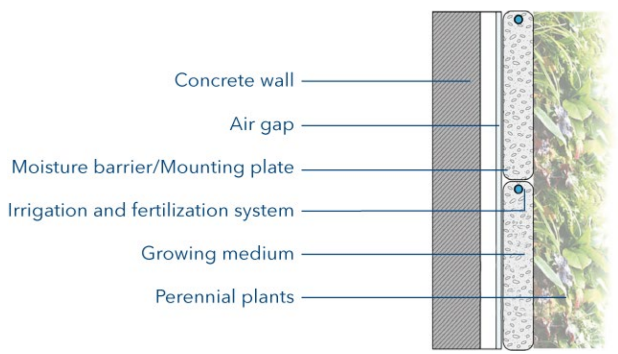


Figure 6. Cross-section of the green wall at Helsingborg Pumphuset. Source: Helsingborg.

Rainwater harvesting and use

Rainwater harvesting and use systems are suitable for situations where the possibilities for stormwater discharge are limited, discharge into the sewerage system is taxed and where there is a need to use water e.g. for irrigation, washing cars or flushing toilets. The size of the rainwater collection tank should be sufficient for one week irrigation needs or one month of household needs. Rainwater tanks can be placed **underground, in the attic of a building or under the gutters by the wall.** In the latter case, they must be emptied for the winter.

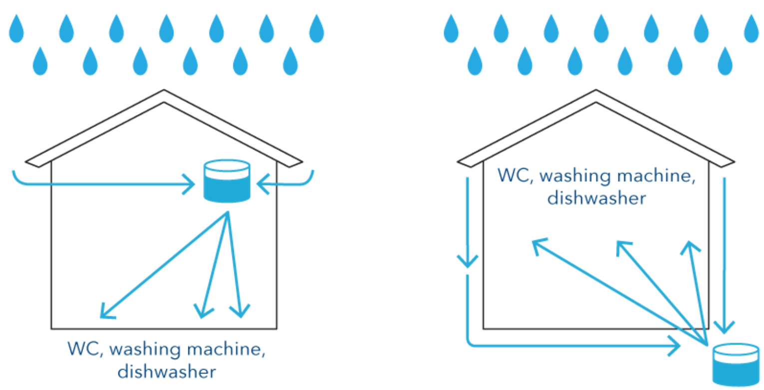


Figure 7. Simplified scheme of a gravity-based (left) and pumped (right) rainwater harvesting system.

External irrigation water tank. Photo: Benoit Rochon. Source: Wikimedia Commons.

Rainwater harvesting system in Tartu, Vanemuise 45. The pillars hide rainwater pipes along which rainwater collected from the roof flows into a 13 cubic meter collection tank hidden under the house. The collected rainwater is used in toilets and washing machines of the building. Photo: Google Maps street view.

Advantages

- Reduces the volume of stormwater runoff at the source
- When used in washing machines, soft water saves the machine (does not cause limescale build-up) and also allows to save on detergent
- Rainwater is soft and therefore well suited for irrigation
- Helps save potable water by reducing its consumption for irrigation and domestic water

Disadvantages

- Retrofitting the systems into an existing building can be complicated and costly
- Collection tanks are generally not very attractive visually
- In all likelihood, the need for pumping will arise
- Rainwater might need treatment to be used in the building

Maintenance requirements

- Regular cleaning and/or replacement of filters
- Annual inspection of the system and cleaning from silts and other debris
- Repair actions as required
- External irrigation water tank is relatively maintenance-free

SUDS techniques for stormwater attenuation

The following describes SUDS techniques **located near buildings**, the main purpose of which is **to attenuate the stormwater runoff in order to reduce the load on the stormwater drainage.** As one of the functioning mechanisms of the SUDS techniques described below is based on the infiltration of rainwater into the soil, it is recommended to install attenuation systems at least three meters away from the buildings in order to avoid damaging the foundation of the building. In case of the building being closer, special attention should be paid to the hydro-isolation of the foundation.

SUDS techniques for stormwater attenuation:

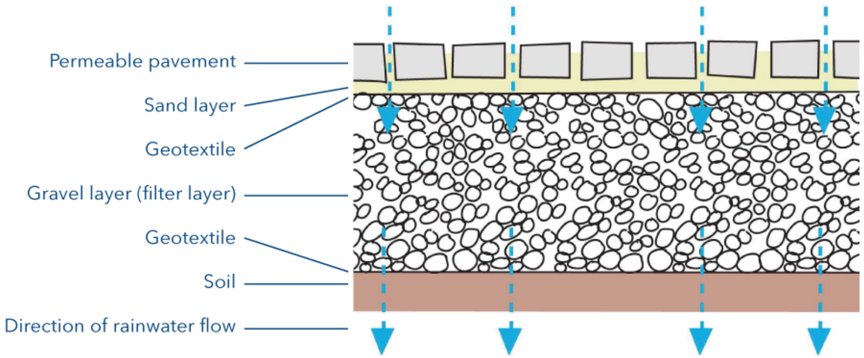
- Pervious pavement
- Stormwater planter and rain garden
- Detention basin

Pervious pavement

Pervious/permeable pavement is artificial surface cover with high hydraulic conductivity that allows stormwater to percolate and infiltrate through the pavement, for example permeable pavers, porous asphalt or plastic grass reinforcement. **Percolating stormwater infiltrates into the soil under the pavement or is collected and drained by a drainage system.** Pervious pavements act as a stormwater drainage system and at the same time allow the area to be used for other purposes, such as a parking lot or light traffic road. Therefore, they are suitable for high density developments with limited space.

Modular permeable pavement in the courtyard of an apartment association. Helsinki, Finland. Photo: Valdo Kuusemets.

Left: Porous asphalt. Photo: JJ Harrison. Source: Wikimedia Commons.
Right: Porous asphalt and conventional asphalt after light rain. Photo: Alar Mik.



