

## Rainwater infiltration

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Where rainwater collection and reuse is not feasible at a certain location, rainwater infiltration for artificial groundwater recharge should be considered as a stormwater management option second to rainwater harvesting. Rainwater infiltration is an approach to surface water drainage, which aims to utilise rainwater as a water supply, recharge groundwater, increase base-flow levels of nearby streams, reduce flood risk and control pollution. The objective is to retain water on site and where possible, clean it and make it available for reuse.

Infiltration is the most effective means of controlling stormwater runoff since it reduces the volume discharged to receiving waters and the negative impacts associated with it. Infiltration is also an important mechanism for pollutant control. As runoff infiltrates into the ground, particulates and contaminants such as metals and nutrients are removed by filtration through the soil, and dissolved constituents are removed by adsorption.

Infiltration techniques have been used for many years to control stormwater quality and flooding. However, infiltration may not be appropriate at all areas due to dense development, low permeability of soils and/or high groundwater level. Decentralised stormwater infiltration can be an additional and cost-efficient alternative resource to conventional stormwater treatment measures which can be applied on site close to the runoff area.

### Benefits

Rainwater infiltration gives rise to several benefits in relation to water quality, biodiversity and vegetation. The main benefits are:

- reduction of the amount of stormwater discharged into the sewer system;
- recirculation of water back to the natural water cycle.

The combination of rainwater harvesting and rainwater infiltration offers technical benefits and exerts positive effects on the environment and the local water balance. A hydraulic load reduction can minimise hydraulic peak loads in the sewer network significantly.

In addition, infiltration of rainwater over a long period can increase and/or stabilise the groundwater reserves.

The main benefits on an individual level are the complete uncoupling from the public sewer. Construction costs will be also reduced if rainwater harvesting and rainwater infiltration systems are planned together in addition to a reduction in the wastewater fees.

### Prerequisites for rainwater infiltration

Several pre-conditions are required for the planning and success of infiltration measures. These include:

- *Groundwater conditions:* the distance to the groundwater and variations in the groundwater levels should be known before any planning is made. It is recommended that the distance to groundwater should be at least 1 - 1.5 m.
- *Soil type and conditions:* the effective porosity and permeability of the soil will influence the infiltration process. Infiltration rates should lie within  $1 \times 10^{-3}$  and  $1 \times 10^{-6}$  m/s. In addition, the bedrock should not be at less than 1.2 m below the infiltration surface.
- *Vegetative cover:* the topsoil layer covered with vegetation (30 cm) will positively influence the infiltration process. During infiltration, rainwater is absorbed by plant roots and is returned back partly to the atmosphere via evapo-transpiration. In addition, the soil-vegetation complex functions as a filter, which reduces surface clogging of the soil.
- *Distance to buildings:* based on the local conditions, it is recommended that a distance to buildings of at least 6 m should be held in order to avoid any negative impacts on the building foundation.

The infiltration rate defines the amount of water that is infiltrated into the ground. Soil permeability and flow conditions particularly limit the amount of rainwater that can be soaked up by the ground. A soil hydraulic conductivity in the range of  $10^{-6}$  to  $10^{-3}$  m/s is generally considered appropriate to achieve reasonable infiltration rates. For long-term infiltration a fall-off due to gradual clogging of the soil must be taken into account. The table below shows the infiltration capacity of different soils.

Soil type	Hydraulic conductivity K (m/s)
Gravel	$10^{-3} - 10^{-1}$
Sand	$10^{-5} - 10^{-2}$
Silt	$10^{-9} - 10^{-5}$
Clay (saturated)	$< 10^{-9}$

### Infiltration technologies

Infiltration systems are designed to capture a volume of stormwater and infiltrate this water into the ground over a period of several hours or even days. Different types of systems can be employed which retain water safely on site including: pervious pavements (e.g. permeable car parks), infiltration basins, vegetated swales, ponds and wetlands and green roofs.

However, no single system can address all stormwater problems and each has certain limitations based on the drainage area served, available land space, costs, pollutant removal efficiency as well as a variety of site-specific factors such as type of soil, slope, depth of groundwater table, etc. Therefore, careful consideration of these factors is necessary in order to select the appropriate technology.

