Project: Sustainable Hydro Assessments and Groundwater Recharge Projects
Project acronym: SHARP

Lead partner: WATERPOOL Competence Network GmbH
Elisabethstraße 18/II, 8010 Graz, Austria
www.sharp-water.eu

APPENDIX: Long version of good practices

GP 14	**Stormwater management – Sustainable precipitation management concepts to save water quality and quantity**

Project Partner:
Saxon State Office for the Environment, Agriculture and Geology (LfULG)

C. NIEMAND & C. GLÖCKNER

1. Introduction Into Decentralised Stormwater Management

Good Practice

In Germany, methods and measures for decentralised stormwater management are considered to be a Good Practice for sustainable groundwater management. The basic idea is that water as a vital resource should be carefully handled and spared in terms of sustainable resource management. Especially at the present time where the projected climate change is expected to increase the frequency of extreme meteorological events like large storms or drought periods, it is desirable to use the latest state of the art and the most recent findings of scientific research to counteract the negative impacts. One of the major challenges in this context is to lessen the impacts on the natural water balance.

In contrast with centralised sewage systems of cities and municipalities, the decentralised stormwater management is a both economically and ecologically appropriate alternative (Sieker at al. 2009). The purpose is to maintain the natural water balance to the largest possible extent and ensure safe drainage. As drinking water is often used for homework where no drinking water quality would be needed (irrigation, washing laundry,…), several geographic areas face already reduced availability of drinking water. So it is urgently required to retain precipitation water for judicious use in households and businesses to bring down the peak demand for drinking water and reduce the groundwater extraction especially during dry periods. In present times, site developers therefore take care to implement stormwater management measures in new residential and industrial estates. A decentralised solution needs to blend into the prevailing framework conditions and should especially combine a series of mutually supporting methods (e.g. green roofs, stormwater storage, stormwater uses, and infiltration systems). The following outlines the methods and their application potential.

General/legal aspects

In Germany, stormwater discharge and stormwater infiltration are regulated by the water law. The federal German Water Resources Act (WHG) defines wastewater as including collected stormwater running off built-up and paved surface areas. Wastewater disposal is a municipal obligation in all federal states (Länder) and includes the removal of rainwater. Section 55 of the Water Resources Act (§ 55 WHG) requires stormwater to be removed by intermittent infiltration, broad irrigation or discharge into a receiving water body. This requirement is based on the premise that the natural water balance should be changed as little as possible. However, the groundwater balance is largely disturbed especially by sealed urban areas. Local stormwater infiltration measures are intended to counteract these effects of urbanisation and to restore a good water balance. Many municipalities and communities provide their citizens with guidelines on near-natural rainwater management practices, so does the City of Dresden (How To Manage Rainwater – Practice Guide by the Environmental Office of Dresden).

In cases where the intended infiltration of stormwater into the groundwater system is considered to be a use of groundwater, a permit under the federal German Water Resources Act needs to be obtained. So a permit is mandatory for the use of technical installations in stormwater infiltration. However, stormwater infiltration by landscaped features (infiltration swales and strips) is a near-natural process requiring no special permit.

2. General background

Introduction into water balance changes from urban areas

Before discussing stormwater management methods, benefits and problems in more detail, this chapter gives a brief outline of the water balance situation in urban areas and the general approach for the management of wastewater including stormwater.

DIN 4049 defines the water balance as follows: "Determination of volumes of the hydrological cycle in a given area during a given time interval." Figure 1 is a simplified representation of the main components and processes of the water balance in an urban area.

The natural water balance in urban areas is largely influenced by buildings and structures like car parks, infrastructures etc… (cf. section 2.1 of KliWES report) (Figure 1).

The water balance suffers quantitative changes:

- A large portion of the precipitation water cannot infiltrate into the soil or run off in a natural course.
- Infiltration into the soil is reduced.

➢ There is a decrease in groundwater recharge and evaporation.
➢ The soil receives less water from soil water or groundwater storage.
➢ The natural retention capacity of the soil (intermittent discharge) is not fully utilised.
    - → reduced runoff base flow in dry periods (river bed dries up),
    - → increased runoff into water bodies during heavy rainfalls (floods).

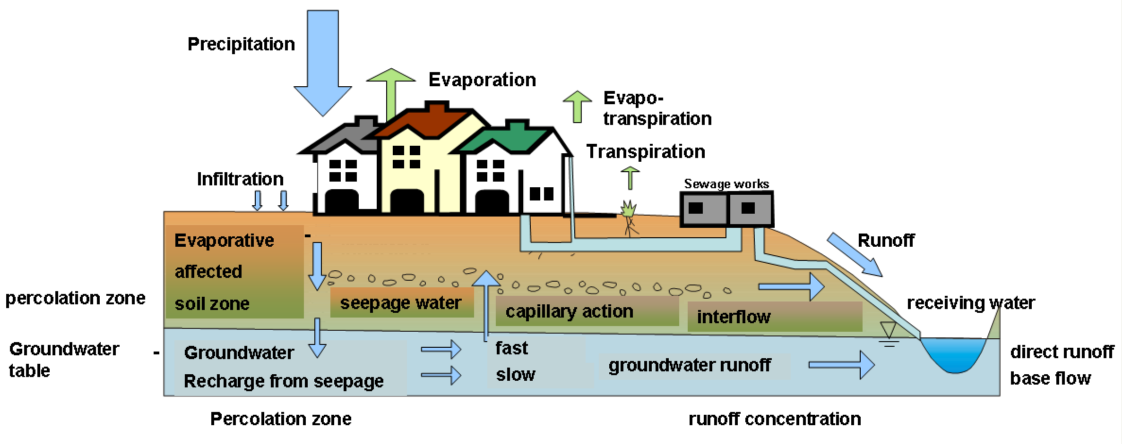

Figure 1: Water balance of urban district / combined sewers (modified on the basis of: Hydrologischer Atlas von Deutschland, BMU 2003 [hydrological atlas of Germany, federal German ministry of the environment]).