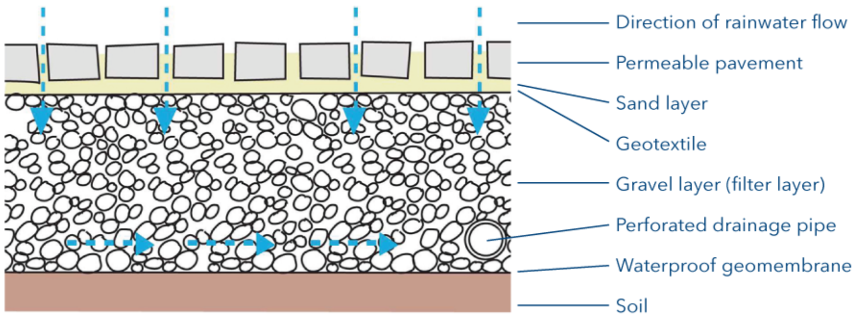


Figure 8. Solution conducting rainwater directly into the soil (above) and separated (isolated) solution (below).

Advantages

- The risk of flooding downstream is reduced by smoothing sharp runoff peaks
- Decreases the content of pollutants in stormwater runoff
- Can be used in high density development areas
- The need for extensive excavation work is reduced, which can reduce construction costs
- Recharges groundwater resources
- Does not require extra space for construction
- Reduces flooding and surface icing
- Reduces the need for grate sewers
- An acceptable solution for communities

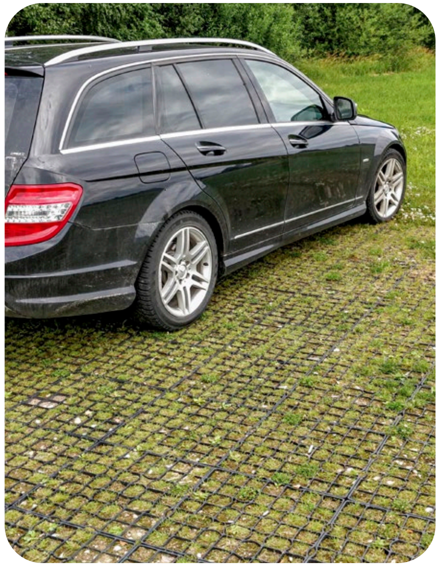
Disadvantages

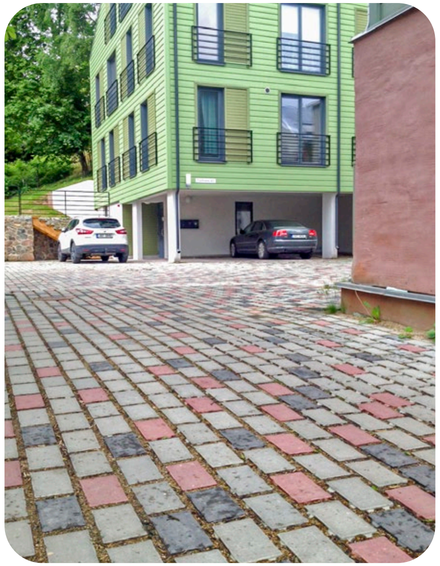
- Lack of experience in designing and building sustainable urban drainage systems
- Clogging can occur if improperly constructed or maintained
- Icing problems may occur in cold climate (but use is still possible)
- Such solutions must be avoided:
  – in areas with heavily polluted surface runoff
  – in the case of soils with low infiltration capacity
  – in areas with high groundwater levels
  – in the vicinity of drinking water wells

Maintenance requirements

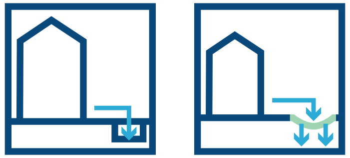
- Weed removal and repair work (replacement of broken paving stones, addition of porous material, restoration and repair of filter layers and substructure)
- Removal of leaves and debris to prevent blockages (including washing of porous material)
- Maintenance of adjacent areas – as required

Permeable pavers in a parking spot. Copenhagen, Denmark. Photo: Gen Mandre.





Left: Plastic grass reinforcement in a less busy parking lot. Estonia. Photo: Gen Mandre.
Right: Permeable pavers. Tartu, Estonia. Photo: Gen Mandre.



Stormwater planter and rain garden

Stormwater planters and rain gardens are shallow vegetated depressions that reduce the flow rate and volume of stormwater runoff and treat it with help of plants and by filtration through a layer of mulch, soil and sand. From the rain garden, the stormwater infiltrates **into the soil and potentially also to the groundwater.** In the stormwater planter, stormwater filtered through the filtering soil layers is **collected in the drainage layer and directed further into the next components of the stormwater management system.** Both, in the rain garden as well as in the stormwater planter, it is advisable to use local plant species that can withstand temporary flooding.

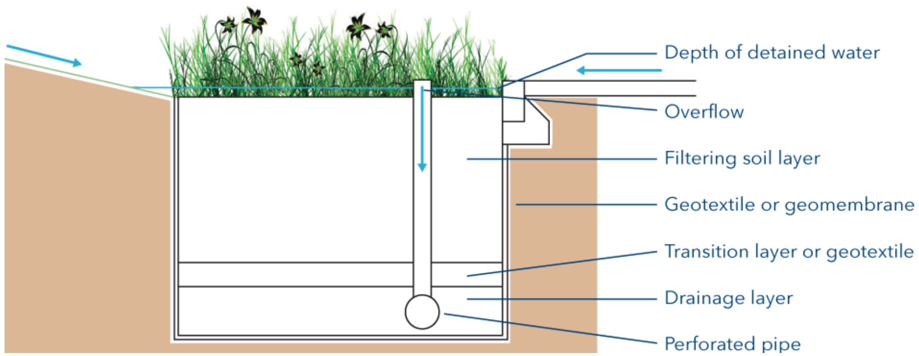


Figure 9. Cross-section of the stormwater planter.