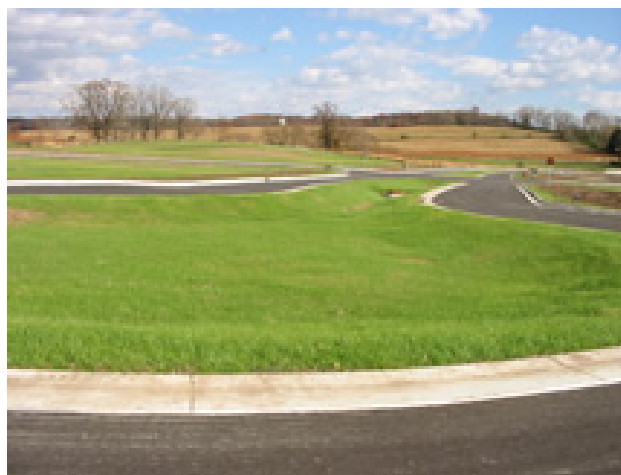
Regardless of the type, stormwater technologies are most effective when implemented as part of a comprehensive stormwater management plan, which includes proper selection, design, construction, inspection and maintenance.

With infiltration systems, one distinguishes between detention and retention systems. While detention systems provide a temporary storage of runoff for subsequent release, retention systems retain stormwater without subsequent surface discharge. In Germany, detention systems are most commonly employed for rainwater infiltration. These include infiltration basins, porous pavement systems and infiltration trenches (trough-trench systems).

### **Infiltration basins**

Infiltration basins (Figure 1) are shallow impoundments designed to capture stormwater runoff, hold this volume and infiltrate it into the ground over a period of days. They provide temporary storage for stormwater, reduce peak flows to receiving waters and allow water to infiltrate directly into the ground. Infiltration basins exhibit a high pollutant removal rate through mechanisms such as filtration, adsorption and biodegradation as the water percolates through the underlying soil.

Infiltration basins may or may not be lined with plants. Vegetated systems are advantageous in that they prevent migration of pollutants and increase the permeability of the soils, thus increasing the infiltration efficiency.



**Fig. 1: An infiltration basin (Source: Schueler, 1987).**

## Infiltration trenches

An infiltration trench (Figure 2) is a long, narrow gravel-filled trench designed to infiltrate stormwater into the ground. Runoff is stored in the void space between the gravel and infiltrates through the bottom and into the soil matrix. Infiltration trenches typically capture a small amount of runoff and therefore may be designed to capture the first flush of a runoff event. They are frequently used in combination with another measure such as a detention basin to control peak hydraulic loads. Infiltration trenches efficiently remove suspended solids, particulates, bacteria, organics and soluble nutrients.



**Fig. 2: An infiltration trench.**

## Vegetated swales

Swales are broad, shallow channels with a dense stand of vegetation designed to convey stormwater runoff. Vegetated swales can be applied for infiltration of low-polluted runoffs from roof surfaces as well as for more polluted stormwater from courtyards and traffic surfaces in new development and redevelopment areas. They are widely applicable as they can be well integrated in open space. Compared to a conventional ditch, a swale is shallow and relatively wide, providing temporary storage, conveyance, treatment and the possibility of infiltration under suitable conditions.

There are very few limitations on the use of vegetated swales. They should not be used in steep slope areas and may be difficult to place in urban settings due to space requirements. Otherwise, they can be adapted for use in most residential, commercial and industrial land development projects.



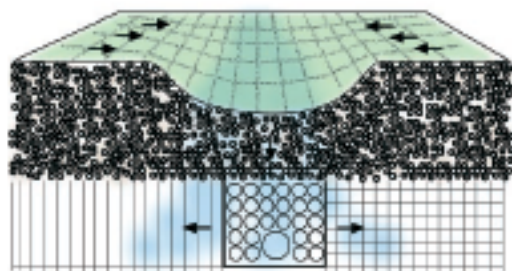
**Fig. 3: A vegetated swale.**

### **Trough-trench systems**

The application of the so-called 'Trough-Trench-System' (in German: Mulden-Rigolen-System) is being currently widely introduced in Germany. This concept is based on the compensation of the increased flow volumes as close as possible to the generated runoff, i.e. at the individual properties or at the edge of the transport network, thus reducing the rainwater runoff flow to a minimum.

The trough-trench system is a combination of surface infiltration in a trough and subsurface percolation from a gravel-filled trench. This system has two important characteristics. First of all, the topsoil between the trough and the trench filters and purifies the infiltrating stormwater. Secondly, the trough is provided with a drain at the bottom. This technology makes possible the discharge of rainwater, in addition to infiltration and decentralised temporary storage. Runoff delay is achieved through a short-term storage in the vegetated trough and long-term storage in the trench.





