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Effects of heavy rainfall on construction-related infrastructure

A project of the research programme "Zukunft Bau" of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) carried out by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning (BBR)

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Scientific assistance
Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR)
Division II 6
Dr. Bernhard Fischer
bernhard.fischer@bbr.bund.de

Contractor
Ingenieurbüro Reinhard Beck GmbH & Co. KG, Wuppertal
Sebastian Arns, Maren Hellmig
info@ibbeck.de

University of Wuppertal, Wuppertal
Prof. Andreas Schlenkhoff

Kommunal Agentur NRW, Düsseldorf
Stefan Vöcklinghaus, Nadine Appler

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Anika Freytag

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01 INTRODUCTION

In the past, heavy rainfall events have occurred to an increasing degree in Germany, some of which have even resulted in deaths (e.g. Münster 2014, Southern Germany 2016). In addition to personal injury, this has also resulted in serious damage to property, particularly to physical infrastructure. The more frequent occurrence and rise in rainfall intensity of such weather events as well as the occurrence of extreme storms, hot spells or droughts is, according to the German Strategy for Adaption to Climate Change (DAS), a result of climate change. A problem we face in our time is that the structures of German cities that have grown fail to account for this development and corresponding measures to manage this have been neglected.

Knowledge of the vulnerability of physical infrastructure as well as taking measures to protect existing buildings or so-called adapted building that takes the local situation into account as well as special building materials are becoming increasingly important. This report will present the vulnerabilities of the individual building materials and describe measures to protect physical infrastructure.

Special attention will also be paid to available areas within the urban domain for binding and using heavy rainfall or allowing it to infiltrate or evaporate. Worldwide, there is an increasing number of strategies employing a so-called sponge city, which handles precipitationwater in the city in a sustainable manner. A return to a more natural water regime in the city means that water will be retained in the area or in special reservoirs in order to use it e.g. for management of green space. Increased evaporation will also lead to a sustainable improvement in the microclimate as cities be cooled overall. At the same time, measures for creating a sponge city cannot only be evaluated and planned over longer timeframes, rather they can also have a positive effect in the event of brief heavy rainfall events. The concept of the sponge city is primarily relevant with respect to long-term, higher-level urban planning as the measures generally concern public areas. It becomes all the more necessary to also break down these concepts to the smallest possible division within a city: a property. Therefore, the term "sponge property" will be introduced in this report.

In addition to the protection of buildings, measures for the storage, infiltration as well as the evaporation and transpiration of a defined heavy rainfall event have been devised at the level of the property. In a computer-based calculation model, the effects of the individual measures were demonstrated on a sample property and then evaluated with the expected costs (cost-benefit analysis). The measures are evaluated considering various local aspects such as topography or soil conditions to allow for transferability.

This project is funded by the research initiative “Zukunft Bau” of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

REASON

It has been proven that the climate is changing to an increasing degree. Heavy rainfall events are occurring to an increasing degree in this context. Corresponding adjustments and measures have been prescribed and/or defined in the German Strategy for Adaption to Climate Change. The principle of the sponge city provides cities with a possibility for responding to the increasing amounts of rain. This means that virtually all rainfall in the city will not run off on the surface, but will be collected, stored and reused. The effects of heavy rain events are counteracted in this way. In this project, this will be broken down to the level of an individual property (sponge property).

02 REASON

The link between an increase in global temperatures and the change to the precipitation situation can be explained physically in that the air is also capable of absorbing more water vapour at a higher temperature. The need for a sustainable concept for dealing with precipitation water from the property will be explored below.

2.1 CLIMATE CHANGE

Climate change

There is now no question whatsoever that the climate – and consequently urban climate – will change. For North Rhine-Westphalia, an increase in the average temperature of approx. two degree Celsius is expected for the mid-21st century (compared to the years from 1961 to 1990). As warm air is capable of absorbing and transporting more water, the increase in temperature will also have effects on the rainfall rates. Analyses of data as well as climate models show that the global volume of precipitation will increase by approximately two per cent for every degree by which the temperature increases (Kreienkamp et al. 2016). Forecasts predict that heavy rainfall and flash floods will increase or at least remain the same depending on the forecast model (UBA, 2015b). It is undisputed that, over the past 15 years, so-called heavy rain events have occurred to an increasing degree, at least in some regions (see Figure 1). Adaptations responding to the resulting problems have been provided for in the German Strategy for Adaption to Climate Change whereupon hot spells and flooding are, in most cases, considered collectively. This guideline, however, mainly addresses heavy rainfall events in conjunction with water retention and reducing run-off on individual properties.

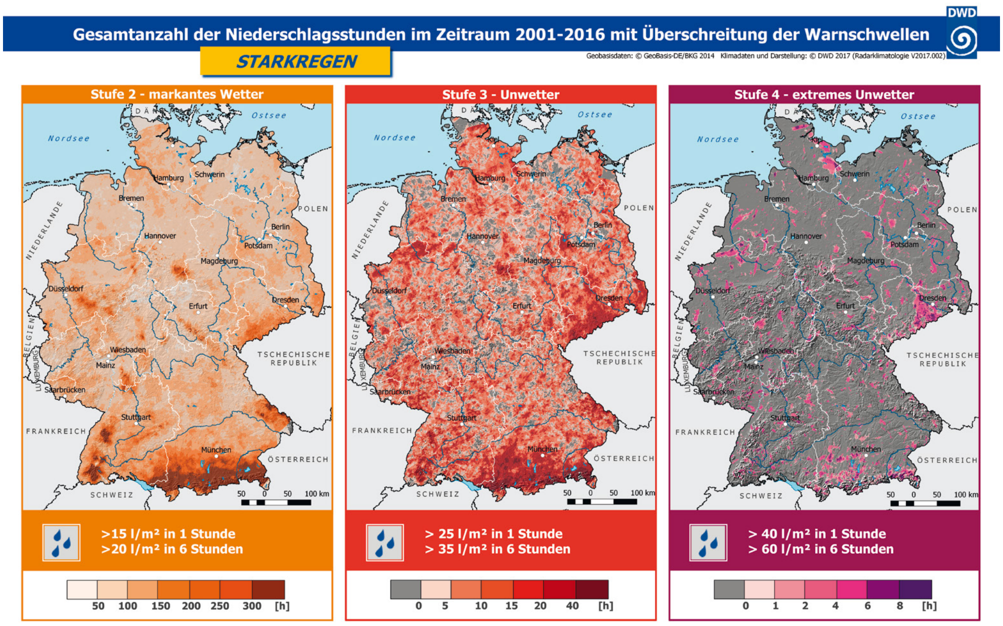


Figure 1
Total hours of precipitation from 2001 to 2016 exceeding warning thresholds (DWD,2016)

Climate --- weather

Climate is based on prolonged periods of time from decades to centuries. The weather, on the other hand, refers to the current condition in the atmosphere (sunshine, rain, wind and so on) within a period of hours to days. When referring to extreme events such as heavy rainfall, this concerns weather extremes whose occurrence (for example frequency) is influenced by climate change.

Urban climate

In this respect, there are climactic effects known as urban climate in cities and metropolitan areas when compared to surrounding regions with little to no development. The urban climate is affected, among other things, by the building structure and development density, the share of sealed surfaces, vegetation and other factors such as traffic and industry (MKULNV, 2011). In this respect, the drainage systems and/or the type of drainage in cities have a negative impact on the natural water balance. As a result, for example, the increased runoff attributed to sealed surfaces can cause overloading of the sewer system and flooding in the event of heavy rainfall. Reduced evaporation and transpiration is one of the factors that causes cities to heat up during the summer.

Heavy rainfall

Heavy rainfall is at hand if very large volumes of rain fall in within a short time in a spatially restricted area, mainly in combination with storm fronts from May to September. In the process, small creeks can turn into torrential rivers (BBK, 2015). The German Meteorological Office (DWD) makes this phenomenon more tangible on the basis of warning levels. There are three warning levels for heavy rainfall:

- Volumes of rain from 15 to 25 l/m² in one hour and/or 20 to 35 l/m² in 6 hours (significant weather warning)

- Volumes of rain > 25 l/m² in one hour and/or 35 l/m² in 6 hours (storm warning)

- Quantities of rain > 40 l/m² in one hour and/or 60 l/m² in 6 hours (extreme weather warning/DWD, 2016).

This definition is consistent for the entire federal territory where factors such as topography, the amount of sealing and the development density are not included in the evaluation. They are, however, crucial with respect to the effect and above all the vulnerabilty of areas when faced with heavy rainfall. In order to better accept and communicate risks, a dimensionless rainfall index has been developed. It is based on local heavy rainfall statistics for every locality in Germany according to KOSTRA (**CoordinatedStorm** Rainfall **Regionalisation** Analysis). In the calculation of the index, the annual incidence is considered to a greater degree than the duration of the events. This means that, in the case of a higher recurrence interval and shorter duration, a high heavy rainfall index is at hand, which is plausible due to potential damage caused by such events (Mudersbach, 2016).

2.2 THE SPONGE PROPERTY SOLUTION

Sponge city

So how can cities respond to increasing heavy rainfall events? Globally, the topic of developing "Sponge Cities", particularly in China, has emerged. The country has to struggle with two interrelated problems: rapid urbanisation and poor water management. In addition to high water consumption in numerous Chinese cities, overloading of the system in the event of heavy rainfall is also a problem. The solution to both is the so-called "Sponge City", a city where nearly all precipitation is collected, stored and reused. Instead of channelling precipitation away, the plan is to use it for gardens; the consumption of potable water will be reduced by utilising precipitation water for toilets and washing machines.

Today, the Chinese city of Changde is already referred to as a "sponge city”. As part of the EU-funded AsiaPro-EcoProject, engineers and landscape architects from Hanover are developing a resource conserving, ecological water management strategy. It comprises treatment plants, pump stations, rainwater reservoirs, sewers and green space. Precipitation water is collected during the downpour and can be used for managing green space or as non-potable water. At the same time, pollution of the neighbouring river is prevented (CRI, 2015; Mlodoch, 2015; Hanover, 2016).

The word "Sponge City" is used in a number of climate adaption strategies and studies. It refers to the principle of channelling less water on the surface and disposing of it in sewers and instead storing it and using it. In the ExWoSt study (Experimental Housing Construction and Urban Development) of the BBSR (Federal Institute for Research on Building, Urban Affairs and Spatial Development) "Überflutung- und Hitzevorsorge durch die Stadtentwicklung – Strategien und Maßnahmen zum Regenwassermanagement gegen urbane Sturzfluten und überhitzte Städte" (Flooding and Heat Precautions through Urban Development -- Strategies and Measures for Rainwater Management to combat Urban Flash Floods and Overheated Cities), the principle of the sponge city is described as an approach for the near-natural management of rain water as well as a possibility for cooling off cities. This primarily concerns developing sustainable reservoirs and drainage systems for urban green space and improving the cooling performance of these areas (BBSR, 2015). In the event of excess (for example, in the event of heavy rainfall), the water is to be stored and subsequently discharged through evaporation and transpiration during heat waves. The resulting cooling counteracts excessive heat (SenStadtUm, 2016).

Another example is provided by the city of Hamburg with the implementation of "Blaue Straßen" (blue streets) as retention areas for rain water. In the process, the water is retained in designated areas to keep damage to the development to a minimum (BWVI, 2015).

Sponge city in Germany

With respect to all strategies and measures, small-scale, individual projects only have limited effects on the complex city climate. They are, however, of considerable significance for the microclimate of the respective areas. It therefore makes sense to also apply the sponge principle to individual properties. Through the decentralised management of rain water and the retention of the water on the property, run-off into the public sewer is reduced thereby protecting the entire city against flooding

Introduction of the term "sponge property"

Derived from the larger-scale concept of sponge cities, the principle will be applied to individual properties. The term *sponge property* will be introduced for such properties in this

guideline. This is accompanied by further positive effects for the property such as a declining rain water fee, saving potable water, an improved microclimate and an improvement of the landscape.

In order to understand the principle of a sponge property, the hydrological processes occurring on a property must be observed. This is why the water balance is of primary importance. When planning a sponge property, the main restriction is the scarcity of space in an urban context. The so-called base area coefficient (GFZ) is therefore of key importance in this respect. Both aspects will be explained below.

2.2.1
WATER BALANCE

In order to address the topic of sponge property, the water balances of a property also have to be clarified.