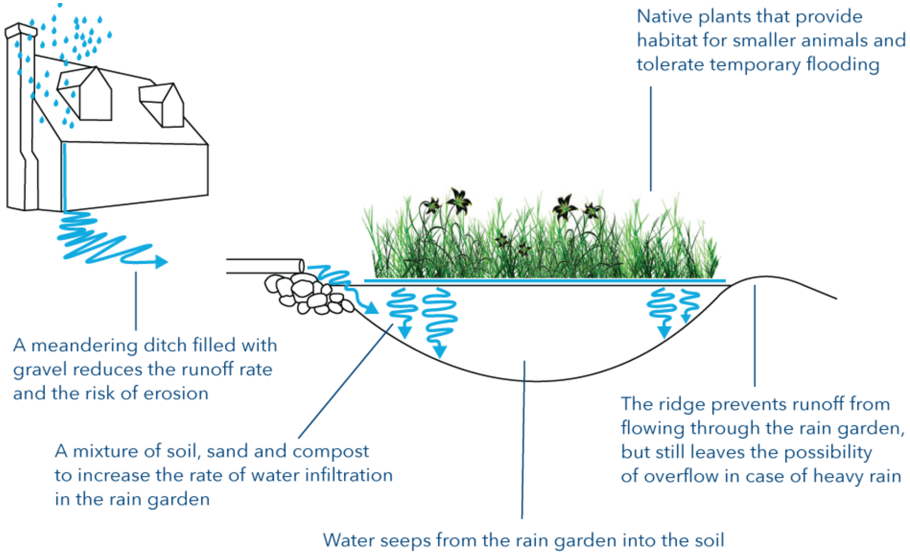


Figure 10. The working principle of a rain garden.

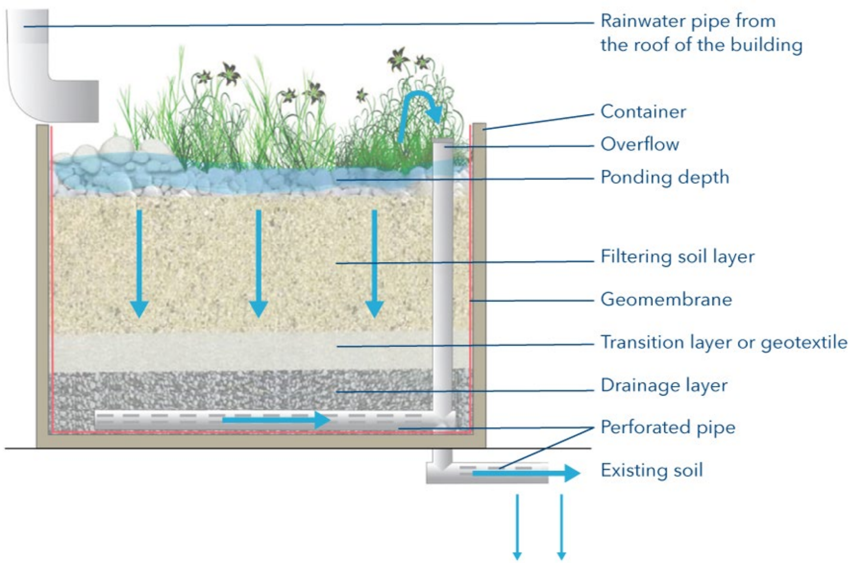


Figure 11. Rain garden in a container on the ground.

Advantages

- Takes up little space, easy to fit into an existing environment
- Suitable for impermeable areas if well designed
- Reduces and attenuates storm-water runoff, removes pollutants
- Attractive, enriches public space
- Flexible for landscape integration
- Easy to maintain

Disadvantages

- Due to its small size, does not significantly reduce the runoff volume
- Not suitable for high slope areas
- Risk of clogging if the surrounding areas are not properly maintained

Maintenance requirements

- Replacement of plants, repair erosion damage, scarifying surface of medium and replacing mulch – as required
- Replacement of filtering medium – every 15 years or as required (if the infiltration capacity is significantly reduced)
- Assessing water levels and infiltration rate, inspection of inlets and outlets and removal of blockages, assessing the status of plants, removal of litter and weeds – quarterly

Rain garden separating the road and sidewalks. Copenhagen, Denmark.
Photo: Copenhagen City Council.

Left: Stormwater planter in the street space. Malmö, Sweden. Photo: Valdo Kuusemets.
Right: Rain garden on the road slowing down the traffic. Helsinki, Finland.
Photo: Gen Mandre.

Detention basin

Detention basins or detention ponds are landscaped depressions that are normally dry except during and immediately following storm events. Stormwater runoff is **attenuated and treated in the detention basin and then diverted to the downstream component of the system via the overflow.** To some extent, also infiltration into the surface, evaporation from the surface and transpiration from plants take place. Contaminants and nutrients are reduced with the help of plants and microorganisms, and suspended solids settle to the bottom of the basin. In dry weather, the basin can be used, for example, as a rest or recreation area.

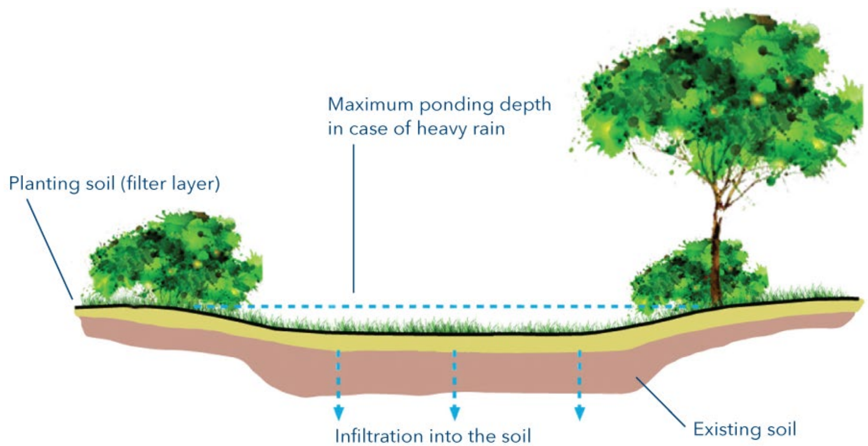


Figure 12. Cross-section of a detention basin.

Advantages

- Reduces the volume of surface runoff
- Removes pollutants efficiently
- Recharges ground water
- Easy and affordable to build
- Easy to monitor performance
- Temporary storage and detention of runoff
- Diverse landscape according to the season

Disadvantages

- High risk of failure due to inappropriate location, poor design or low pre-treatment of runoff
- Covers a large area
- Geological survey must confirm the suitability of the soil type for infiltration
- Not suitable in case of highly contaminated runoff

Maintenance requirements

- Removal of litter, inspection of inlets and outlets and clearing if needed, inspection of physical damage – monthly
- Inspection of sediment accumulation and removal if needed – annually
- Cutting of grass, maintenance of vegetation (replacement of dead plants, pruning trees and bushes), repairing erosion and other damage – as required

Detention basin in a park. Malmö, Sweden. Photo: Gen Mandre.