When comparing the natural water balance with the urban mean water balance in Germany, there is a clear shift in water balance components (Fig. 2).

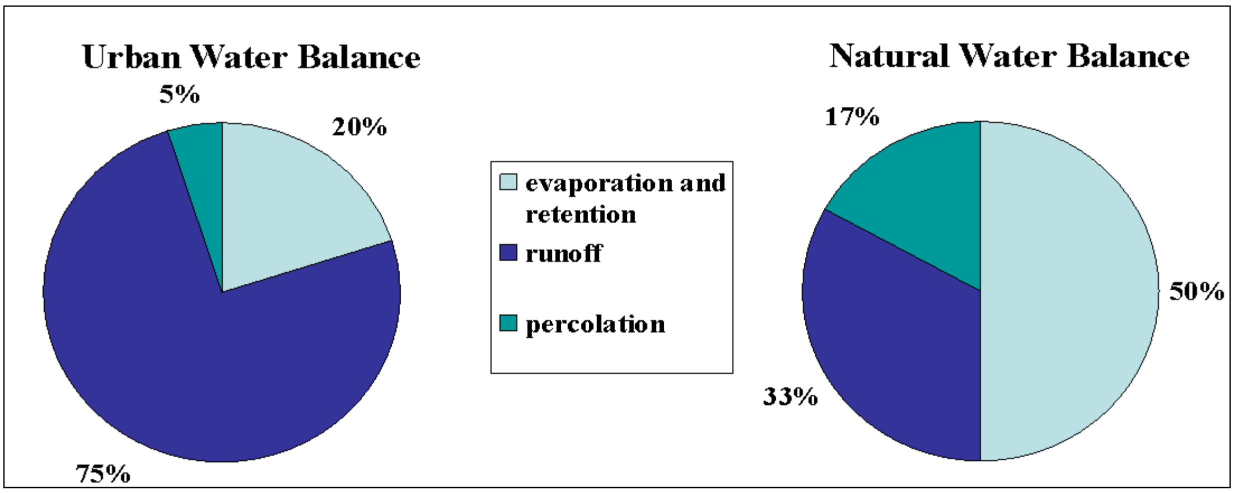

Figure 2: Comparison between the urban and the natural water balance (after Mönninghoff 1993, modified).

Stormwater management

Stormwater is led away as quickly and as completely as possible. There are two main types of stormwater drainage:

- separate from foul water, or
- together with foul water in a combined sewage system.

Both methods are basically the same cost, but have clear benefits and drawbacks.

A combined sewer system needs just one sewer. But the sewage treatment plant needs to be dimensioned larger, because it receives and treats the stormwater along with the foul water. An advantage of combined sewer systems is to remove polluted stormwater flushed off the roads, especially at the beginning of rain events. However, in case of large storms, the sewer system and the sewage treatment plant may be overloaded so that the sewage (both stormwater and foul water) is discharged into the receiving body without any treatment. Especially in the light of increasing urbanisation, the foul water base load tends to become higher and higher and so the combined sewers face a general increase in overflows. To provide for better protection of the receiving water bodies, there is a general trend towards separate storm sewer systems. An additional advantage is that the separate storm sewers can be used to collect and filter and finally infiltrate the stormwater into the soil. Also, this makes a contribution to groundwater recharge.

In contrast with the past, today's preference and support is for decentralised stormwater management solutions. Only contaminated stormwater in need of treatment will be forwarded to the combined sewer system and further to the sewage treatment plant.

3. Stormwater management methods

Green roofs

Green roofs help retain rainwater. They provide water storage room for the natural water balance due to specific rooftop plants growing in an appropriate soil substrate.

Most different rooftop planting approaches can be used, but the basic structure is always the same. Figure 3 is a schematic view of a basic green roof structure.

The root layer is a protective barrier for preventing roofing damage from plant roots. The drainage layer on top of the root layer stores the available water, which is evaporated and consumed by the plants. It is covered by the filter layer and then by the substrate layer. The latter varies according to the needs of the plant species used for the green roof.

A green roof allows for a mean annual rainwater retention of about 50 %. Another positive aspect is the climatic effect on the rooms below the green roof – cooling in summer and warming in winter.