Water balance

Introduction of the water balance

The water balance equation originally comes from hydrological and meteorological studies of large areas. It describes the relationship between rain, evaporation and transpiration as well as the resulting positive or negative water balance over, in most cases, prolonged periods of time. However, the formula can also be applied to small areas and timeframes:

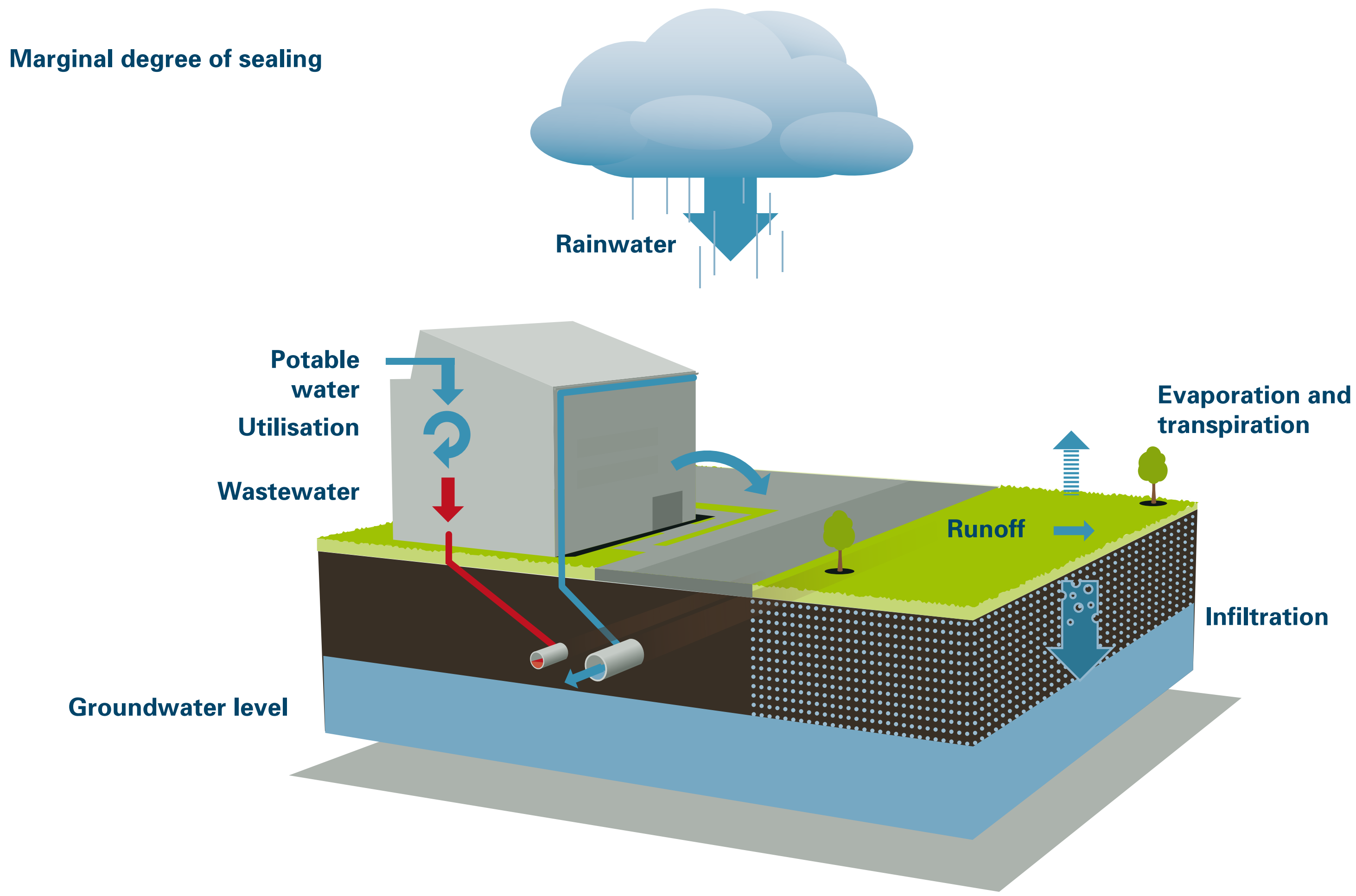
$$A = N - Vd \pm \Delta S$$

Where: A = runoff
N = rainfall
Vd = evapouration and transpiration
ΔS = change to ground storage

The water balance equation represents the relationship between runoff, amount of rainfall, evaporation and transpiration and underground stage (including infiltration). Depending on the area considered, all parameters may vary greatly. Below, the water balance will be used to illustrate the effects of various property designs and devise a property where runoff is virtually zero until the rain has stopped.

When it comes to the conventional use of water, virtually no exchange takes place between potable water on one hand and rain water on the other. Potable water is used and subsequently disposed of in nearly the same amount as wastewater and is also used for garden cultivation depending on the property design.

The rain water in turn infiltrates, evaporates and transpires or runs off. The extent to which each process occurs is decisively dependent on the design of the property. While the majority evaporates and transpires or infiltrates with unsealed surfaces, surface runoff (Figrure 2 (top)) prevails with sealed surfaces (Figure 2 (bottom)).



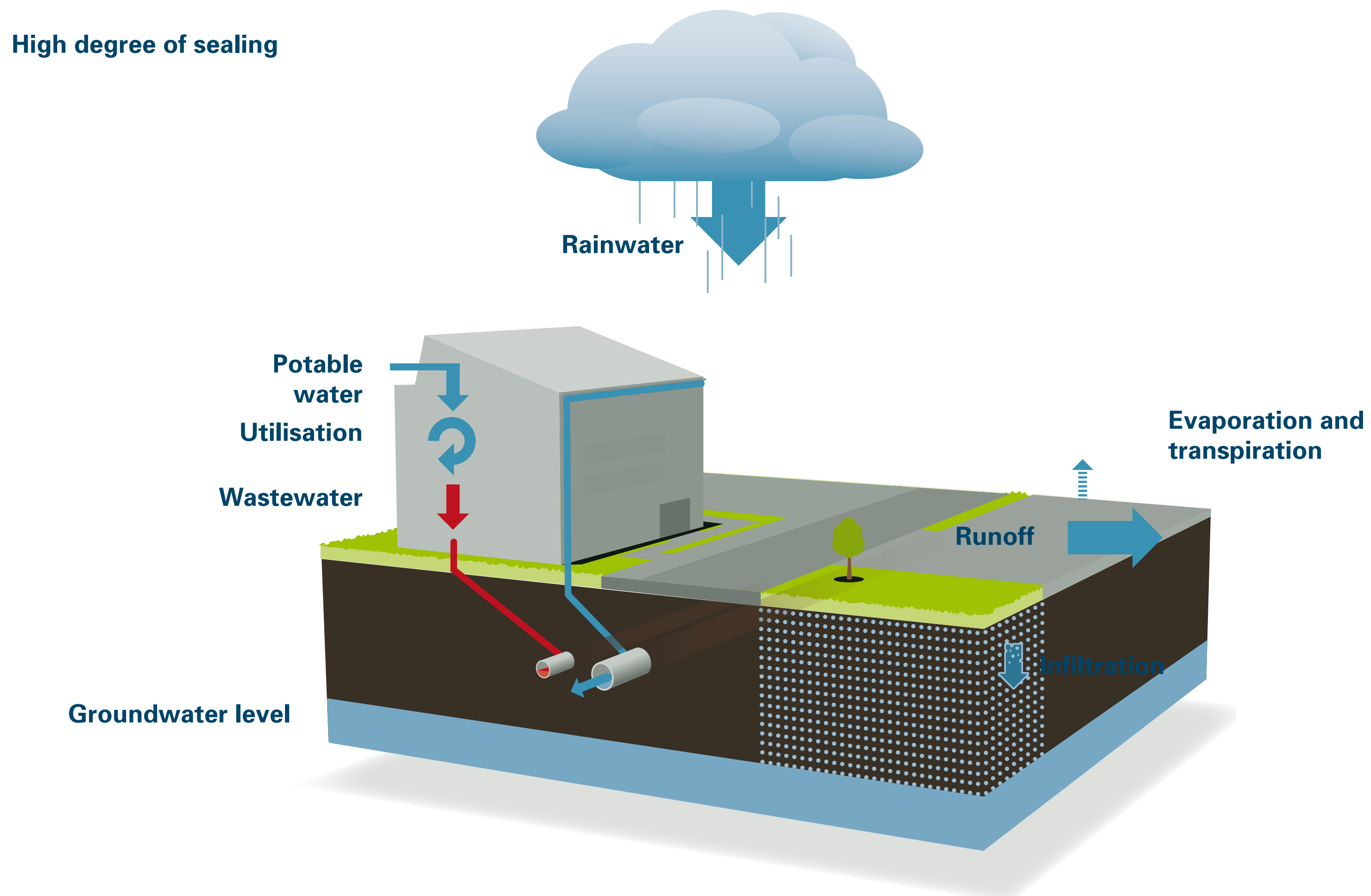


Figure 2
Comparison of the water balances between a primarily unsealed (top) and extensively sealed property (bottom) with conventional water usage

Neither high level surface runoff or nor excessive infiltration correspond to the strategy of 100 per cent retention. In order to achieve this objective, runoff must be virtually zero in the water balance after the rain has ended:

$$A_{t=0} = N - V \pm \Delta S \sim 0$$

Where:
- A = runoff
- t = time after the rain
- N = rainfall
- V = evaporation and transpiration
- ΔS = Change to ground storage

Retention/ usage

Therefore, an additional reservoir is needed to retain the water on the property. Possible variants for this are described in greater detail in Section 5. In this model, the surface water that runs off is retained by a storage basin. The water stored in this way can then be used; any surplus in the reservoir is released with a delay thereby taking the burden off the entire system. This combination of potable water and the rainwater cycle saves potable water in the home. Depending on the design of the reservoir, the water can also continue to evaporate, transpire and infiltrate.

Water balance of a sponge property

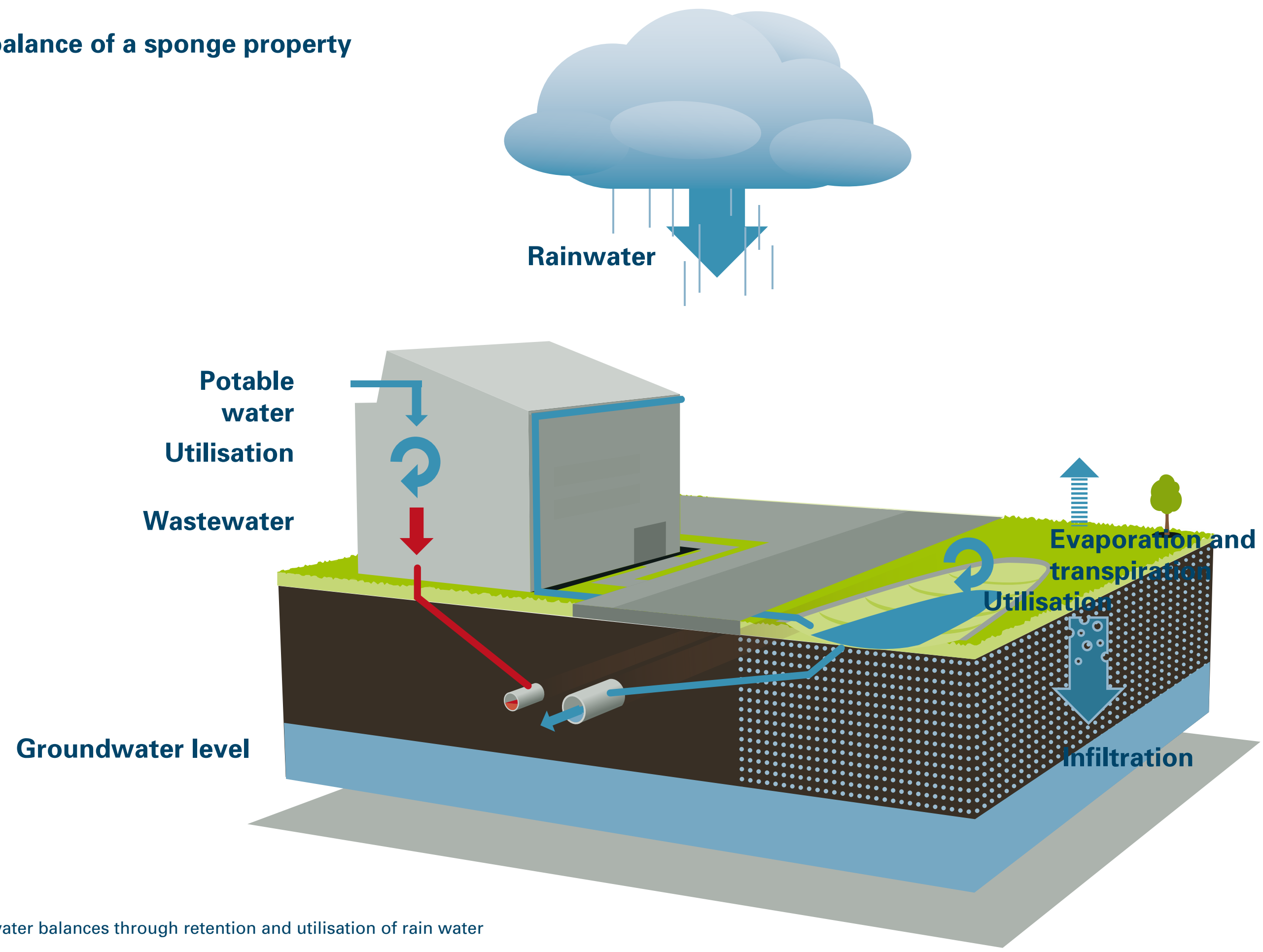


Figure 3
Linking of water balances through retention and utilisation of rain water

2.2.2 BASE AREA COEFFICIENTS

Boundary conditions

The question as to which reservoir suits which location depends on the respective property. The proportion of built-up and sealed area to the undeveloped area of the property (cf. base area coefficient) is decisive. In the event of low base area coefficients (GRZ) and large unsealed areas, a surface reservoir is ideal. If the property is extensively developed, underground storage in tanks in the basement or retention on the roof make more sense.

*Permissible base area that may be covered with physical structures

Table 1: Upper limits with respect to determining the extent of structural use (only GRZ as per BauNVO (Federal Building Ordinance) in this case (2013))

Building area	Base area coefficient (GRZ)*
Small housing estates (WS)	0.2
Purely residential estates (WR) general residential areas (WA) Holiday house settlements	0.4
Special residential areas (WB)	0.6
Village areas (MD) Mixed areas (MI)	0.6
Core areas +(MK)	1.0
Commercial areas (GE) Industrial areas (GI) Other special areas	0.8
Weekend home areas	0.2

In addition to the proportion of sealed area, the climactic water balance for the area is important for the concept of retention. It is based on the rainfall, evapouration and transpiration, infiltration and runoff and differs greatly in Germany depending on the region and season. Corresponding mean values can be found in the Hydrological Atlas of Germany (HAD). In areas with a high level of rainfall, water must be retained to a greater degree than in dry areas.

Seasonal differences must also be considered with such a setup. In the winter, the evaporation and transpiration rate is significantly lower than in the summer; the same goes for infiltration. Even if short-lived, severe heavy rainfall mostly occurs during the summer months when the water can still be used to a full extent, the winter months must also be considered during which prolonged periods of precipitation are common (DWD, 2016).