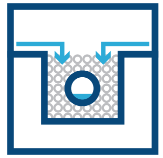
Detention basin in the courtyard of an appartment association. Helsinki, Finland. Photo: Sandra Oisalu.

SUDS techniques for stormwater treatment

In addition to draining and temporarily storing rainwater, the following solutions also allow the water to be cleaned of contaminants such as sludge and other solid particles, nutrients, heavy metals, and the like. Removal of contaminants can take place in a number of ways, including through **filtration through the soil / filter layer, during sedimentation or biologically** (with the help of plants and micro-organisms).

SUDS techniques for stormwater treatment:

- Filter drain
- Filter strip
- Swale
- Pond
- Constructed wetland
- Soakaway
- Infiltration trench
- Infiltration basin



Filter drain

Filter drain is a shallow trench filled with porous material (stones, gravel) that usually includes a drainage pipe. In essence, the filter drain is similar to an infiltration trench but unlike the infiltration trench, it includes the outflow for excess water. **The filter drain enables filtration, temporary storage and conveyance of the stormwater runoff to the downstream components of the stormwater system.** Filter drains can successfully replace traditional piping for rainwater diversion, and the use of such a solution along roads eliminates the need for curbs and stormwater gutters. The filter drain can easily become clogged (especially in the case of fine-grained soil types (clay, sediment, sludge, etc.)), so the rainwater discharged into it should be **pre-treated, e.g. by means of a filter strip or sediment tank.**

Filter drain protecting the foundation of an apartment building from rainwater flowing from the street. Copenhagen, Denmark. Photo: Gen Mandre.

Advantages

- A fast and suitable solution for draining water from the road
- Easy to integrate into green areas and fit well next to roads
- A good solution for places where a ditch cannot be built (e.g. for safety reasons or due to lack of space)

Disadvantages

- High potential for clogging, not suitable for catchments with fine particle soil types (clay, sediment, mud, etc.)
- Only suitable for relatively small watersheds
- High risk of failure due to poor maintenance, inappropriate location or high pollution (debris)

Maintenance requirements

- Removal of litter, inspection of inlets and outlets and cleaning if needed – monthly
- At locations with high pollution loads, replacement of geotextile and washing or replacement of the overlying filter medium – five yearly, or as required
- Inspection of pre-treatment systems and removal of sediment – twice a year, or as required
- Clearing perforated pipework of blockages – as required

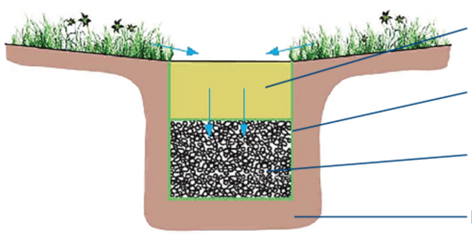


Figure 13. Cross-section of the filter drain.

Filter strip

The filter strip is a gently sloping vegetated area at least 2.5 m wide that **infiltrates and attenuates surface runoff and filters out silt and other particulates and pollutants from water.** The filter strip shall be designed so that the runoff crosses the strip as an even sheet. The filter strip is a simple and inexpensive solution that is suitable for pre-treatment of surface runoff before it is directed to the subsequent components of a sustainable drainage system.

Filter strip before a vegetated swale. Copenhagen, Denmark. Photo: Gen Mandre.

Advantages

- Easy and inexpensive to build
- Suitable for pre-treatment of surface runoff before the subsequent SUDS components
- Aesthetic and easy to integrate with green areas
- Fits to the edge of a large impermeable surface
- Promotes evaporation and infiltration into the soil

Disadvantages

- Not suitable for areas with steep slopes
- Does not significantly reduce the runoff flow rate in case of extreme rain events
- Not suitable for areas with rapid surface runoff and groundwater contamination risk

Maintenance requirements

- Maintnance of vegetation (removal of invasive species, weeds, dead plants), inspection of filter strip surface to identify evidence of erosion, compaction, ponding, sedimentation and contamination – monthly (at start, then twice a year)
- Removal of litter/debris and cutting of grass – monthly or as required
- Repair measures (repair damage, reseeding, removal of sediment and pollution (e.g. oil residues)) – as required

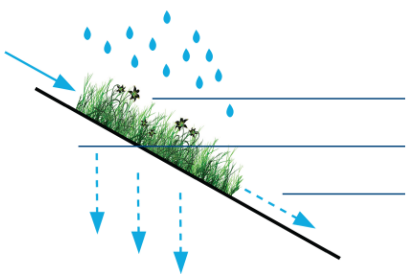
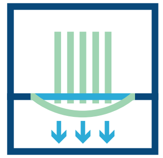


Figure 14. The working principle of a filter strip.



Swale

The swale is a shallow, flat bottomed, vegetated open channel designed **to collect, convey, infiltrate and treat** surface water run-off. Swales consist of filter layers with different water permeability (organic layer with plants, topsoil, sand (gravel) and, if necessary, a drainage pipe). Swales can be permanently or temporarily filled with water. Swales are well suited for draining light traffic roads, driveways or parking lots.

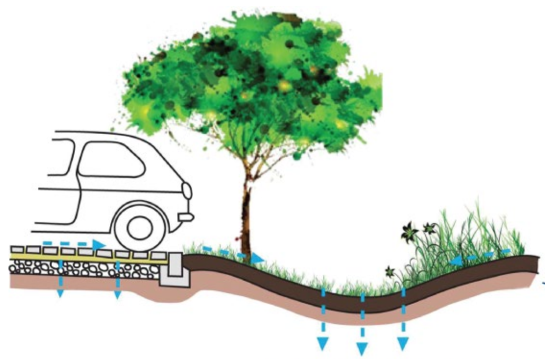


Figure 15. Cross-section of a swale with directions of water flow. When crossing flat slopes, the water flow rate decreases and runoff is even throughout the swale.