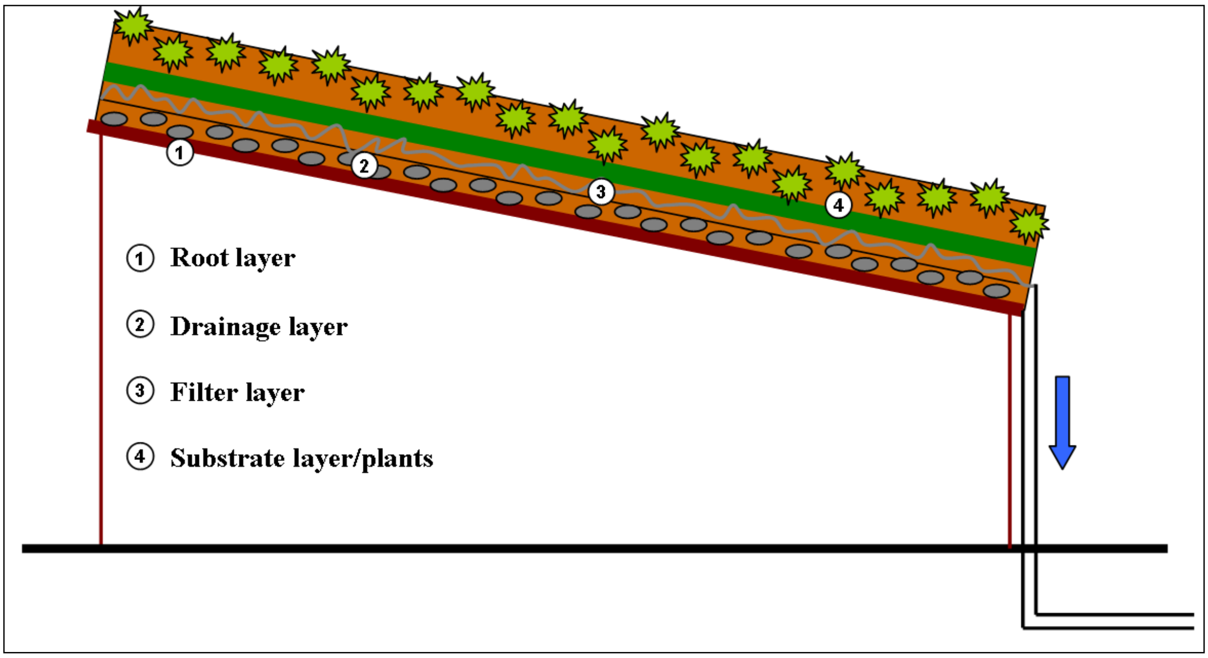

Figure 3: Principle sketch of a green roof.

Stormwater infiltration methods

Filter strips

Vegetated filter strips are the simplest method of near-natural stormwater infiltration. The principle is to direct the stormwater runoff to a readily pervious area for infiltration. This method is used for smaller surfaces, pavements, courtyards, or driveways with low traffic loads. The stormwater from said areas is passed directly, i.e. without any intermediate storage, to adjacent filter strips with a permanent grass or vegetation cover where the water can percolate into the underlying soil. Figure 4 is a schematic representation of a vegetated filter strip.

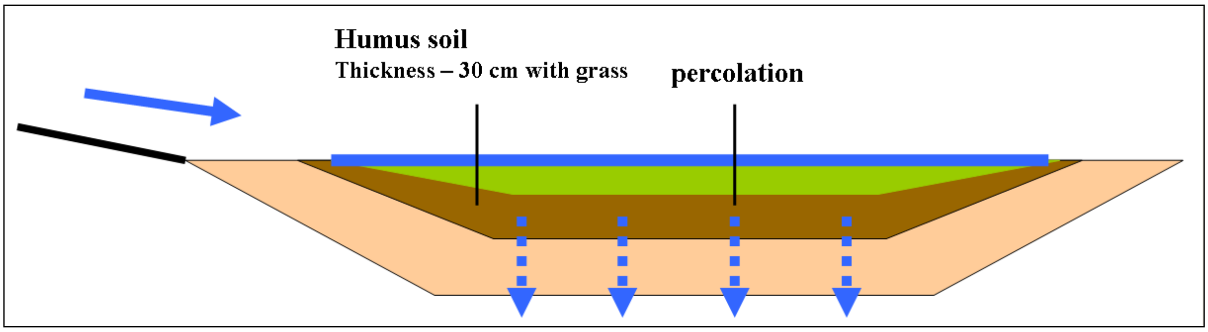

Figure 4: Sketch of principle of a vegetated filter strip.

The basic condition is the availability of open space in sufficient size in relation to the associated impervious area (minimum ratio is 1 : 0.7). The water permeability of the soil should be good to very good (kf > 10-6 m/s) and the depth to groundwater table should be no less than 1 m. Vegetated filter strips are particularly suited for smaller paved areas and traffic zones with low traffic loads.

The infiltration area offered by filters strips can provide a clear increase in evaporation thus having a positive effect on the microclimate. This method relieves the sewer system and can be used to replenish groundwater (depending on the soil) and the stormwater is cleaned while passing through the soil. Such infiltration areas can be sized according to guidelines existing in Germany (e.g. DWA – ATV 138) or to suitable water balance models. The filter strip should be vegetated (grass, shrubs, trees) and properly maintained. The inflow region should be periodically cleaned and protected from contamination or clogging (e. g. by leaves).

Infiltration swales

In contrast with filter strips, infiltration swales (shallow infiltration basins) are designed to temporarily store the water before percolation. Swales are easy to construct. Their ponding depth is low. They consume less space than filter strips. Also, they can be combined with ponds or wet biotopes. Figure 5 is a schematic representation.