ENGINEERING AND RESEARCH

There are numerous laws and regulations that must be considered when implementation a sponge property. This concerns the duty to dispose of wastewater, flood mitigation, the duty to treat precipitation water, standards for sizing drainage systems and for using rain water.

03 CURRENT STATE OF REGULATIONS, ENGINEERING AND RESEARCH

The drainage of properties, buildings and corresponding municipal duties are provided for in laws and regulations. In most cases, this concerns the channelling and disposal of precipitation water. Below, the most important statements and reference to the issue of heavy rainfall are summarised.

WHG
Definition

The Federal Water Act defines **precipitation water** as wastewater if it collectively runs off of built-up, sealed areas (Section 54 para.1). It is therefore subject to the duty to dispose of wastewater. Rainwater, which falls on unsealed areas, is therefore not wastewater (Groth, 2014).

Precipitation --- wastewater

The runoff (precipitation water) collected from the area with the built-up or sealed areas (precipitation water) is wastewater (Section 54 para. 1 no. 2 WHG)

The **duty to remove wastewater** comprises the collection, channelling, treatment, infiltration, use for irrigation of precipitation water (Section 54 para. 2).

Heavy rainfall often results in damages due to flooding. In common parlance, this is referred to as **high water**. Pursuant to *WHG Section 72*, high water is "temporary flooding of land normally not covered by water, particularly by surface water bodies or sea water infiltrating coastal areas. Flooding from wastewater facilities is excluded in this respect". Flooding due to heavy rainfall therefore not only falls under the term high water if it does not originate from overloaded wastewater facilities.

High water --- heavy rainfall

"High water is temporary flooding of land normally not covered by water, particularly by surface water bodies or sea water infiltrating coastal areas. Flooding from wastewater facilities is excluded in this respect". (Section 72 WHG). High water therefore also refers to flooding as the result of heavy rainfall, but not flooding from sewer

Protecting against flooding on the private property also falls under the general duty of care. Section 5 para. 2 WHG states the following in this regard: "Every person, who can be affected by high water, is obligated, to the extent possible and reasonable for them, to take suitable preventative measures to protect against the adverse effects of high water and to minimise damage, in particular to adapt the use of properties to possible adverse effects for people, the environment or property brought about by high water." This stresses above all the duty of the owner to **protect property**. At the same time, it must be ensured that the natural runoff of unconfined water onto lower properties is impaired neither to the detriment of the higher property nor intensified to the detriment of the lower property nor otherwise modified (Section 37 para. 1 WHG; LUBW, 2016).

The regulations and laws concerning the implementation of a sponge property are listed below.

BauGB (Building Code)

In urban land-use planning, the principles for flood prevention can be derived under the aspect of adaptation to climate change. The climate protection amendment of the Building Code of 30 July 2011 comes into force in the new climate protection clause of Section 1a para. 5 Building Code.

In Baden-Württemberg and North Rhine-Westphalia, climate protection laws have already been passed, which legally define climate protection targets and adaptation to climate change (SUBV, 2015).

North Rhine-Westphalia separation decree

Treatment duty

In Germany, the treatment duty and the type of treatment of precipitation water are stipulated at the federal state level. With the *separation decree of 2004* (circular decree of 26 May 2004), NRW introduced strict guidelines for the **treatment of precipitation water** in the separation procedure. The duty and type of treatment are determined based on the origin of the precipitation water (category I - uncontaminated; category II – slightly contaminated; category III – highly contaminated). For the analysis of an individual property (except for the yards of industrial operations and long-term parking areas), mainly categories I and II are considered, which do not require treatment and can therefore be discharged into a water body or, according to the sponge city principle, can infiltrate in the direct vicinity. The *DWA-A 102* is set to replace the NRW separation decree as a nation-wide solution.

DIN EN 752

Sizing

The **sizing of public drainage systems** is provided for in *DIN EN 752*. For technical and economic reasons, the sewer systems are not designed to handle every extreme event. Depending on the area, the design may account for a recurrence interval of T_n = 1 to 10 years. Sensitive areas are assessed based on the frequency of flooding. Depending on the area, flooding may only occur every 10 to 50 years.

DWA-A 118

Flooding and excess head are defined in *DWA-A 118*:

- **Flooding:** When wastewater and/or rainwater leak from a drainage system or are not able to enter it and either remain on the surface or enter into buildings

- **Excess head**: State of stress on the sewer system when the water level exceeds a defined reference level.

DWA-M 119

In supplementation to *DWA-A 118*, further-reaching rules regarding the questions of municipal flooding protection have been devised in *DWA-M 119*. Systematic analyses with graduated levels of detail with respect to the risk of flooding, the potential for damage and finally, the risk of flooding in the event of heavy rainfall are in focus. The regulations form the basis for municipal flooding prevention with respect to drainage systems and urban flash floods.

DIN EN 12056
DIN 1986-100

When it comes to analysing a **property**, the drainage of the property including drainage **within the buildings** is particularly decisive. The latter is provided for in *DIN EN 12056* . It replaces parts of the "*old*" *DIN 1986* . It provides for the determination of the reference rainfall intensity according to KOSTRA data at the national level:

- Decisive duration of rain D = 5 min

The recurrence interval for property areas excluding roof areas without planned retention must amount to at least T_n = 2 a

- The recurrence interval for drainage of roof areas must amount to at least T_n = 5 a

- Emergency drainage of flat roofs for $r_{5,100}$ (a 100-year rainfall event lasting five minutes)

For properties over 800 m³, a flooding analysis is performed with a rainfall intensity of at least D = 15 min and recurrence interval of T_n = 30 a. For the differences from the calculated rain intensity and the carrying capacity of the sewer network, retention systems must be built if applicable (DIN 1986-100, 2016).

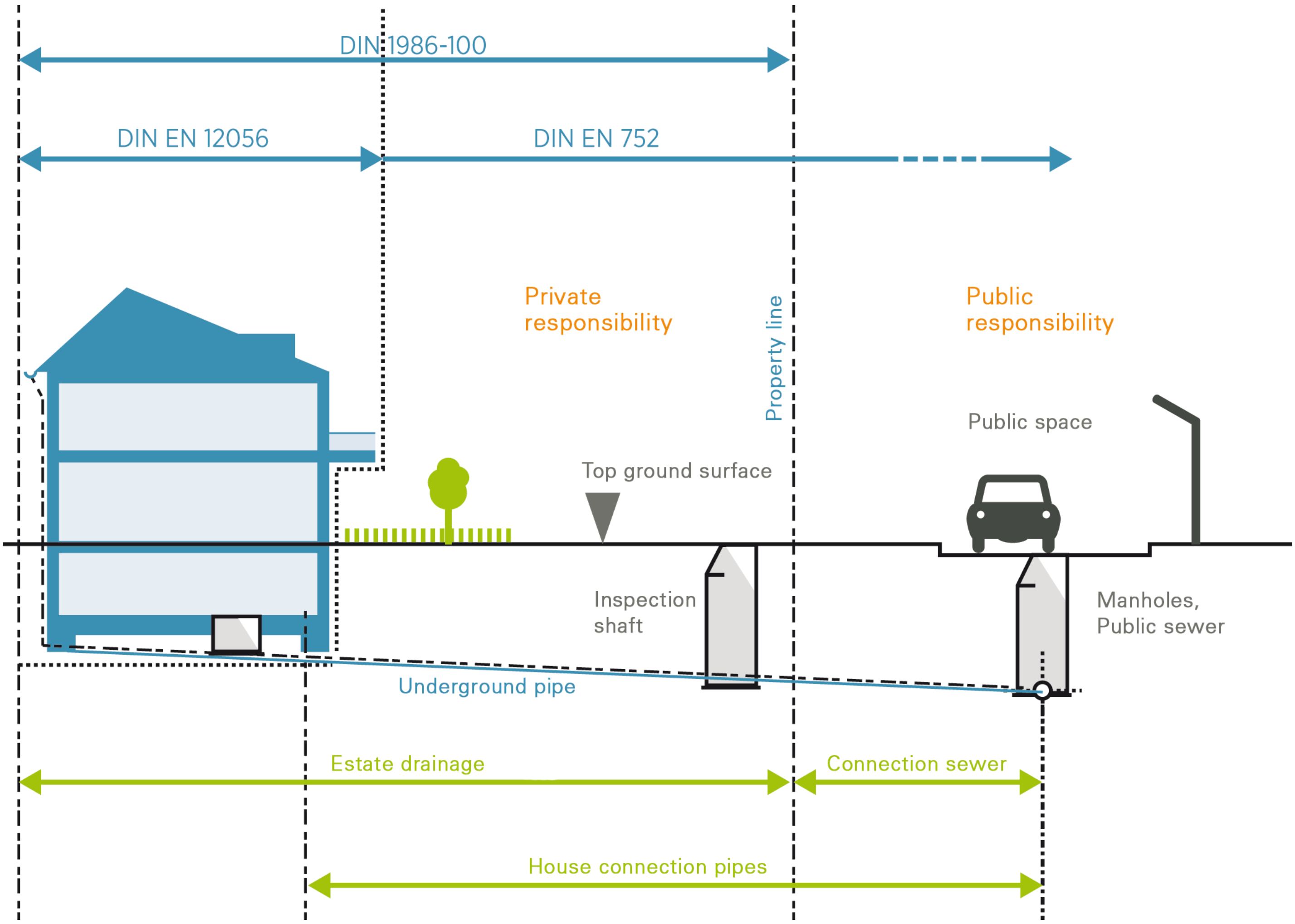


Figure 4
Application areas of the standard on drainage inside and outside of buildings, edited in accordance with DIN EN 12056 and Scheffler (2007)

DWA-A 102
Natural water balance

The draft of the DWA-A 102 adopts the idea of adapting the drainage system to resemble **the natural water balance** . The work sheet defines the natural water balance as the objective for new development areas, conversion areas and urban redevelopment areas. Drainage systems of the future should primarily be provided with vegetation and permeable areas, which are based to the furthest extent possible on the natural balances of evaporation and transpiration, runoff, infiltration and groundwater recharge (DWA-A 102, 2016).

DIN 1989-1
Use of rainwater

The boundary conditions for **the use of rainwater** by households, commercial establishments, industry as well as public institutions, for example, for toilets, cleaning, cooling or care of green space are set out in *DIN 1989-1*. It contains notes on qualitative and quantitative requirements of rainwater. Roofs (predominately flat roofs) are best suited as areas for management. For private households, it is recommended that all suitable areas are used. Retention is possible above and below the ground whereupon water should be protected from exposure to heat, frost and light. The reservoir size is calculated based on the proportion of the rainwater collected to the need for non-potable water.

VULNERABILITY AND RESILIENCE

Every property has a different level of sensitivity to heavy rainfall with respect to heavy rainfall at different points. Vulnerability will be referred to in this context. At the same time, the extent of possible damages caused by heavy rainfall depend, for example, on the construction, duration of rainfall, rainfall intensity as well as the protective measures taken. Similar to the extent, the nature of the damages may vary: from wet walls to total failure of the electrical system; an adapted construction is required in order to reduce the extent of damage.

04

4.1 VULNERABILITY AND RESILIENCE

So how sensitive is a property to heavy rainfall? This refers to so-called vulnerability. According to UBA 2015a, it is "the extent to which a system is susceptible and therefore incapable of handling adverse effects of climate change, including climate variability and extremes". This also includes climate variability and extremes like heavy rainfall, heat and hail (DAS, 2008). The term resilience is just as important in this context. It describes the capability of a system to remain functioning and to quickly regain the original characteristics when subjected to inner and outer effects such as, in this case, extreme weather events impacting the property (BBK).

Vulnerability and resilience can be influenced by specific measures. They include measures on the property such as ground sills or depressions. It is also important to adapt the buildings themselves, for example, by elevating the entrances to prevent the ingress of water. If such measures or similar measures cannot be implemented, suitable building materials in particular are decisive for the resilience of the buildings.

4.2 OBJECTS REQUIRING PROTECTION (BUILDING MATERIALS AND CONSTRUCTION)

Objects requiring protection

The extent of damage caused by heavy rainfall depends on various factors:

- Construction
- Location (topography, relief, landscape, degree of sealing, development density)
- Rainfall intensity and duration
- Carrying capacity of the soil and the public drainage system
- extent of preventative measures to reduce risks and protective measures of municipalities, developers and citizens (BBK, 2015).

While heavy rainfall, for example, in flat areas can result in increased surface runoff and overloading of drainage systems, it can lead to disastrous flash floods in steeper areas. Heavy rainfall undoubtedly poses an extraordinary risk to life and limb (86th UMK (Conference of Environment Ministers, 2017). Nonetheless, only risks for the building fabric of a property will be explored in connection with this guideline. Damage to building contents and injury to persons will not be considered.

In a developed environment, typical damages due to heavy rainfall are the infiltration of the building by water and damage to the building fabric, the support structure and infrastructure facilities. The chemical and microbiological contamination of the water can also cause substantial damage; contamination, for example, with mineral oils, chemicals or faeces also cannot be ruled out (LUBW, 2016).

If precipitation infiltrates, **soil moisture** increases. If basement walls are not sealed, the water can enter the building fabric and building. The results may be cracks, crumbling plaster, wet walls and mould.

Heavy rainfall causes **the accumulation of surface water and runoff**, which is often not considered when constructing buildings. At the same time, the water can enter through any opening in the building that is not water tight such as entrances and garages at ground level, basement windows and doors as well as home connection bore holes. The ingress of water through building connection lines, which have not been secured, particularly in the event of backwater in a public sewer should not be forgotten (BMUB, 2016).

Functioning roof drainage is also important. In the event of heavy rainfall, particularly with obstructed gutters and downpipes, the water will spray over the gutters, run down the walls of the house, infiltrate sensitive areas and building openings.