Advantages

- Adds greenery to the area and increases biodiversity
- Can be easily fitted in the design of green areas, streets etc
- The need for deep excavation is reduced, which can reduce construction costs
- Removes contaminants from runoff

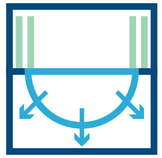
Disadvantages

- In the case of a high sediment content in the surface runoff, a clogging problem can occur
- Small in size, suitable as a local measure
- Not suitable for areas where the groundwater level is higher than 1.8 m from the ground
- Not suitable for slopes of more than 20%

Maintenance requirements

- Maintenance of vegetation (removal of invasive species, weeds, dead plants), inspection of swale surface to identify evidence of erosion, compaction, ponding, sedimentation and contamination – monthly (at start, then twice a year)
- Removal of litter/debris and cutting of grass – monthly or as required
- Repair measures (repair damage, reseeding, removal of sediment and pollution (e.g. oil residues)) – as required

Left: A swale in a green area. Malmö, Sweden. Photo: Gen Mandre.
Right: A swale on the edge of the parking lot. Copenhagen, Denmark. Photo: Gen Mandre.



Pond

A pond is a body of water permanently filled with water, the water level of which rises with higher rainfall. Ponds help to **reduce the risk of flooding, purify water** (through sedimentation, micro-organisms and vegetation)**, diversify urban space and support biodiversity.**

Left: A pond on the territory of the apartment association. Malmö, Sweden. Photo: Gen Mandre.
Right: A pond in a public park. Vantaa, Finland. Photo: Sandra Oisalu.

Advantages

- Cleans water of contaminants
- Adds value to the plot
- High aesthetic, ecological and attractive potential
- An acceptable solution for communities
- Cooling effect of ponds (e.g. during a heat wave)
- Water reservoir (e.g. irrigation water, fire water)
- Ice rink in winter

Disadvantages

- Does not significantly reduce the volume of runoff
- Health and safety considerations may lead to the fencing of the pond
- Not suitable for steeply sloping areas
- Anaerobic conditions can occur without regular inflow
- Invasive species may increase the need for maintenance

Maintenance requirements

- Inspection of water quality – monthly
- Removal of litter/debris, cutting of grass – monthly or as required
- Maintenance of other vegetation, removal of invasive species and weeds, inspection to identify erosion, damages, blockages – monthly (at start, then half yearly)
- Removal of sediment from the shores and bottom of the pond – approximately every five years
- Damage repair – as required

Constructed wetland

Constructed wetlands are artificially created wetland ecosystems to treat stormwater (and waste water). The treatment takes place through **physico-chemical and biological processes such as sedimentation, precipitation, uptake by plants and microbial degradation.** Constructed wetlands must always be the last element in a sustainable urban drainage system, otherwise there is a high risk of excessive siltation. Wetlands remove sediment, heavy metals and dissolved nutrients from surface runoff. In addition to water treatment, they are also attractive landscape features that support biodiversity, provide educational opportunities and can be successfully integrated into the urban environment.

There are two types of constructed wetlands:

- **Open water constructed wetland** – a shallow pond filled with aquatic plants (e.g. reed, cattail), which is suitable for the treatment of less polluted surface runoff, for example in residential areas.
- **Soil/vegetation filter** – a cavity about 1 meter deep, separated by a waterproof layer and filled with filter material (coarse sand, gravel, etc.), where the common reed grows.