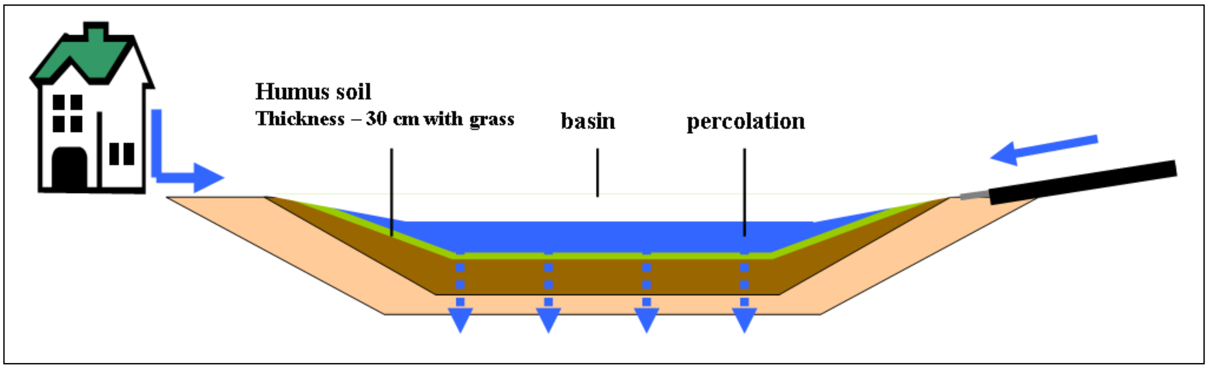

Figure 5: Sketch of principle of an infiltration swale.

The soil under the swale should have a good to very good water permeability (kf > 10-6 m/s) to allow the ponded water to drain within short periods (within one day approximately). Infiltration swales are appropriate for stormwater from roofs, courtyards and traffic zones.

Infiltration swales can increase evaporation thus having a positive effect on the microclimate. This method relieves the sewer system and can be used to replenish groundwater (depending on the soil) and the stormwater is cleaned while passing through the soil. Again, the swales can be sized according to guidelines existing in Germany (e.g. DWA – ATV 138) or to suitable water balance models. The area should be vegetated (grass, shrubs, trees) and properly maintained. The inflow region should be cleaned and protected from contamination or clogging (e.g. by leaves). Swales can be given different depths, depending on the open space available or on the design desired. Recommendable depths are between 20 cm and 30 cm. Again, a depth to groundwater table of more than 1 m is required.

Infiltration trenches, infiltration pipes

For infiltration by trenches and pipes, the stormwater is directed along the surface contour either into an infiltration trench (also known as ditch) filled with gravel or other material (e.g. stone) or underground into a perforated drainage pipe (infiltration pipe) embedded in gravel or other material. Figure 5 is a schematic representation of the general structure. Infiltration trenches are distinguished by the material used for their construction: gravel, lava or plastic trenches. In gravel or lava, the storage volume can be increased by inserting a drainage pipe to form a combined trench-pipe system. Since the percolation level is lower than for filter strips and infiltration swales, the depth to groundwater table must be proportionally high.

The plastics industry offers an increasing number of hollow body elements for infiltration trenches and pipes. The outstanding feature of these elements is their high available storage volume of about 95 %. This reduces excavation needs and thus space requirements. The industry offers elements that can also be installed under traffic areas.

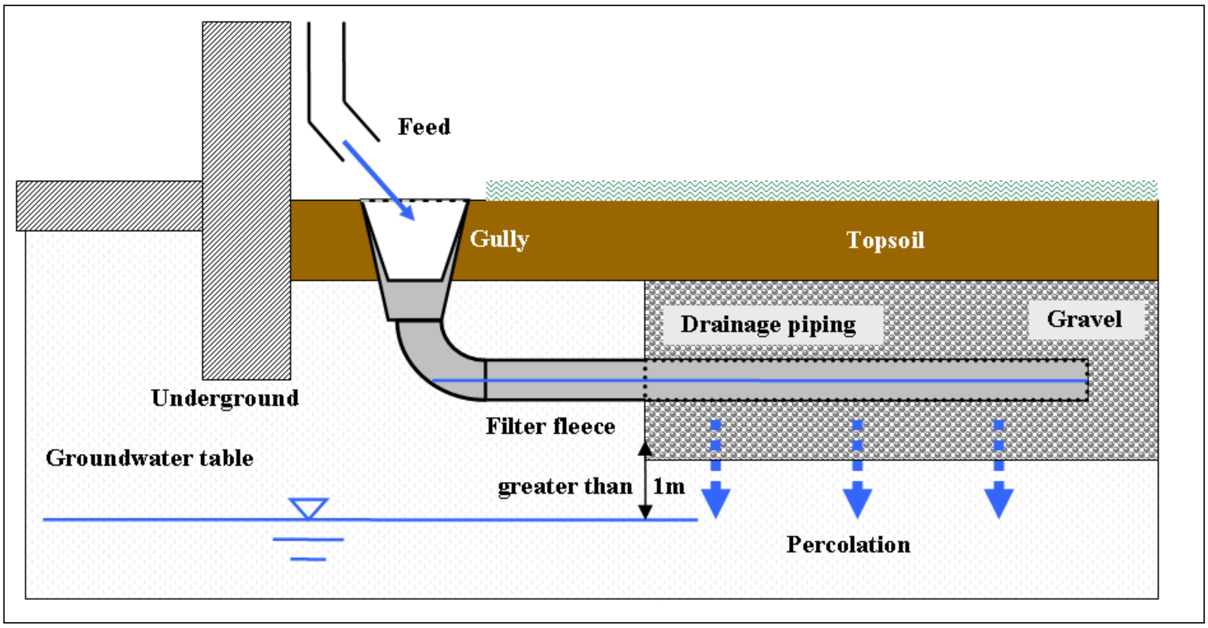

Figure 6: Sketch of principle of infiltration trenches.