Damages

The **damage to the building fabric** generally depends on the duration and height of the impounding. While the water may remain in the building for days or weeks in the event of river flooding, flooding as the result of heavy rainfall tends to be shorter. Moisture damage, however, tends to occur every time high water occurs. Typical damages to the building fabric due to flooding are:

- Visible moisture penetration and water level lines
- Efflorescence of building component surfaces
- Moisture and changes to shape and volume due to frost
- Separated coatings
- Consequential damages such as a reduction of the thermal insulation properties, infiltration by microorganisms or corrosion signs (BMUB, 2016).

The extent of the damage significantly depends on the materials used during construction. Components with water-soluble constituents or constituents that could swell such as gypsum are often useless once they have come into contact with water. Other materials can deform to the point of being useless, for example, wood, especially parquet. Depending on the type of installation, drying can be a problem; for example, in the case of floating screed installed on insulation (BDZ/ VDZ, 2002).

Table 2: Water-resistant and non water-resistant building materials
compiled from BDZ/VDZ (2002), BUMB (2016), Eurobaustoffe (2016)

Area of use	Building materials: not water-resistant	Building materials: water-resistant
Building materials	• Gypsum • Absorbent materials • Textiles	• Asphalt • Lime • Stoneware • Cement
Outer wall sheathing	• Wooden panels • Thermo-layercompositesystem • Gypsum plaster • Fibre insulating materials	• Mineral plaster on the basis of cement and/ or hydraulic limes • Resin bound plaster • Fibre cement panels • Synthetic foundation • Stoneware tiles • Water-resistant insulation
Walls	• Wood (boards, chipboards, partitions) • Lightweight partition walls (gypsum boards)	• Concrete, lightweight concrete • conventional brick-on-brick construction (sand-lime brick, clay brick, concrete blocks) • Cellular concrete • Glass bricks • Clinker bricks
Windows and doors	• Wood (unsealed)	• Wood (sealed) • Galvanised steel • Plastic • Aluminium
Inner wall sheathing	• Gypsum plaster • Gympsum boards • Wallpapers • Wood • Cork • Textiles • Dispersion coating	• Mineral plaster based on cement and/or hydraulic limes • Tiles • Whitewash • Mineral paints
Floor coverings	• Cork • Wood-block paving • Solid wood • Parquet /laminate • Textile coverings • Linoleum • Marble • Sandstone	• Clinker bricks • Concrete • Screed • Tiles • Mastic asphalt • Epoxy resin surfaces • Artificial stone • Natural stone (granite, dolomite)

Table 3: Water sensitivity of building materials
modified according to BDZ/VDZ (2002)

Building materials	Example	Water sensitivity
based on gypsum	• Filler and structure gypsum • Gympsum boards • Plaster gypsum	high
based on lime	• Mortar, plaster • Sand-lime bricks	marginal to none
based on cement	• Mortar, plaster • Concrete, precast concrete parts • Building bricks, plaster • Screed	none
fired	• Clay bricks • Clinker bricks • Stoneware • Stoneware	none
made of wood	• Beams • Boards	low
	• Lightweight wood wool building boards • Parquet • Chipboards	high
made of asphalt	• Sealing sheets • Paint coats	none
made of metal	• Steel girders • Copper/zinc sheets • Lead skirting	none
made of plastic	• Plastomers (e.g. polyethylene, polystyrene) • Thermosets (e.g. polyester, epoxy resin) • Elastomers (e.g. nitrile rubber)	low to none

Another factor is **pollutants** in the water, which could cause **hygienic problems**. The concentration of these pollutants depends on the origin of the water. Precipitation water that has run off the surface has a lower level of pollutants than backwater in the sewer.

Substances, which accumulate in the flooded area, can lead to serious problems. The most common problem is leaked **heating oil** from tanks that have not been secured. Oil causes substantial, in some cases irreversible, damage to the building fabric as it is almost impossible to remove it from the material. The residue can also be harmful to health (BMUB, 2016; Eurobaustoffe, 2016).

Electrical installations in the building are very susceptible to damage caused by flooding. Above all in the regions, which are not considered typical flooding regions, potential damages caused by water are often overlooked or neglected. If power connections are located under the flood line (frequently the backwater level in urban areas), the entire electrical system of the building can be damaged as a result. The heating burners are also often installed in the basement – they also have to be protected against the ingress of water.

MEASURES FOR PROTECTING AGAINST HEAVY RAINFALL AND BINDING OF HEAVY RAINFALL

There are various possibilities for protecting the building fabric against damages caused by heavy rainfall. Water can be strategically channelled away from buildings or ingress can be prevented through sealed walls, doors and windows. One possibility for binding heavy rainfall is strategically storing the water in the sewer network, on roofs, in depressions or even on roads and channelling it away in a controlled manner after the rainfall event. In particular, infiltration on unsealed areas, evaporation and transpiration are decisive when it comes to preventing runoff.

05

5.1 STRUCTURAL MEASURES FOR PROTECTING AGAINST HEAVY RAINFALL

Protective measures

There are various possibilities for protecting a building against damages caused by heavy rainfall:

Channelling water away from the building:

In general, terrain sloped towards the building poses a risk. Even small measures help to keep the water away from the building. Depressions on the property can, for example, be used or created so that water can be channelled to them in a targeted manner.

In depressions and sloped locations, **ground sills** can prevent precipitation water from running off of the road onto the property and endangering the structure. Above a certain water level such as in the case of river flooding, however, they are useless.

Sealing the outer walls:

If insufficiently sealed, the water slowly infiltrates the building components. Sealing with watertight concrete (white tub) or asphalt sealing on the outer wall (black tub). These measures should already be taken into consideration during construction. Though upgrading is possible in most cases, it requires significantly more resources and is significantly more expensive (Hamburg Wasser, 2012). Other weak points of the outer and basement walls are pipe openings and joints that allow moisture to penetrate into the walls.

Infiltration through light shafts, windows and doors:

Ground-level entrances should be avoided to protect against flooding. Even small sills by stairs and light shafts along basement windows and doors can stop the water. Basement entrances and light shafts should also have a drain, which is connected to the drainage system or the sewer network. With the latter, protection against backwater must also be evaluated (Hamburg Wasser, 2012). However, edges along entrances are not compliant with the accessibility of public buildings required by law – ramp systems are a good compromise in this respect.

If water accumulated in front of basement windows and doors cannot be prevented by the use of sills, there is a series of watertight, pressure-resistant installations that can be used. Either the windows and doors are already designed and sealed to withstand flooding and water pressure or additional hatches and/or doors are installed (Hamburg Wasser, 2012). Depending on the model, the hatches close automatically in the event of flooding or have to be manually locked.

Backwater from the sewer network:

Backwater protection is required if building connections in the building are located under the backwater level. The height of the backwater level is determined in the drainage regulations of the municipalities. This may be the height of the next closest shaft or the curb. Without backwater protection, neither the municipality will be liable for damages nor will the insurance pay.

There are two ways to prevent backwater into the building. A **wastewater pump station** pumps the water out of a collecting tank above the backwater level before it is fed into the building connection line. In this way, it breaches the principle of **communicating pipes** and water is unable to infiltrate the building from the sewer. Alternatively, **backwater valves** can be installed. These valves prevent water from infiltrating the building. Most valves consist of an automatic double valve. One automatically closes when water flows backwards while the other is an emergency valve that can be manually engaged (Hamburg Wasser, 2012).

5.2 STORAGE

Heavy rainfall can be held back in full or in part by reservoirs. At the same time, there are various ways to solely retain or use water as non-potable water.

5.2.1 RETENTION IN THE SEWER

If the sealed areas are already connected to the sewer, they do not necessarily have to be disconnected. The sewer itself has a storage capacity, though it is limited. The combination with underground detention basins and controlling the outflow makes it possible to achieve 100 per cent retention. As the water is immediately channelled off in this respect, no synergy effects with other environmental potential are possible with such an underground system.

5.2.2 RETENTION ON THE ROOF (GREEN ROOF/ BLUE ROOF)

If the buildings have a certain construction (to the extent possible flat roofs), retention of the water on the roof lends itself. The building statics must always be considered in this respect. Many of these constructions have a substantial weight and are not suitable for every building.

In general, unsealed areas delay and reduce run-off. The same applies to the green roof, which is often referred to in this context. Depending on the design, its acts as a buffer with varying efficiency, stores precipitation thereby reducing runoff. Blue or retention roofs can retain up to 100 % of a downpour depending on the design. Green roofs without other additions do not have any extra tanks, but only function using the pore volume in the substrate. These roofs retain up to 50 % of heavy rainfall (Optigrün, 2015). The water evaporates and transpires after the rainfall or is discharged in a controlled manner.

App-based control of drainage, with which a retention roof can be controlled similar to a dam, offers an innovative solution. This roof form contains further reservoirs under the green layer. Capillary connections ensure that the plants on the green roof can always be supplied with the stored water. If a severe rainfall event is announced, the throttles release the water from the reservoir to free