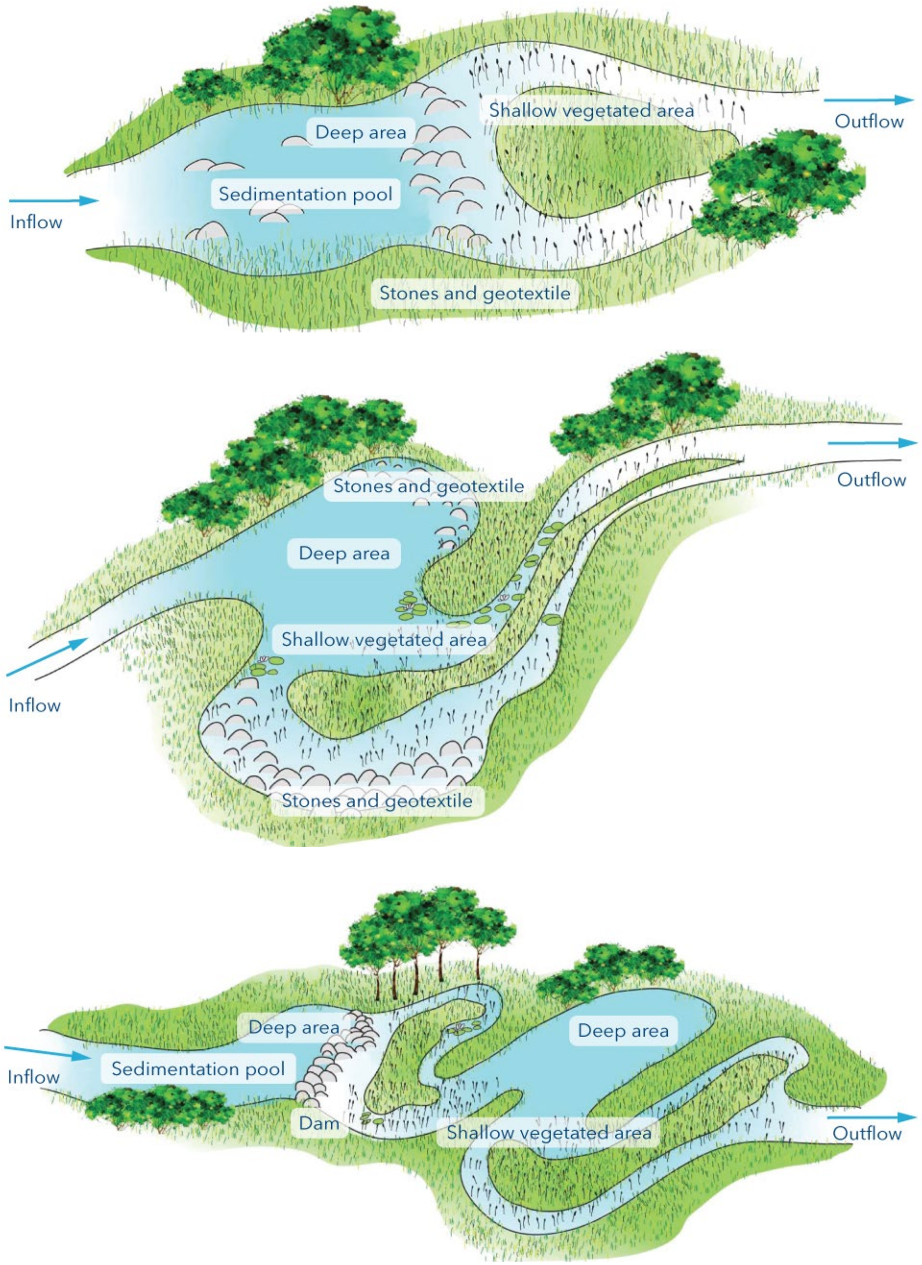


Figure 16. Examples of wetlands with flow retarding elements, deeper and shallower sections.

Advantages

- Withstand the fluctuating hydraulic and pollution loads characteristic of surface runoff, which is a problem in conventional treatment plants
- Open water constructed wetlands effectively purify water of organic matter and nitrogen
- In addition to organic matter and nitrogen, soil/vegetation filters also remove phosphorus and persistent organic pollutants from water effectively
- Partially built with local resources (sand, gravel, local labor)
- Enhance local biodiversity and landscape diversity and can be part of the overall landscape design
- Are based on natural cleansing processes and acting as eco-systems; they have lower energy consumption than conventional wastewater treatment systems and can be considered as ecological treatment systems
- Constructed wetlands generally have lower maintenance costs than conventional treatment systems

Disadvantages

- Need a relatively large area
- The treatment result is not always well controllable, the residence time is long and the treatment performance cannot be changed quickly
- Constructed wetlands are sensitive to overload, especially in cold climates
- Can become a secondary source of pollution as a result of overload and poor maintenance
- Invasive species may increase the need for maintenance
- Not suitable for steeply sloping areas

Maintenance requirements

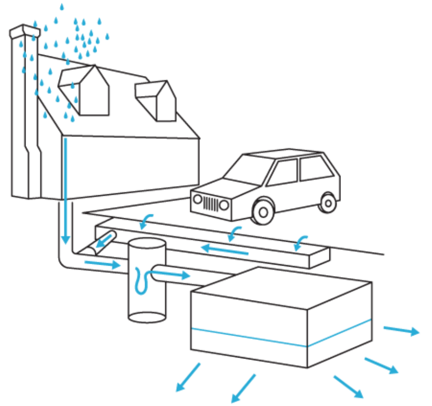
- Inspection of water quality – monthly
- Removal of litter/debris, cutting of grass – monthly or as required
- Maintenance of other vegetation, removal of invasive species and weeds, inspection to identify erosion, damages, blockages – monthly (at start, then half yearly)
- Removal of sediment from the shores and bottom of the wetland – approximately every five years
- Damage repair – as required

Viikki Säynäslahdenpuro stormwater wetland. Helsinki, Finland. Photo: Jolanda Lipu.

Wetland park. Nummela, Finland. Photo: Sandra Oisalu.

Soakaway

Soakaway is an excavation that is filled with a void-forming material that allows **the temporary storage of water before it soaks slowly into the ground.** Soakaways help prevent puddles, treat runoff and recharge groundwater. Soakaways can be used, for example, under playgrounds, recreation areas, sports grounds or parking lots, or on the roadsides.



Left: Building a soakaway. Photo: Pipelife Eesti AS.
Right: Figure 17. Working principle of an underground soakaway. This solution is well suited to the urban environment to prevent the formation of puddles on impermeable surfaces. Rainwater is routed through pipes and a septic tank to the soakaway, where it can infiltrate into the soil.

Advantages

- Significantly reduces the volume and flow rate of surface runoff
- Takes up little space on the ground and allows the land to be used for other purposes
- Recharges ground water
- An acceptable solution for communities
- Easy to integrate to the existing environment

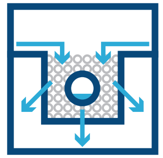
Disadvantages

- Not suitable for soils with low infiltration capacity
- The suitability of the soil must be tested by a geological survey
- Not suitable in case of contaminated surface runoff due to low treatment capacity
- Over time, the performance may decrease, and infiltration capacity may decrease with heavy rainfall
- Difficult accessibility in case of problems

Maintenance requirements

- Removal of litter/debris, management of vegetation (incl. removal of invasive species and weeds), removal of sediment and debris from pre-treatment components, health check of the soakaway (incl. inlets and outlets, ventilation openings, overflows) – monthly
- Damage repair – as required
- Inspection of accumulated sediment and removal if necessary – once every five years

An example of a Pipelife Stormbox infiltration module that increases the capacity of an underground soakaway. High-porosity plastic modules can be used to build a temporary rainwater collection tank (by assembling the required number of modules and enclosing the structure with geotextile or geomembrane). Photo: Pipelife Eesti AS.



Infiltration trench

Infiltration trench is a shallow excavation filled with gravel or other porous material that allows **the temporary storage of water before it soaks into the ground.** If necessary, a drainage pipe is installed inside the porous material. The infiltration trench significantly reduces the volume and flow rate of surface runoff and purifies the water, but does require regular maintenance to prevent clogging.

Infiltration trench separating the road and sidewalks. Copenhagen, Denmark. Photo: Gen Mandre.

Advantages

- Significantly decreases the volume and flow rate of surface runoff
- Reduces the amount of pollution entering the natural water body
- Easy to integrate with landscaping, fits well on the edges of the road

Disadvantages

- The risk of clogging is difficult to detect
- Risk of clogging if the surrounding areas are not properly maintained
- Suitable only for small catchments
- Problems often occur due to poor maintenance, inappropriate location, or high pollution (debris)

Maintenance requirements

- Removal of litter/debris, inspection of inlets and outlets, removal of blockages – monthly
- Inspection of upstream components and removal of sediment if necessary – half yearly
- In places with a high pollution load, replacement of the geotextile and replacement or washing of the top filter layer – once every five years

Infiltration basin

Infiltration basin is a flat-bottomed, shallow landscape depression used **for infiltration and treatment of stormwater runoff.** As a precautionary measure, it is advisable to create an overflow to convey excess water to the downstream component of the stormwater system. As a large area, the infiltration basin allows a large amount of rainwater to be treated at the same time, but contaminated water must be prevented from entering groundwater (in some cases, pre-treatment may be necessary before infiltration).