There is no evaporation of water. This method relieves the sewer system and can be used to replenish groundwater (depending on the soil).

<u>Infiltration swale-trench systems</u>

Quite often, exclusive swale infiltration is not feasible because there is not enough open space available in urbanised areas. In such case, a combined infiltration swale-trench system may be appropriate (Figure 7.). Stormwater is directed along the surface contour to the swale. The subsurface trench increases the intermediate storage volume thereby ensuring that the swale is not ponded for an excessive period and remains permanently operative. The infiltration swale-trench system is a suitable method in an urban environment with reduced open space availability or for soils having just moderate water permeability values (k_f < 1*10-6 m/s).

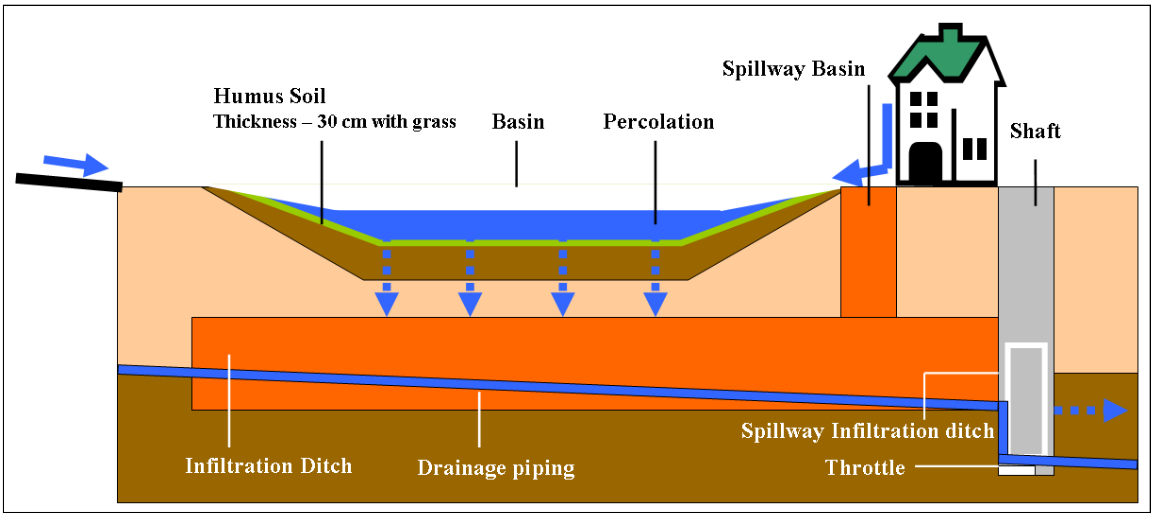

Figure 7: Sketch of principle of combined infiltration swale-trench system.

Soakaway manhole system

In contrast e.g. with infiltration strips or swales, a soakaway manhole is an underground structure with no vegetative soil layer. The construction of a soakaway manhole is subject to authorisation under the water law. In the interest of groundwater protection, manholes should be used only where other methods are not feasible.

The soakaway manhole collects and stores stormwater under ground. The walls of the soakaway manhole, which are mostly made up of concrete rings, allow stormwater to flow into the manhole. Figure 8 illustrates the manhole structure.

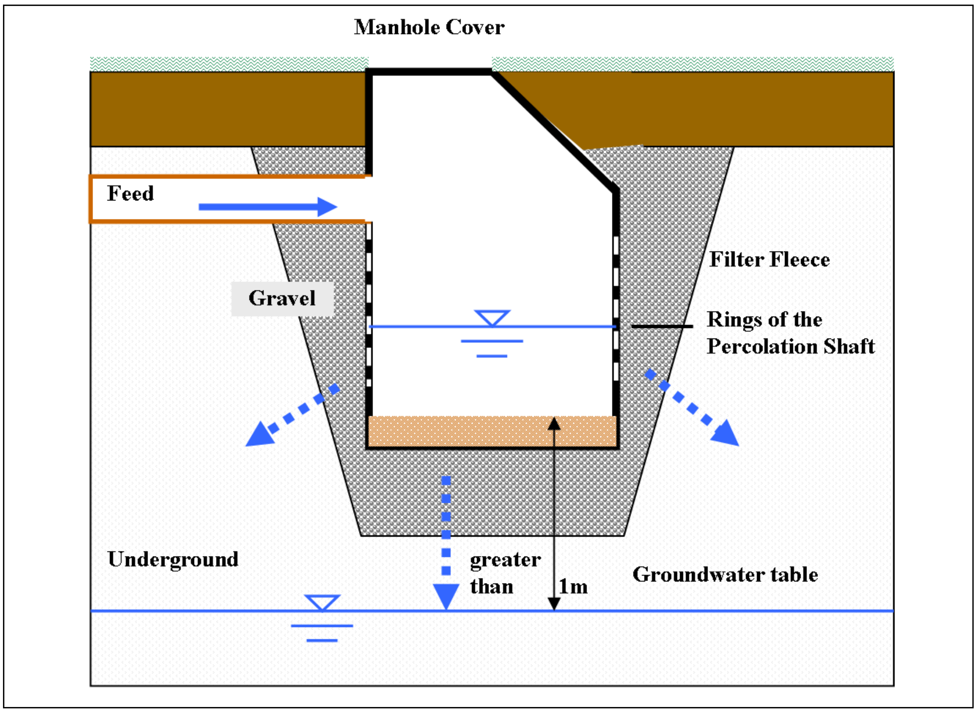

Figure 8: Sketch of principle of infiltration manhole.