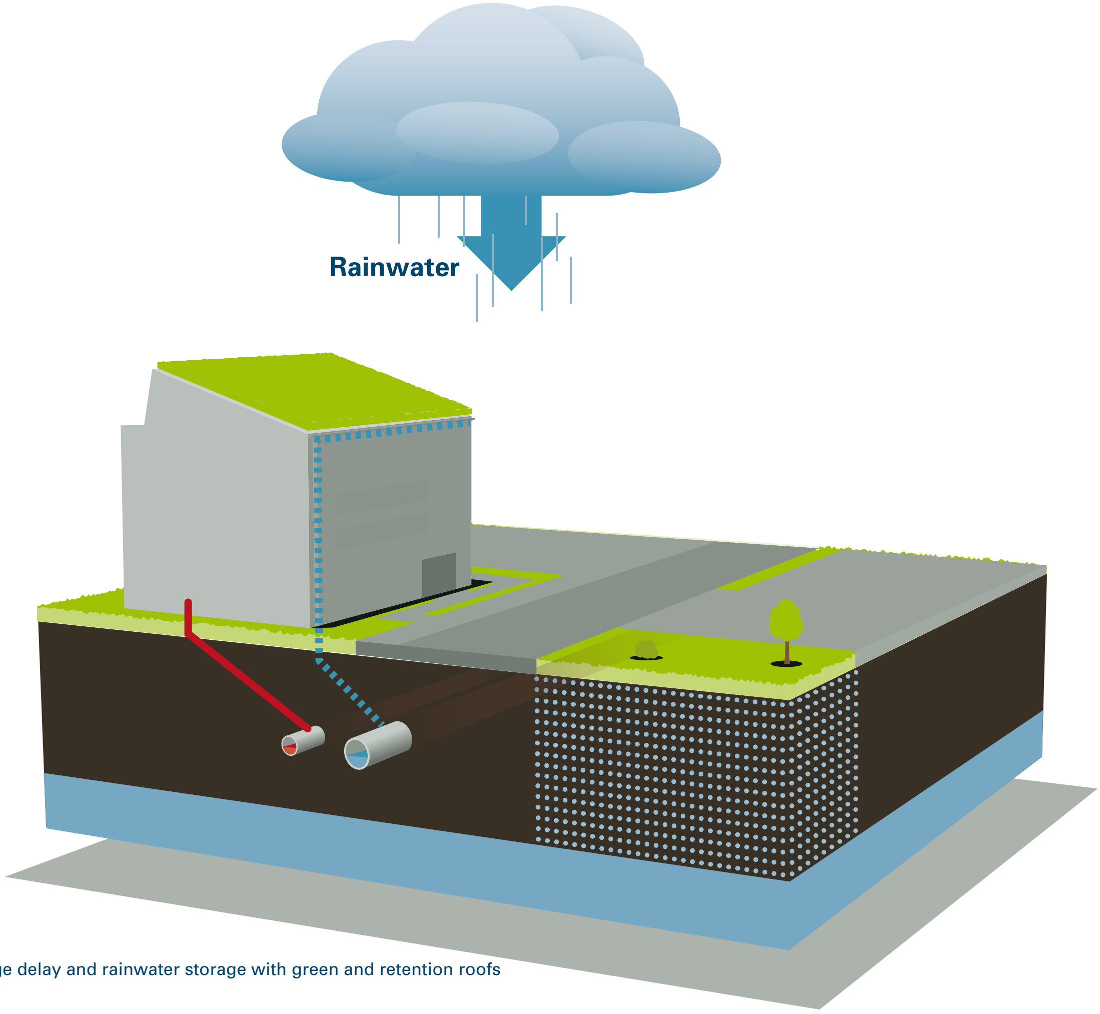


Figure 5
Discharge delay and rainwater storage with green and retention roofs

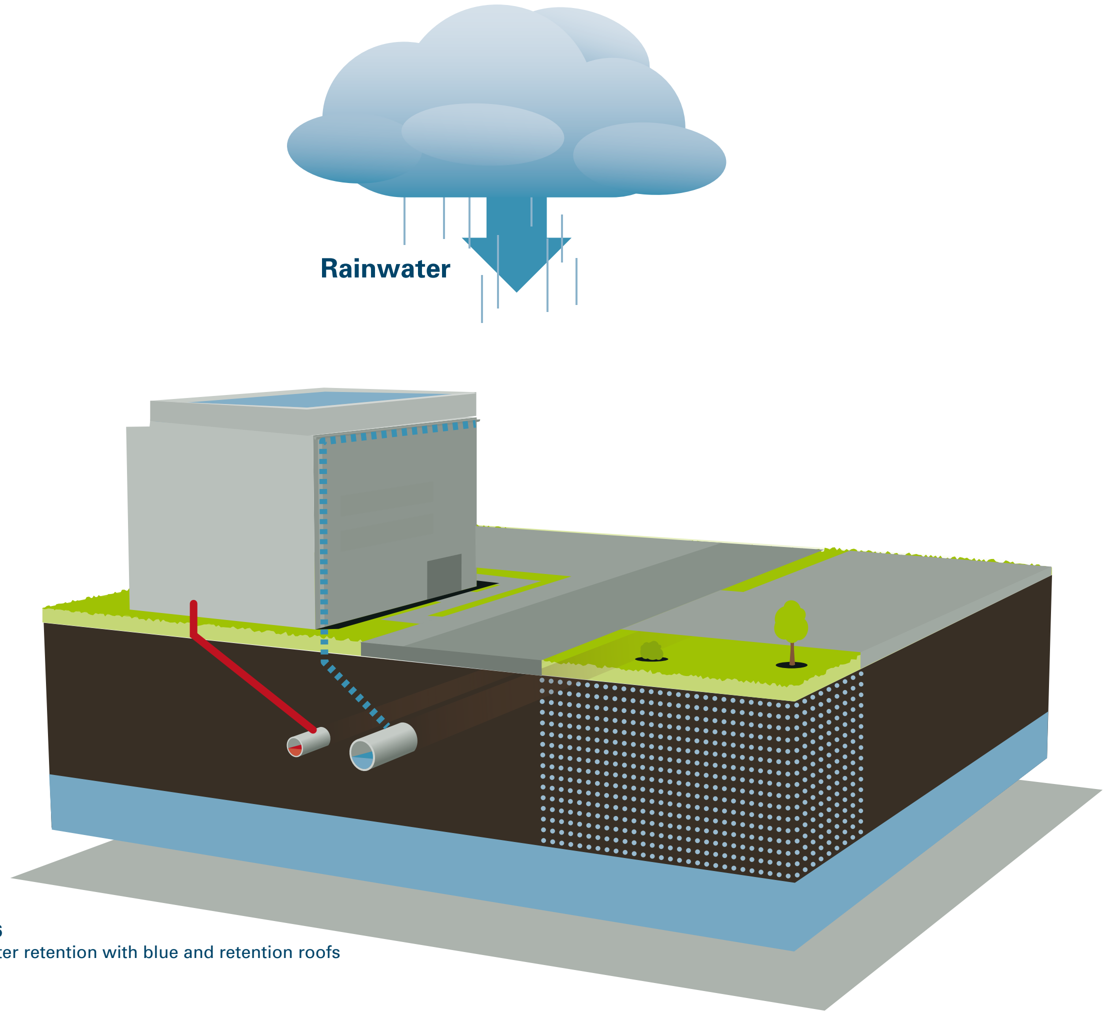


Figure 6
Rainwater retention with blue and retention roofs

up storage space. This mitigates peak runoff from the roof areas and, at the same time, permanently supplies the green roof with water (Optigrün, 2016).

Legal framework for storage on the property

Retention on the property with combined runoff control can generally be provided for in by-laws to the extent this is compliant with the duty to dispose of wastewater as well as building planning and usage fee law.

5.2.3 UNDERGROUND RESERVOIRS

Water from sealed areas and roofs of a property can also be directed to the reservoirs instead of the sewer. Above ground and underground basins are differentiated from one another whereupon their design depends on the available area. With a very large base area coefficient (GRZsuch as e.g. in core areas, the water must be stored underground; in tanks in unused basement rooms or in reservoirs. With these types of storage, the water can be used further (Mall, 2016). Tanks and underground reservoirs can also be used in the presence of a steep slope because the water must be transported to the tanks via pumps depending on the location on the property. In the event of rainfall that is so severe that the reservoirs are filled up, the additional water will run off via a spillway.

Legal framework

The legal framework corresponds to the requirements for storage in basins. (see Section 5.2.4)

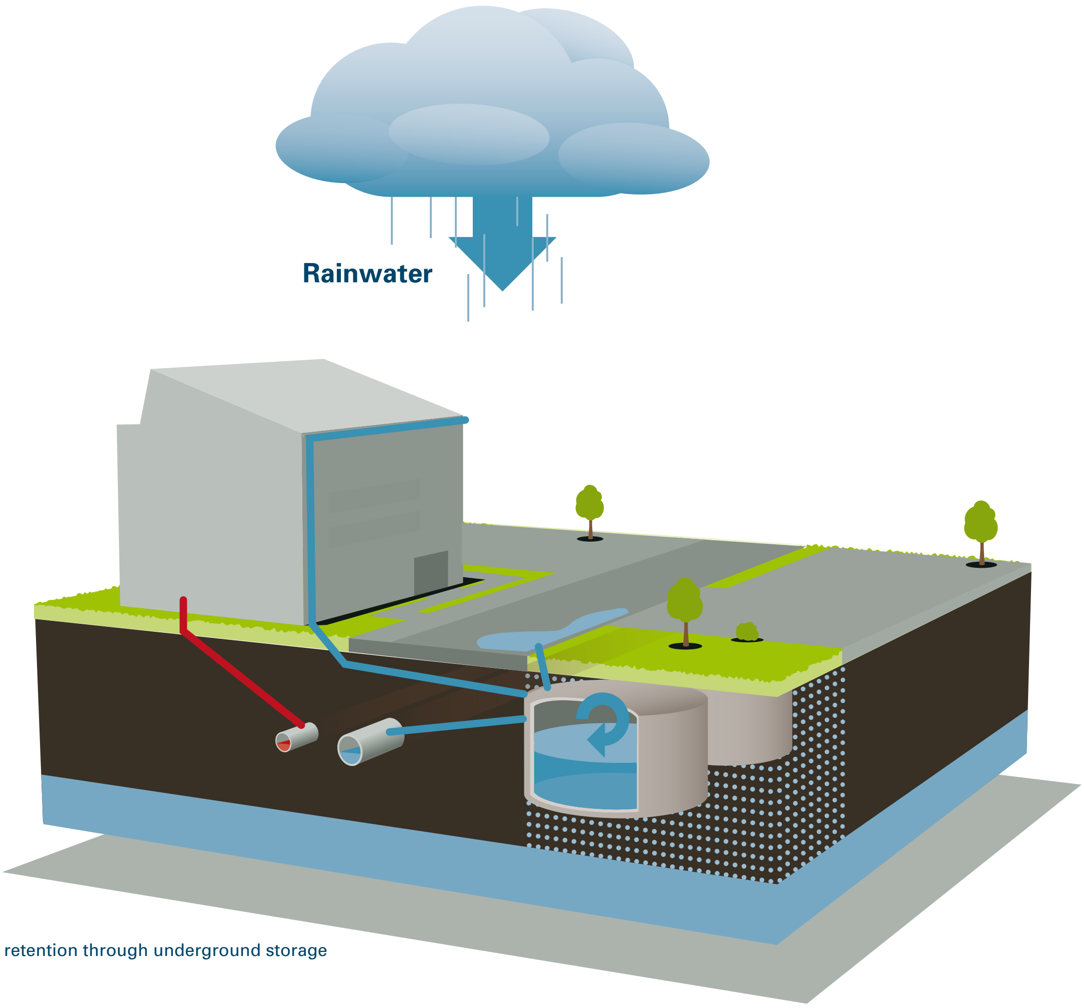


Figure 7
Rain water retention through underground storage

5.2.4 RETENTION BASINS

If enough space is available, a retention basin for interim storage of the rainfall is an effective measure for collecting water and directing it away from endangered areas. By modifying the slope on the property or creating small trenches, the water can be redirected to the retention basins on the surface. It can also be directed there via pipes. If heavy rainfall is more seldom, retention basins must have a spillover to the sewer. If the soil conditions are suitable, a basin reservoir can also be combined with a an infiltration system (see Infiltration).

Depending on the design, high water levels may occur in the flooded retention basins, which could pose a risk to people. In such cases, the retention basins should be secured to prevent unauthorised entry.

Legal framework

1. To the extent infiltration occurs after storage in underground or above ground basins, in addition to the creation of the statutory basis, release from the duty to pass on wastewater (cf. Section 49 para. 4 NRW Federal State Water Law) or partial release from the compulsory connection and usage requirement also occurs providing this complies with wastewater and building planning law. In consideration of Section 55 para. 2 Water Resources Act, no concerns relating to water law and water management or other public-law regulations may conflict with this.

2. The allocation of water from the reservoir for other use (for example, rainwater utilisation system) generally requires a corresponding statutory provision.

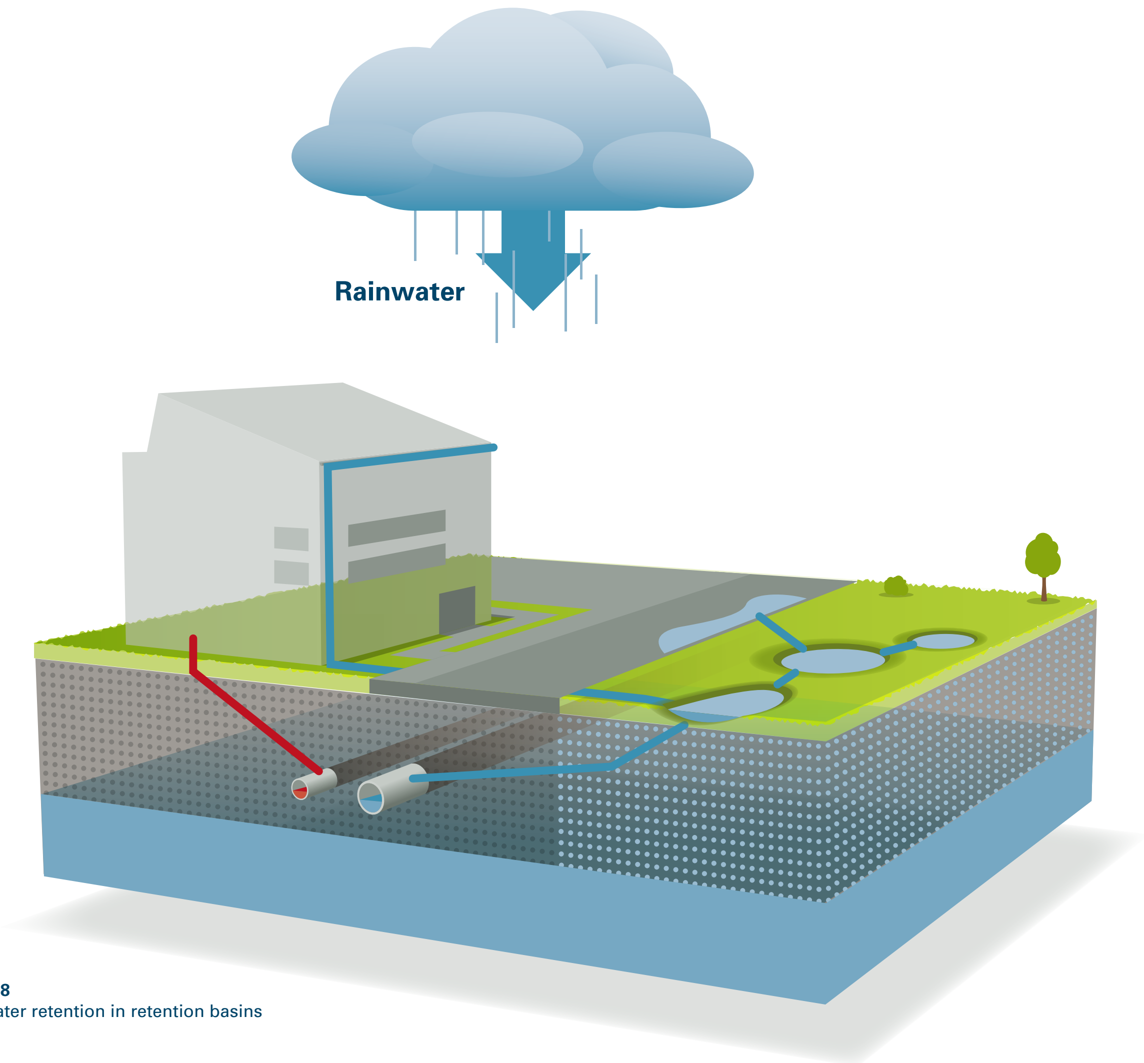


Figure 8
Rainwater retention in retention basins

5.2.5 RETENTION ON THE SURFACE

In addition to retention basins or reservoirs, the water can also be retained at least temporarily on the surface for interim storage. Level traffic areas and parking lots are particularly suitable for this, however, this type of retention can lead to the area not being used for a period of time or only to a limited extent. The level to which the water rises and how long it remains there must be determined on a case by case basis. It must be noted that important points of entry for rescue vehicles must remain passable. Orientation values of 20 cm water level on the street and 10 cm water level on footpaths are proposed. The retention of the water in the area may not subject stress to the surrounding building fabric, even if the storage system is overloaded. With an increasing slope or less favourable makeup of the terrain, such a reservoir can no longer be realised or only through substantial structural intervention in the terrain.