Infiltration basins can be used in dry weather, for example as playgrounds or recreation areas, but their **temporary flooding must be taken into account.** By landscaping them with trees, shrubs and other plants that can withstand temporary floods, pleasant recreation areas for people and also habitats for wildlife can be created.

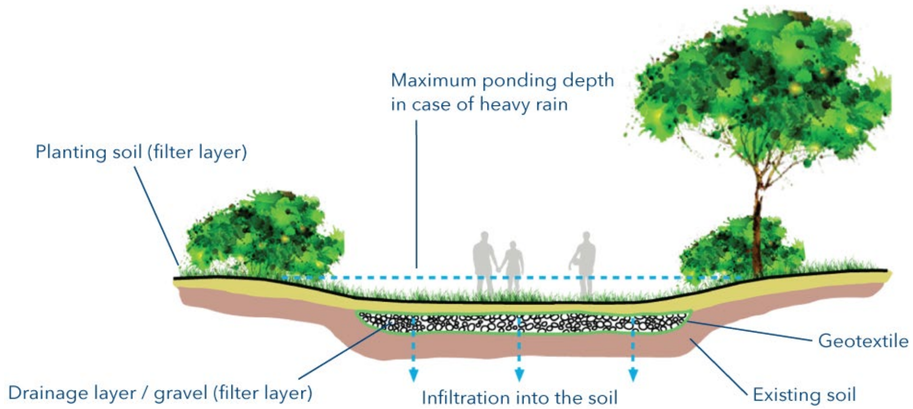


Figure 18. Cross-section of an infiltration basin.

Infiltration basin in urban environment. Copenhagen, Denmark.
Photo: Copenhagen City Council.

Infiltration basin in a playground. Helsinki, Finland. Photo: Gen Mandre.

Advantages

- Reduces the volume of surface runoff
- Effectively removes pollutants by filtering water through the soil
- Recharges ground water
- Easy and affordable to build
- Easy to monitor performance
- Temporary storage and detention of runoff

Disadvantages

- High risk of failure due to inappropriate location, poor design or insufficient pre-treatment of runoff
- Geological survey must confirm the suitability of the soil type for infiltration
- Not suitable in case of highly contaminated runoff
- Covers a large area

Maintenance requirements

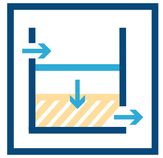
- Removal of litter, inspection of inlets and outlets and clearing if needed, inspection of physical damage – monthly
- Inspection of sediment accumulation and removal if needed – annually
- Cutting of grass, maintenance of vegetation (replacement of dead plants, pruning trees and bushes), repairing erosion and other damage – as required

Conventional stormwater management techniques to be combined with SUDS

The following treatment devices and stormwater pipes can be successfully combined with the sustainable drainage techniques described above.

Standard traditional stormwater management techniques to be combined with SUDS:

- Sand filter
- Silt trap and oil separator
- Stormwater pipes



Sand filter

A sand filter is a stormwater treatment device where sand is used as a filter. The sand filter **removes various sediments and suspended solids from water and reduces water turbidity.**

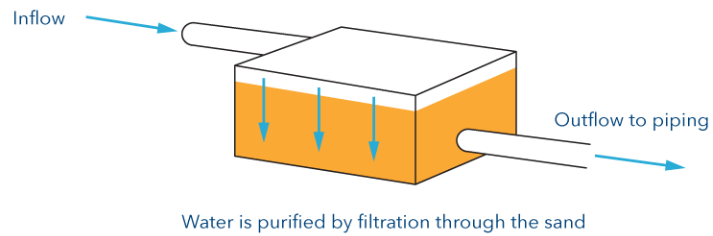


Figure 19. Working principle of a sand filter.

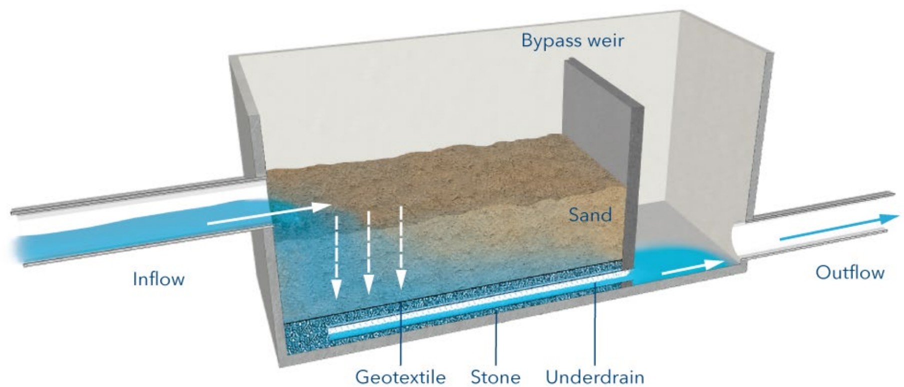


Figure 20. Working principle of a sand filter. Source: Philadelphia Water.

Maintenance requirements

- Removal of debris from the catchment area, removal of sediment from upstream components of the system, maintenance of vegetation, removal of weeds and invasive vegetation – monthly or as required
- Inspection of the operation of grate sewers and inlets and outlets – monthly
- Inspection of the sediment accumulated in the tank and removal if necessary – monthly
- Peeling the top layer of filter sand – annually
- Removal of settled oil – annually or when the filter is half full
- Replacement of sand in the filte – as required

Silt trap and oil separator

Silt traps remove sand and mud from water. Oil separators are designed to treat wastewater and stormwater containing oil products. The main areas of use are parking lots, roads, industrial plants, petrol stations, car washes, repair shops, warehouses, etc.