Due to the low storage capacity of the soakaway manhole, the native soil must have a high permeability (k_f □ 10^{-5} m/s). As soakaway manholes have low space requirements, they are very well suited for small housing estates.

Rainwater harvesting

The average water consumption in Germany is approximately 130 litres per capita per day. Drinking water is used for laundry purposes, meals and drinks, washing and showering, dishwashing, and toilets, facility cleaning and garden irrigation. Using rainwater can help reduce the consumption of drinking water for purposes requiring no drinking water quality.

In this case, the rainwater is not conveyed back into the natural water balance, but re-used for household purposes. Nevertheless, this approach has a positive effect on the natural water balance, because less drinking water needs to be supplied and water resources are spared. There are two basic types of rainwater harvesting systems in the household area. One is the exclusive use of collected rainwater for the irrigation of gardens. This solution is easy to implement and moderately expensive. The other type is the collection of rainwater for actual household purposes. Rainwater can be supplied for flushing the toilet or feeding the washing machine. Figure 9 is a schematic representation of how rainwater is used for household purposes.

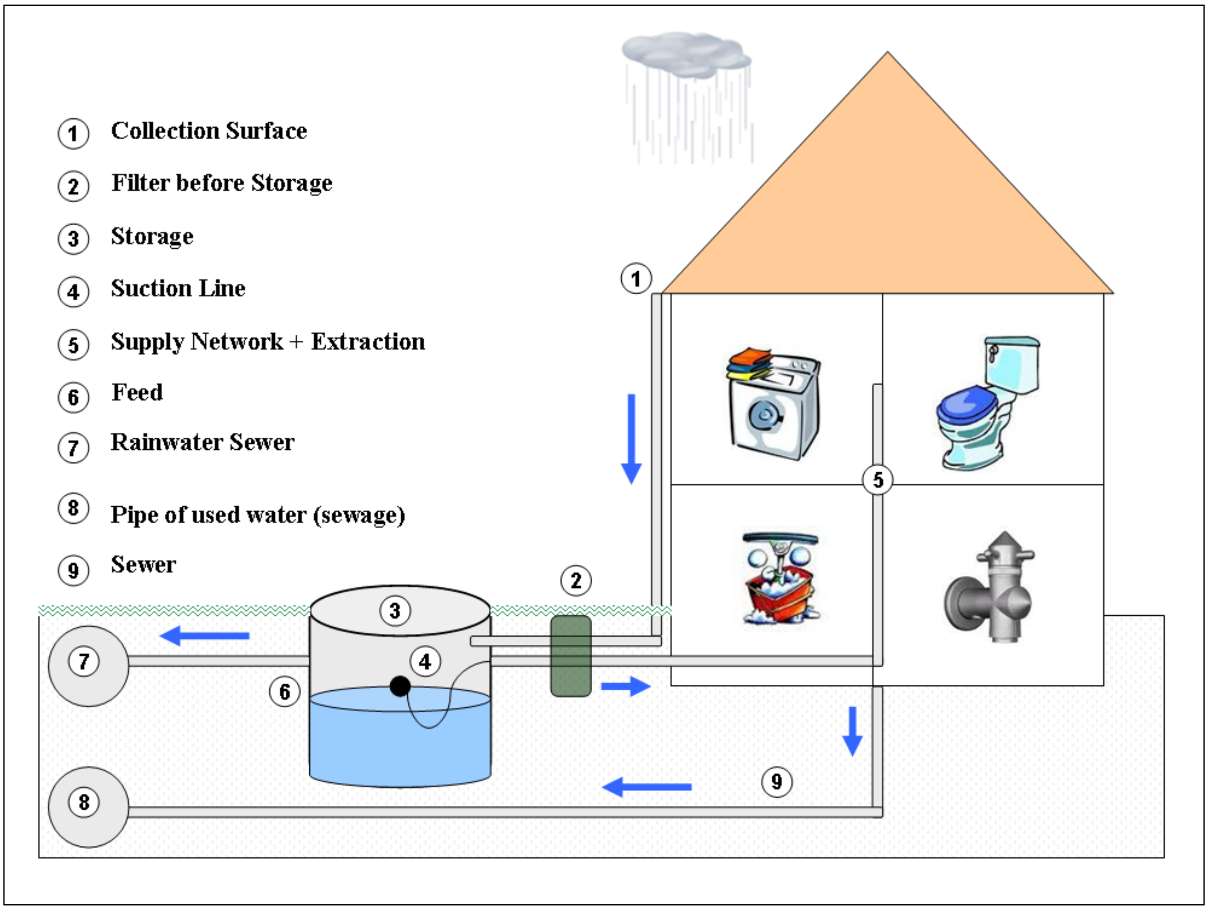

Figure 9: Sketch of principle of a rainwater harvesting system for household use.