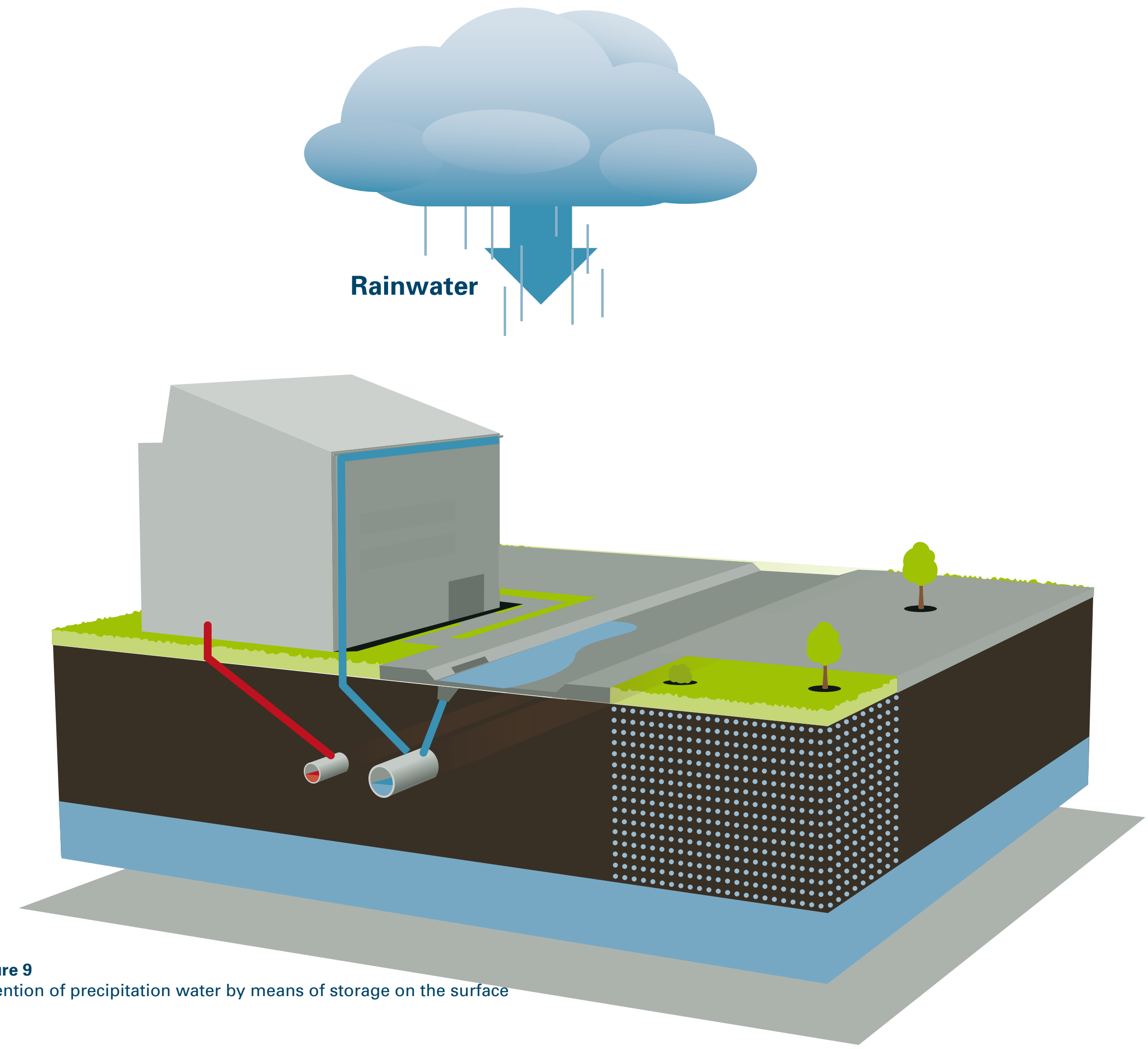
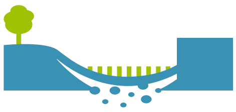


Figure 9
Retention of precipitation water by means of storage on the surface

Legal framework

As this measure also involves infiltration of the precipitation water, a statute, to the extent it complies with wastewater and building planning law, can be implemented or complete (cf. Section 49 Abs. 4 LWG NRW) or partial exemption from the compulsory connection and usage requirement may occur. In consideration of Section 55 para. 2 Water Resources Act, no concerns relating to water law and water management or other public-law regulations may conflict with this.



5.3 INFILTRATION

Unsealed areas reduce the runoff while this effect is restricted in the event of heavy rainfall through the quick saturation of the soil. The effectiveness also depends on the soil conditions. As a result, sand and gravel, for example, allow a significant portion of the water to infiltrate.

In addition to natural infiltration, corresponding facilities can be used to release surface and roof water into the soil. This possibility lends itself particularly in the event of frequent rainfall events. The behaviour of these systems in the event of more seldom heavy rainfall and their effectiveness with respect to protecting property varies from case to case. Depending on the size of the area, different facilities are suitable as they have a different effect on the ground water and the natural water balance:

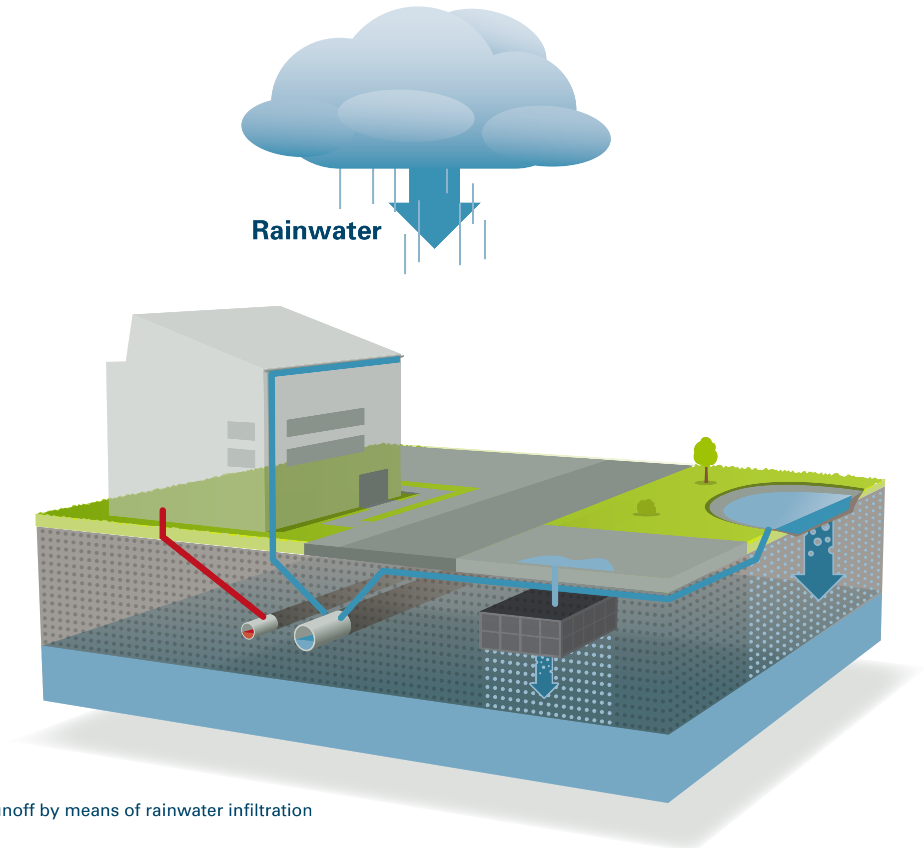


Figure 10
Reduction of runoff by means of rainwater infiltration

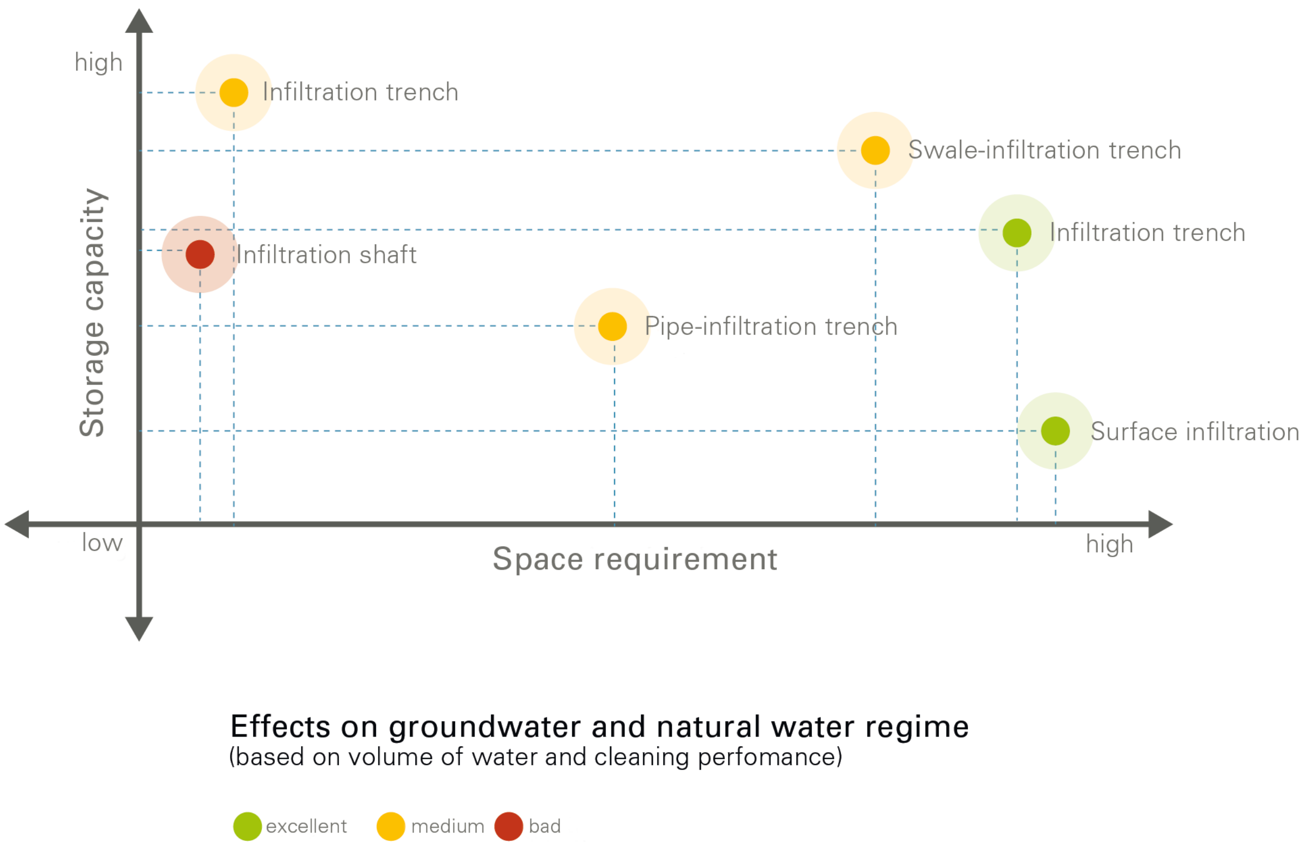


Figure 11
Comparison of different infiltration systems, expanded in accordance with GRAF (2016)

Figure 11 evaluates the infiltration systems in terms of the space they require, storage capacity and effect on groundwater. It has been shown that though shaft and infiltration trench infiltration require less space, they offer moderate to high storage capacity, which, however, may affect groundwater to a greater degree.

In general, the current condition of the own and neighbouring properties may not deteriorate through the construction of an infiltration system. Infiltration systems in sloped areas are also critical as water may quickly leak and erosion may occur. The respective by-laws stipulate which infiltration systems are not approved under certain circumstances.

Legal framework with respect to infiltration on the property

In general, infiltration on the private property can be stipulated in by-laws to the extent this complies with wastewater and building planning law or complete exemption from the NRW duty to pass on precipitation water (cf. Section 49 para. 4 NRW Federal State Water Law (LWG)) and/or partial exemption from the compulsory connection and usage requirement can occur. In consideration of Section 55 para. 2 Water Resources Act, no concerns relating to water law and water management or other public-law regulations conflict with this.

5.4 EVAPORATION AND TRANSPIRATION

Evapouration and transpiration on green areas via beds or depressions can be viewed as having the added positive effect of 100 per cent retention and also has a positive effect on the micro climate and as a preventative measure with respect to heat. If the soil is saturated, surplus water runs off on the surface.

The actual amount that evaporates and transpires depends on the property's vegetation and season. The majority of transpiration occurs via plants and the remaining evaporation takes place at the surface. The fact that water evaporates and transpires much less readily in winter than in summer is attributed on one hand to less vegetation and foliage and on the other to less solar radiation and air temperature. In general, the rate of evaporation and transpiration is lower when surface runoff is fast - such as on streets.

In the event of frequent rainfall events, **interception** also reduces the volumes of water that reach the ground. The rain drops first remain on the leaves and do not reach the ground. During heavy rainfall, however, this effect is negligible.

Interception

The retention and collection of precipitation (rain or snow) on the surface of vegetation is referred to as interception. The water evaporates and does not reach the ground.