According to Eurostandard EN 858, **the treatment of oily wastewater begins with the settling of heavier particles in the water in a silt trap**, which is installed in front of the oil separator or built into its housing. A sampling well with a rotary valve for sampling sewage is installed after the oil separator. Closing the rotary valve prevents water from escaping from the device in the event of oily or impermissible water.

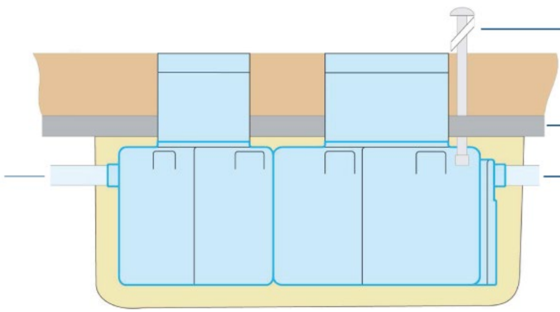


Figure 21. Oil separator. Source: Keskkond & Partnerid OÜ.

Installation of oil separator and silt trap. Haabneeme, Viimsi. Photo Alar Mik.

Maintenance requirements

- Emptying the oil separator as required or annually (fill with water after cleaning). It is a good idea to keep a maintenance log for this device
- Inspection of coalisator filters – quarterly
- Emptying the silt trap – at least three times a year

Stormwater pipes

The SN8 stormwater pipe for self-flowing systems is usually used to **direct rainwater into wells or artificial recipient.** The ideal choice is a double-walled polypropylene pipe, the corrugated outer surface of which ensures the mechanical strength and impact resistance of the pipe. The surface of the inner layer of the pipe is smooth, which ensures excellent performance of the self-flowing system. Due to the design features, these pipes are lighter and at the same time stronger than ordinary smooth-walled pipes. Polypropylene pipes are more durable and have better temperature resistance than PVC pipes, and in addition, polypropylene is a 100% recyclable material.

The stormwater piping **must be functioning also in winter.** A sufficient installation depth is usually 0.8–1 m. In a place where there is a risk of frost, the pipes are covered with insulation boards so that the heat coming from below protects the pipes and the surrounding soil from freezing.

Stormwater pipes. Photo: Alar Mik.

Maintenance requirements

- Removal of debris from the bottom of the rainwater well – monthly
- Check for blockages – quarterly
- Removal of sludge accumulated in the well sediment tank and removal of blockages by pressure washing – as required

Capability of different SUDS techniques

L Low space requirement
M Medium space requirement
H High space requirement

● High/primary process
○ Some options, subject to design

Technique	Space requirement	Management Train Suitability						Benefits: Runoff volume control			
		Prevention/site management	Conveyance	Pre-treatment	Source control	Site control	Regional control	Conveyance	Detention	Infiltration	Water harvesting
Green roof	L	●		●	●				●		
Green wall	L				●				●		
Rainwater harvesting	L	●	○		●			○	○	●	○
Pervious pavement	L	●			●	○			●	●	○
Stormwater planter	L/M				●	●			●	●	
Rain garden	L/M				●	●			●	●	
Detention basin	L/M				●	●			●	●	
Infiltration trench	L/M		●		●	○		●	●		
Filler strip	L/M			●	●			○	○	○	

Technique	Benefits: Water quality treatment							Social and environmental benefits	
	Sedimentation	Filtration	Adsorbtion	Biodegration	Precipitation	Uptake by plants	Nitrification	Amenity	Biodiversity and habitat
Green roof		●	●	●	●	●	●	○	●
Green wall		●			●			●	●
Rainwater harvesting	○	○	○	○	○	○	○	○	○
Pervious pavement	●	●	●	●				○	○
Stormwater planter	●	●	●	●	●	●	●	●	●
Rain garden	●	●	●	●	●	●	●	●	●
Detention basin	●	●	●	●	●	●	●	●	●
Infiltration trench		●	●	●					
Filler strip	●	●	●	●				○	○

Technique	Space requirement	Management Train Suitability						Benefits			
								Runoff volume control			
		Prevention/site management	Conveyance	Pre-treatment	Source control	Site control	Regional control	Conveyance	Detention	Infiltration	Water harvesting
Swale	M		●		●	●		●	●	○	
Pond	H					●	●		●	○	●
Wetland	H		○			●	●	○	●	○	●
Soakaway	L				●					●	
Infiltration trench	L/M		○		●	●		○	●	●	
Infiltration basin	H					●	●		●	●	
Sand filter	L			●		●	○		●	○	
Silt trap, oil separator	L			●							
Stormwater pipes	L		●			●		●	●		

Technique	Benefits								
	Water quality treatment							Social and environmental benefits	
	Sedimentation	Filtration	Adsorbtion	Biodegration	Precipitation	Uptake by plants	Nitrification	Amenity	Biodiversity and habitat
Swale	●	●	●	●		○		○	○
Pond	●	●	●	●	●	●	●	●	●
Wetland	●	●	●	●	●	●	●	●	●
Soakaway		●	●	●					
Infiltration trench		●	●	●					
Infiltration basin		●	●	●				○	○
Sand filter		●	●	●	●				
Silt trap, oil separator	●								
Stormwater pipes	○	○							

Source: CIRIA publications: The SUDS Manual. 2007.

Further information

- Web page of the project “LIFE UrbanStorm”.
  urbanstorm.viimsivald.ee
- The SuDS Manual. CIRIA, 2015.
  www.ciria.org > Bookshop > Free publications.
- Website about SUDS created by CIRIA.
  www.susdrain.org
- Information about SUDS in Denmark.
  www.wsud-denmark.com
- SUDS in Tåsinge Square, Copenhagen (Denmark).
  www.klimakvarter.dk/en/projekt/tasinge-plads
- SUDS in Västra Hamnen district, Malmö (Sweden).
  www.balticurbanlab.eu > Good Practices > Västra Hamnen area.
- Scandinavian Green Roof Institute.
  www.greenroof.se/en
- Report about the Eco-city Augustenborg (Malmö, Sweden).
  www.greenroof.se/wp-content/uploads/anthology.pdf
- Website of the project “Integrated Stormwater Management (iWater)“.
  www.integratedstormwater.eu

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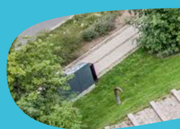

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