Stormwater from the roof is diverted into a storage tank (cistern) The water is cleaned from dirt particles by a filter installed before the storage tank. Once in the underground storage tank, the water is kept in a cool place at subsurface temperatures. The collected rainwater is passed via a suction line into the piping system for household supply. After use, the water is drained into the sewer system. If the stormwater flow exceeds the storage capacity of the cistern, the excessive water is either allowed to overflow into the sewer system or to percolate into the ground.

4. Efficiency and difficulties of decentralized stormwater management

The various stormwater management methods have different effects on each of the components of the water balance. The following chart (Figure 10) gives a general outline.

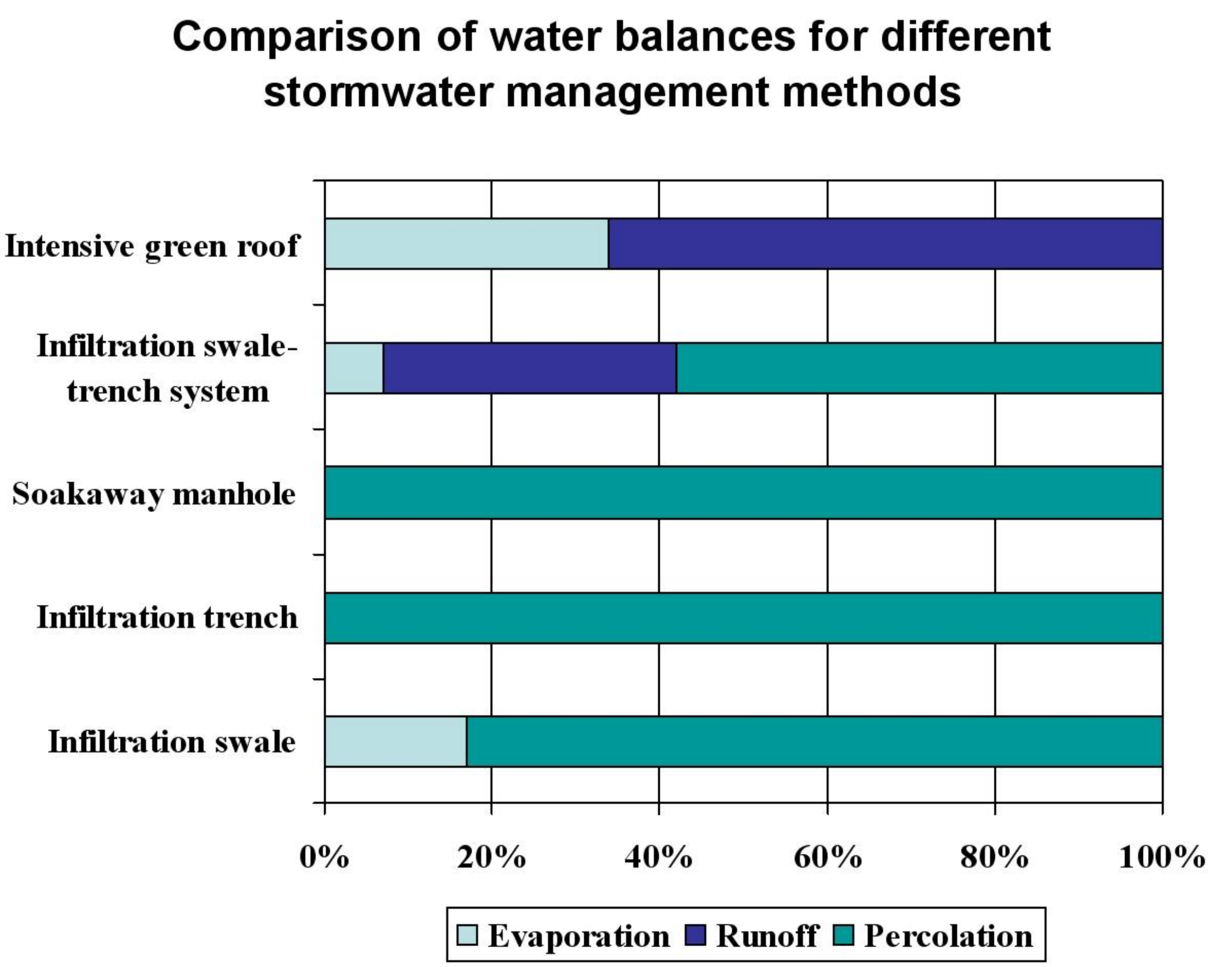

Figure 10: Comparison between water balances of different stormwater management methods (Source: Sieker, 2000).

Green roofs cause the larger part of the precipitation water to be evaporated. The remaining part is diverted as stormwater runoff. The exclusive use of this method would mean that there is no water infiltration into the ground and no recharge of groundwater. The combination with an infiltration method is desirable. On the other hand, infiltration manholes and trenches are exclusively limited to infiltration. In this case, the stormwater is conveyed underground into a closed manhole or into a trench where the collecting water can neither evaporate nor run off. Infiltration swales mean that the major part of the stormwater percolates into the ground. However, since the water is not stored underground in a confined space, but in a depression open to the atmosphere, a certain percentage of the collecting water can evaporate. As clearly shown by the foregoing examples, the various stormwater management methods have highly different impacts on each of the components of the water balance. If the purpose of stormwater management is to reduce stormwater runoff and replenish groundwater, then infiltration by trenches, manholes and swales are the most appropriate approaches.