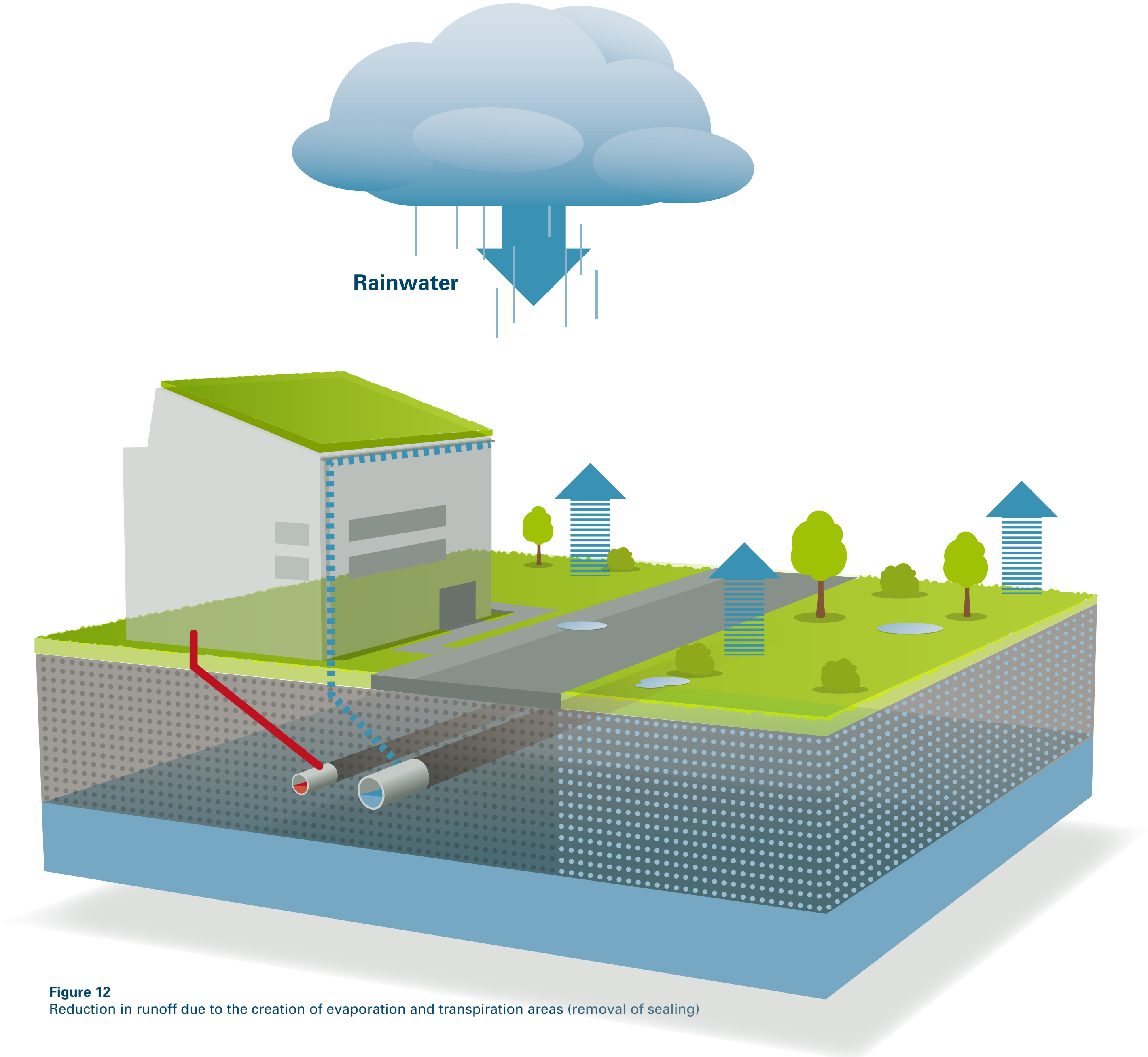


Figure 12
Reduction in runoff due to the creation of evaporation and transpiration areas (removal of sealing)

5.5 REMOVAL OF SEALING

The removal of sealing offers many benefits. The less sealed area on a property, the more water can infiltrate the soil and also counteract a decline in the groundwater level. If areas cannot be completely unsealed, a range of pavement systems exists that permit infiltration and at the same time, can carry traffic loads.

This is accompanied by the fact that water evaporates and transpires much more readily in green areas than on sealed ones. As a result, the removal of sealing increases the evaporation and transpiration of a property.

Legal benefits of removing sealing in an area and evaporation and transpiration

The removal of sealing in an area and evaporation and transpiration can contribute to precipitation water having to be redirected from built-up and/or sealed surfaces in order to prevent flooding of neighbouring properties and public traffic areas as the water from precipitation can naturally infiltrate areas where sealing has been removed.

5.6 DRAINAGE

Regardless of the type of reservoir, it must be emptied after a rain to make room for the next rainfall. It can be emptied e.g. into the sewer in a controlled manner. Depending on the system and season, portions of the water can be allowed to infiltrate or evaporate and transpire.

Legal framework for the controlled discharge of stored precipitation water

Retention on the property with combined runoff control can generally be provided for on the basis of by-laws to the extent they duly comply with the duty to dispose of wastewater as well as building planning and usage fee law.

ANALYSIS OF EFFECTIVENESS

The analysis based on a model of the following sample property shows how effective the measures for binding heavy rainfall actually are. Laser scan data is used for the model and a surface runoff model has been developed. Subsequent sprinkling with artificial rainfall makes it possible to obtain information on how the initial state changes and how the respective measures show their effectiveness. In the process, it is shown that the retention of the precipitation in particular is a decisive factor in providing protection against heavy rainfall. It can also be carried out with relative ease and effectiveness on the sample property. A legal assessment of feasibility will also be provided.

06 ANALYSIS OF EFFECTIVENESS BASED ON A SAMPLE PROPERTY

Below, the measures will undergo an analysis of their effectiveness and be examined on the basis of a sample property. As the infiltration characteristics of soil vary greatly depending on the location, it has been assumed for the following analysis that infiltration is not possible. As these measures tends to have smaller scale, the analysis can still be transferred to locations with permeable soils. In this case, however, the effect of infiltration on neighbouring properties must be observed (see Section 5.3).

A surface runoff model is used for the analysis; sprinkling with artificial rain occurred across its area. The measures will then be evaluated based on the flow channels and flooding, particularly of buildings and based on water balances.

The sample property is based on a property that actually exists, but its characteristics were changed for the analysis.

6.1 THE SAMPLE PROPERTY

Sample property

For the sample property, an area with flat, uniform topography covering 76,180 m² was selected. The average incline amounts to 3.64 %. The property is built up with different multi-storey offices; an old palace and printing press are also located there. The buildings are primarily fitted with flat roofs (total roof area of: 15,870 m²). Most buildings are without a basement. With a total of 44,300 m², approximately 58 % of the property is sealed. This corresponds to approximately the share in residential, village and mixed-use zones (see Section 2.3, Table 1). In addition to the buildings, the property primarily comprises parking lots and access roads to the sealed area. Unsealed areas on the property are primarily green space planted with trees.

LEGEND

Use

- Parking lot
- Street
- Roof area
- Roof area with basement
- Paths
- Green space

Figure 13
Overview plan for the accompanying property

Table 4: Core data for the sample property	
Size	76,180 m²
Green space	31,880 m²
Sealed surface	44,300 m²
Roof areas	15,870 m²
Streets	14,680 m²
Parking lots	6,800 m²
Paths	6,950 m²
GRZ	0.6
Average incline	3.64%

6.2 COMPUTATION MODEL

The analyses for the respective measure were performed using a computer-based calculation model, which on one hand calculates the runoff into the sewer network (sewer network model) and, on the other hand, the runoff on the surface (surface runoff model). Via defined links, the water – as is also the case in real life – reaches the sewer network from the surface and vice-versa; it also returns to the surface when the network is overloaded. A rain occurring across the area of the surface runoff model serves as an input variable.

6.3 MODEL PARAMETERS

Setup of the model

Laser scan data was used within a 1m grid for the surface runoff model. The high points were connected to a uniform triangular network with areas of half a square metre. In the process, the buildings were viewed as break lines not permitting flow through them.

Surface roughness

The makeup of the terrain surface decisively affects the runoff on the surface. As a result, higher flow rates and lower water depths occurred on smooth surfaces compared to rough surfaces. In order to render the runoff behaviour mathematically, a parameter, which accounts for the roughness, is required. The equivalent sand roughness k simulates a surface structure having grains of sand of the same side. As a result, a road surface with an approximate coefficient of roughness of k = 1 - 10 mm.

In order to render the roughness of the surface and the capacity of the soil for infiltration, all areas were divided into categories. The sealed areas (buildings, streets, paths and parking lots) have an equivalent sand roughness of k = 10 mm; infiltration is not possible in these areas. An equivalent sand roughness of k = 80 mm was assigned to the green areas.

The sewer network (rainwater network) was digitalised based on an as-built plan. Street drains that were drawn in were connected directly to the shafts. The following assumptions generally applied:

- No infiltration (0 mm/h)
- No surface runoff to neighbouring properties, no external inflow
- No runoff into the public sewer system
- Separated sewer system (only rain water is considered)

– the combination of all retention measures should retain the water during the rain water event. In order to manage the reservoirs in a sensible manner and make room for subsequent rainfall, the reservoirs must be drained after the rainfall. This drainage was no longer part of the simulations and must be determined separately.

A number of model parameters will be explained below.

6.3.1 ARTIFICIAL RAIN

From KOSTRA-DWD (German Meteorological Office), the rain was selected for a city roughly corresponding to the German average. A 100-year event according to KOSTRA-DWD 2010 lasting one hour was adopted as artificial rain. This corresponds to a depth of precipitation of 47.5 mm/h and a rainfall intensity of 131.9 l/s*ha. Artificial rain based on Euler's type II distribution was selected.

For the coupling between the surface runoff model and the sewer network model, it was assumed that conventional roof drainage can drain a five-year event into the sewer without a problem. In the event of heavy rainfall, the excess water sprays over the gutters or reaches the surface by means of emergency drainage. The difference of the rain discharged via the roof to the artificial rain was apportioned to the remaining surface. The artificial rain applied to this area was increased slightly as a result. The following figure shows the artificial rain applied with Euler's type II distribution.

SELECTED ARTIFICIAL RAIN

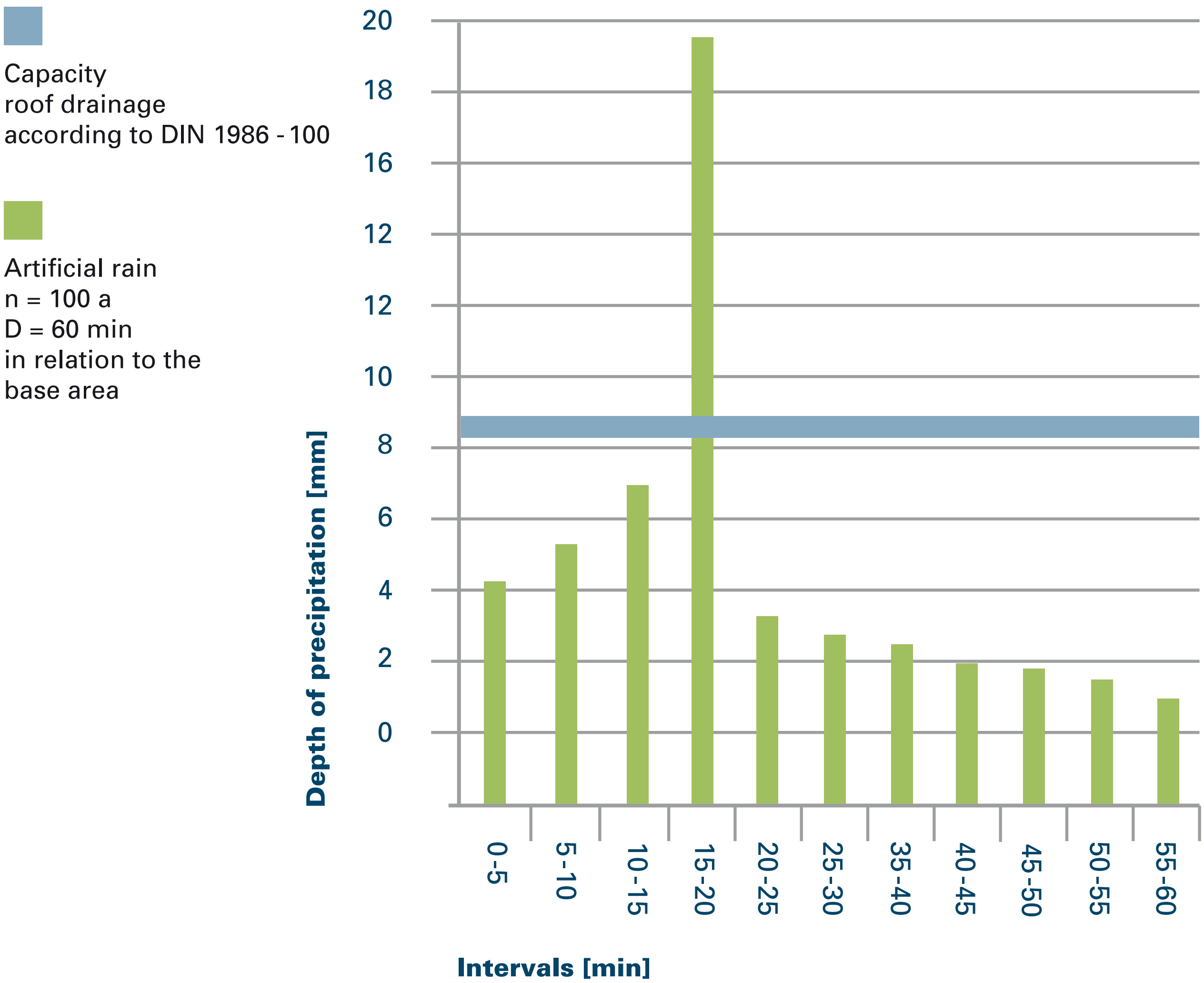


Figure 14
Selected artificial rain

6.3.2
SOIL PARAMETERS

Defining an average infiltration rate for Germany does not make sense due to geographical variations. As the water levels on the property with nearly impermeable soils (such as clay) on one hand and, on the other hand, highly permeable soils (such as sand or gravel) can differ greatly, a study with different soil values was performed initially. For this, the sample property was assigned different infiltration rates with presaturation of the soils. The result showed that the infiltration capability significantly affected the retained volume of water. With an artificial rain with a volume of 3,600 m^3, approximately 1,000 m^3 was, for example, able to infiltrate with sandy soils. The following table shows the results of the parameter study.

In order to ensure that the results of the model can also be transferred to properties with highly unfavourable soil conditions, it was assumed for the following simulation that also no infiltration took place on the green areas.

Table 5: Analysis of the parametric study of soil parameters
(infiltration rates according to Horten/Paulsen, 1986; Brouwer, 1986; Ward & Robinson, 1990)

Soil type	applied infiltration rate	infiltrated volume (rain volume V = 3,600 m^3, duration of rain D = 1 h)	Share of rain volume
Clay	0 mm/h	0 m^3	0 %
Clay loam - loam	5 mm/h	~ 380 m^3	10 %
Loam - sandy loam	10 mm/h	~ 620 m^3	17 %
Sand	20 mm/h	~ 1000 m^3	30 %

6.4
INITIAL STATE

The results of the calculation for the initial state show the maximum water levels for the entire duration of the calculation time (in this case, two hours). These water levels do not necessarily occur at the same time. It is apparent that the water collects in the depressions on the access roads, parking lots and green area. Due to the nearby outer limit along the edge of the model, the water also collects in the depression on the green area between the access roads. The low point of the property is located on the access road along the western boundary of the model. Water levels of over 50 cm occur here.