**Fig. 4: A trough-trench system (Behörde für Stadtentwicklung und Umwelt, Hamburg).**

### **Operation and maintenance**

Generally, operation and maintenance of stormwater infiltration systems depend on the type of technology applied, on the characteristics of the soil or material used as infiltration medium and on the degree of pollution of the infiltrated water.

Clogging effects also play a significant role for the maintenance of infiltration structures. Depending on the particle size of the soil material, the functioning of the structure can be limited. After a certain operation period, the exchange of filtration material (gravel, sand, etc.) becomes necessary. Stagnant water and/or permanent overflows from troughs are good indicators for declining infiltration rates which makes maintenance measures necessary.

With regard to the 'trough-trench-systems' only some maintenance work is necessary, such as the removal of foliage to avoid permanent impoundment of water. Contrary to central basins, these decentralised infiltration troughs are characterised by a significantly lower load per surface area, which further reduces the risk of clogging and the maintenance expenditure.

### **Costs**

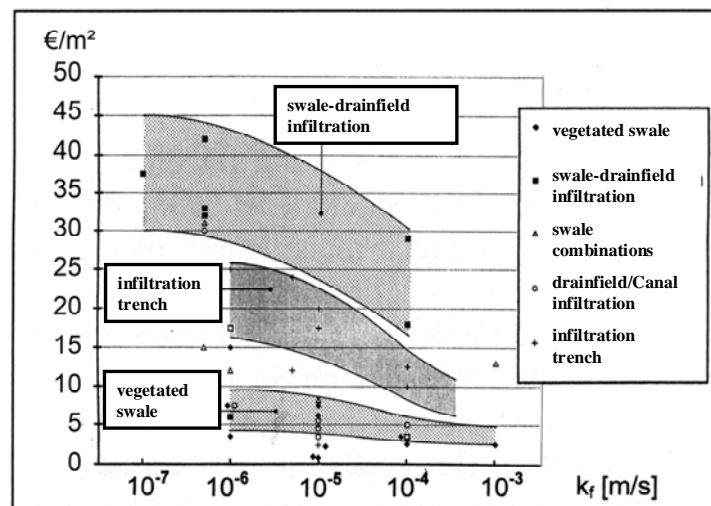
Structural measures that aim at rainwater infiltration are generally cost-intensive. The planning process for decentralised concepts is rather costly since many factors have to be taken into account.

Governments, and federal states in some European countries, such as Germany, support and promote the implementation of infiltration measures. Legislation provides a legal basis, and a specific charge strategy encourages property owners to implement infiltration measures. However, no general guideline is available that regulates issues regarding cost coverage.

The costs for an infiltration technology mainly depend on the type of technology and the proper design. Figure 5 shows the dependency of the construction costs from the soil infiltration coefficient ( $K_f$ ), as is the case in Germany. The cost/m<sup>2</sup> corresponds to

the relevant area, which drains into the infiltration structure, for example, a vegetated swale, and not to the whole area of the swale.

As an example, if a 1,000 m<sup>2</sup> surface collection area with a runoff coefficient of 30% is connected to the infiltration system, the system has to be designed based on the amount of stormwater collected from a surface area of only 300 m<sup>2</sup>. With a cost of 10 €/m<sup>2</sup> (Figure 5), the construction of a vegetated swale with a 1,000 m<sup>2</sup> surface area will entail total capital costs of about 3,000 €.



**Fig. 5: Dependency of the construction costs from the infiltration coefficient ( $K_f$ ) in Germany (modified after Londong & Nothnagel, 1999).**

### Advantages and disadvantages

Compared to classical methods (end-of-pipe solutions), which aim at the disposal of stormwater as soon as possible and reducing emissions of pollutants, decentralised concepts including stormwater infiltration systems represent a more sustainable solution. However, prompt benefits are hardly visible and rather play a role in the long-term run (e.g. influence on the groundwater level).

General advantages of decentralised stormwater infiltration systems include:

- increased natural groundwater recharge
- reduction of flood risk in sewers and receiving waters
- purification of the stormwater as a result of the filtration characteristics of the soil layer
- costs are 'decentralised' and investments can in part be shifted to the future.

On the other hand, there are also certain drawbacks that cannot be neglected. These include:

- infiltration may not be appropriate in areas where groundwater is a primary source of drinking water due to the potential of contaminant migration
- potential of infiltration is limited in areas with poorly permeable soils

- reduced infiltrative capacity and even clogging may be encountered due to sediment accumulation necessitating frequent maintenance
- possible superstructure damage due to the presence of water in the ground.

Frequent maintenance checks help minimise the last two risk potentials.

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