The re-use of collected stormwater on gardens has a positive effect for the water balance because of local groundwater recharge. If stormwater is collected for re-use in households, it will finally flow into the public sewer system and thus be removed from the natural hydrological cycle. In each case, it is therefore wise to check which rainwater uses are most appropriate in a specific location.

The combination of several methods makes it possible to achieve an almost natural water balance. A study was carried out (Göbel, 2007) to find how the water balance could come as close as possible to non-built areas. As a result, the study recommends a green roof percentage of 30 % in combination with a downstream infiltration trench in order to provide near natural stormwater and groundwater management for a typical plot of land.

It should always be kept in mind that complete infiltration of all of the stormwater is not useful. This approach might cause the groundwater table to rise to undesired levels. In addition, the amount of pollutants in the stormwater must be so as to allow infiltration without impairing the quality of the groundwater or soil.

It is possible to use filters for removing the pollutants contained in the stormwater (e.g. from metal roofs). According to Dierkes et al, 2006, passive filters allow 90% of the pollutants (suspended solids, heavy metals, mineral oil. phosphor) to be removed.

Furthermore, it is important to thoroughly check the hydrogeological and geological conditions and to make perfectly sure there are no previous contaminations of the soil.

Summary

As a basic condition for sustainable groundwater management, it is necessary to ensure that the groundwater body retains its major characteristics and can be regenerated in a natural way. In urbanised areas, the natural water balance is disturbed by a high percentage of impervious surfaces. They reduce infiltration and groundwater recharge, thereby leading to a lower groundwater table – and thus causing a change in major groundwater characteristics. The conventional urban drainage solution is based on the principle of discharging the stormwater immediately, and to the largest possible extent, as sewage into the public sewer system. This concept is associated with quality problems in the water bodies due to stormwater inflows from the separate storm sewer or due to overflows from the combined sewer system. During the past few decades, this approach caused high investments into and operating costs of stormwater treatment facilities and overflow tanks, with a major part of the facilities being used during rare (heavy rainfalls) events only.

Appropriate measures (green roof, stormwater infiltration and rainwater harvesting) and their combination can help restore the natural water balance quite closely. So it is possible to properly use the retention and cleaning capacities of the soil and to reduce runoff peaks. Methods for decentralised stormwater management are to be recommended and can be transferred to other regions or countries.

When using groundwater as one of our most important drinking water resources, it is necessary to do everything to provide compensation for the deficit thus created. Such compensation can be achieved e.g. by the judicious and effective use of decentralised stormwater management methods as presented in this paper. This is the only way to guarantee for sustainable groundwater management.

References:

BMU (Bundesministerium für Umwelt) (2003):.Hydrologischer Atlas von Deutschland. Wasserwirtschaft-Wassertechnik 36(2): 33-36.

Sieker; F., H. Sieker; U. Zweynert; P. Schlottmann (2009): Konzept für eine bundeseinheitliche Anforderung an die Regenwasserbewirtschaftung. Bundesministerium für Umwelt BMU (Hg). http://www.umweltdaten.de/publikationen/fpdf-l/3815.pdf

Dierkes,C. , P. Göbel, M. Lohmann and W.G. Coldewey (2006): Development and investigation of a pollution control pit for treatment of stormwater from metal roofs and traffic areas . Water science & Technology Vol.54 No 6-7 pp. 291–298.

DWA-Arbeitsblattes A 138 "Planung, Bau und Betrieb von Anlagen zur Versickerung von Niederschlagswasser" (2005): Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V. (Hg.).

DWA-Merkblattes M 153 "Handlungsempfehlungen zum Umgang mit Regenwasser(2007):Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V. (Hg.).

Göbel, P., W.G. Coldewey, C. Dierkes, H. Kories, J. Meßer and E. Meißner (2007): Impacts of green roofs and rain water use on the water balance and groundwater levels in urban areas. Grundwasser Volume 12, Number 3, pp. 189-200.

Landeshauptstadt Dresden Umweltamt (Hg.)(2004):Mit Regenwasser wirtschaften. Dresden. Broschüre. 54 S.

Mönninghoff, H. (Hg.) (1993): Wege zur ökologischen Wasserversorgung : ° Wasserspartechnik °Doppelte Wassernetze °Regenwassernutzung °Grauwasserreinigung °Politische Handlungsmöglichkeiten - 1. Aufl. - Staufen bei Freiburg : Ökobuch, 1993. - 138 S.

Sieker, H. (2000). Generelle Planung der Regenwasserbewirtschaftung in Siedlungsgebieten. Institut für Wasserbau und Wasserwirtschaft der Technische Universität Darmstadt, Mitteilungen, Heft 116, Darmstadt.

Umweltbundesamt 2005: Versickerung und Nutzung von Regenwasser –Vorteile, Risiken, Anforderungen. Dessau, Broschüre. 44 S. http://www.umweltdaten.de/publikationen/fpdf-l/2973.pdf

WHG, § 55; http://bundesrecht.juris.de/whg_2009/__87.html (downloaded on 17.03.2011)