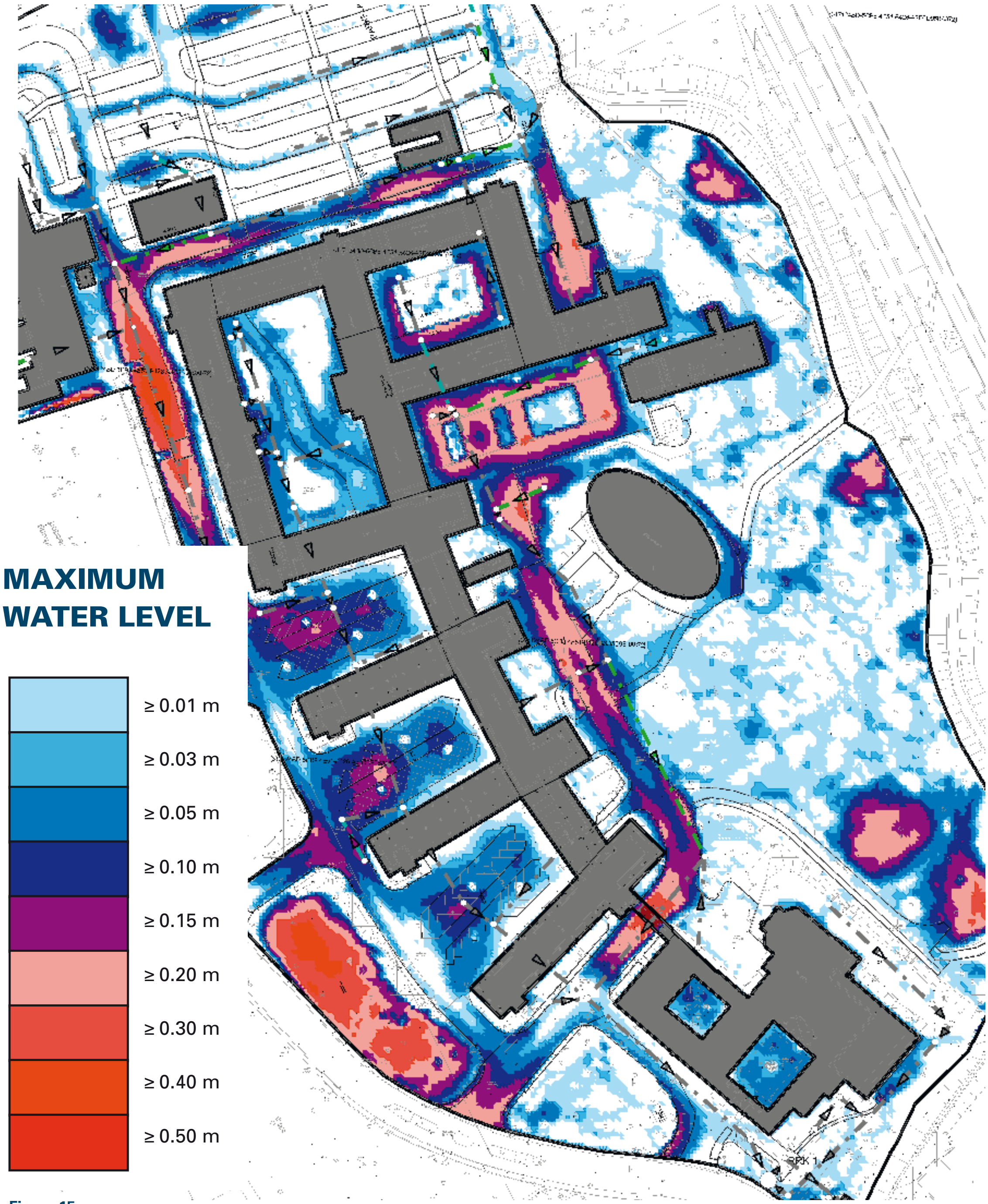


Figure 15
Calculation results for the initial state

6.5 MEASURES

The following figure summarises all possibilities of a sponge property as can be used in different combinations:

The "measures" for providing protection against heavy rainfall and for binding heavy rainfall presented in the Section "Measures" are evaluated below with reference to the model of the sample property. Furthermore, the legal feasibility will also be assessed in a brief statement. At the same time, this concerns a summary of a comprehensive analysis, which can be found in the appendix (to the corresponding online publication on www.bbsr.bund.de).

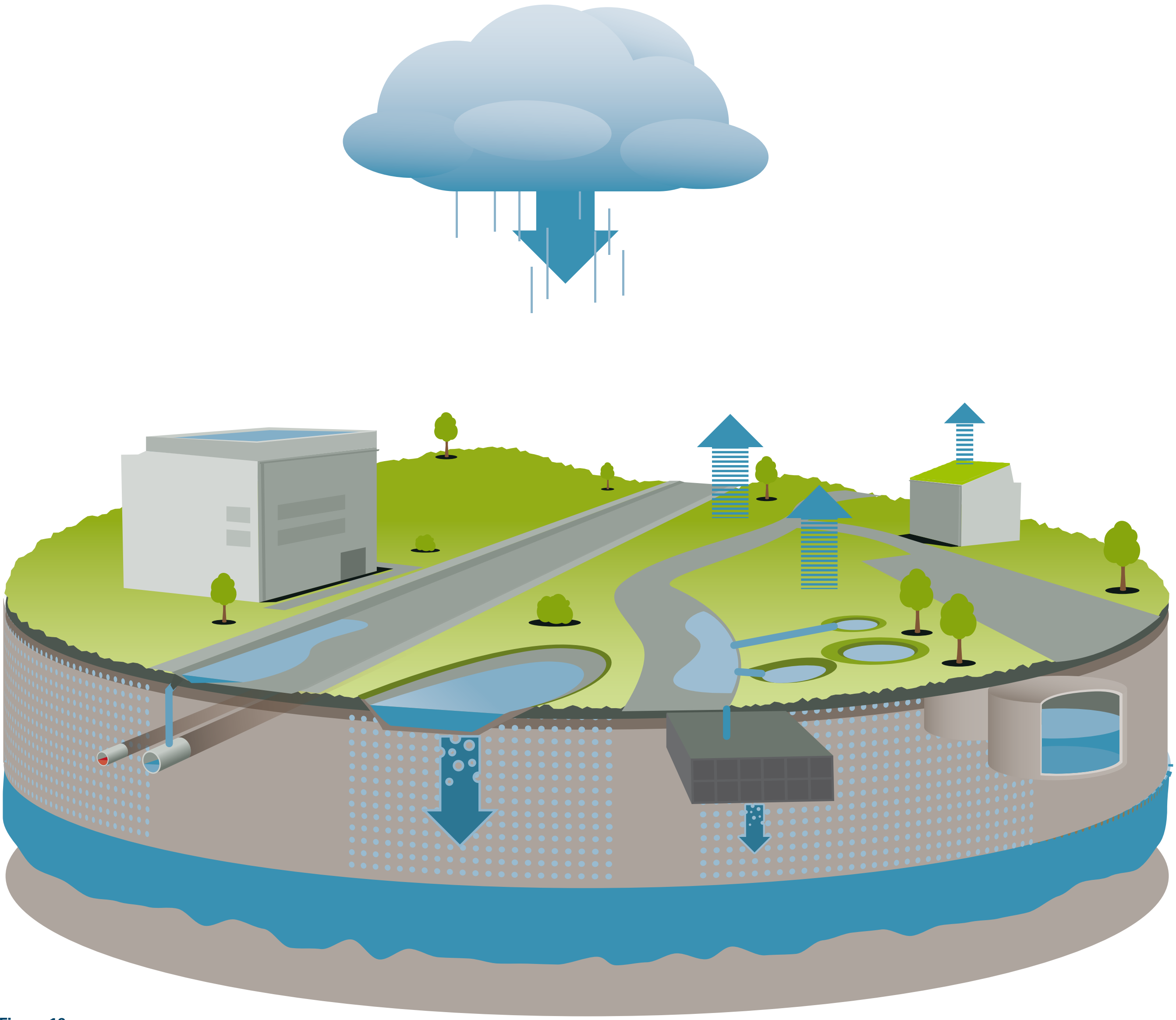


Figure 16
Measures for a sponge property

6.5.1 RETENTION IN THE SEWER

The rain water network of the sample property has a volume of 960 m³ and is used as an underground reservoir for the precipitation water. In the model, the sewer was closed with a throttle valve. The closure of the network causes it to fill up like a reservoir. Excess hydraulic head occurred at some points (49 shafts). Based on the flat terrain and the lack of pressure head, the excess head volumes are very limited (maximum 1.4 m³). As a result, 90 % of the sewer volume can be used as a reservoir. The remaining 2640 m³ of the precipitation water remains at the surface in the depressions and retention basins (see Figure 8). This version is the initial state for all other considerations.

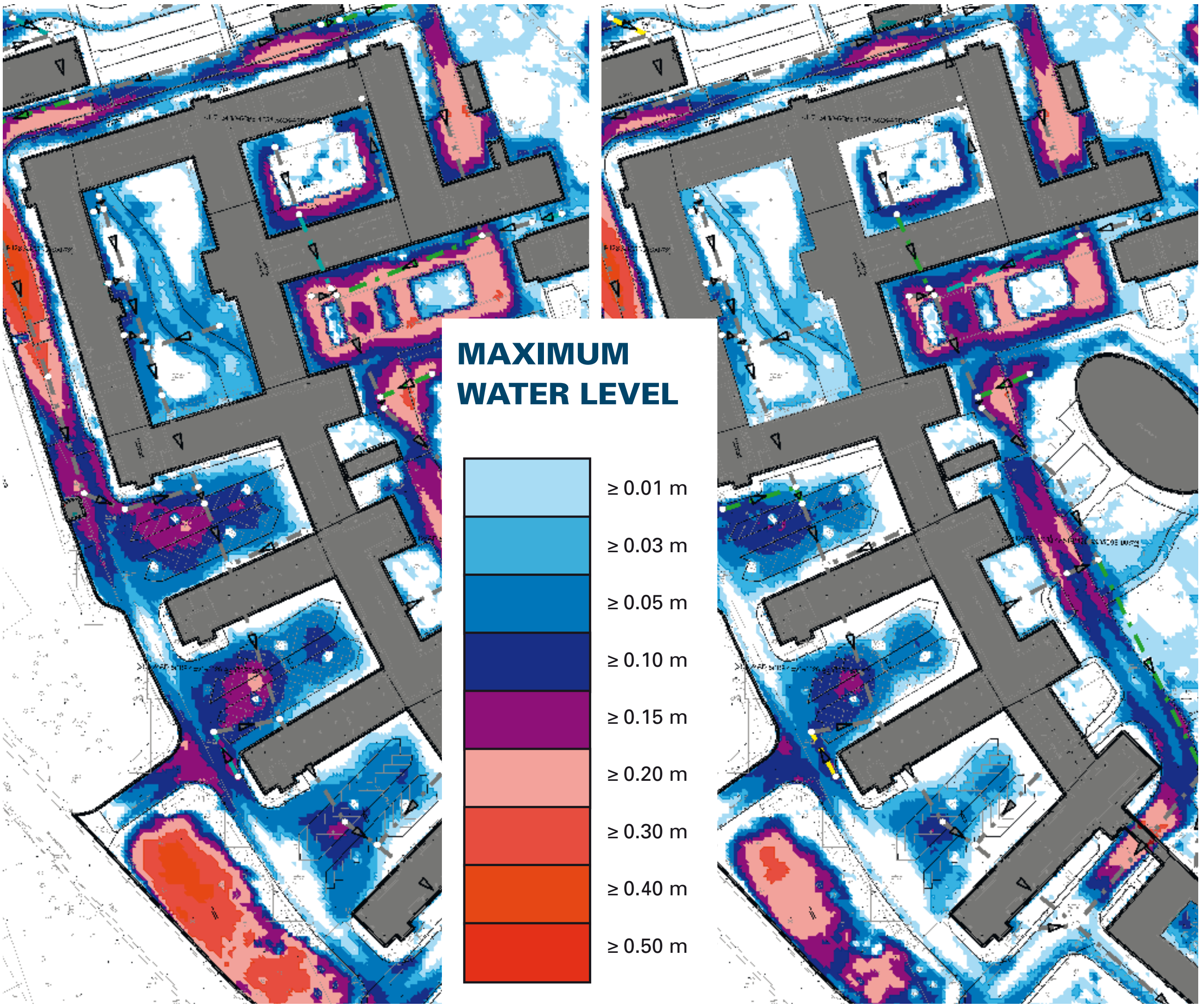
6.5.2 RETENTION ON THE ROOF (GREEN ROOF/ BLUE ROOF)

The development of the sample property predominantly with flat roofs is highly suitable for buffering the runoff and roof-based retention. The model distinguishes between two variants.

First of all, the green roof was rendered. These roof forms are much flatter and as a result lighter; they have a relief or a spillover. They do not have an additional water reservoir and instead only retain the water in the vegetation and substrate layer and gradually release it.

In the model, the quantity of precipitation of a 60-minute, five-year event was discharged to the sewer via the roof. For precipitation volumes exceeding a 100-year artificial rain, it was assumed that they are retained by the green roof so that no water reaches the surface from the roofs. It was calculated that 350 m³ were retained. For the roofs, this means a water level of approx. 2.2 cm whereupon it is not present on the surface of the roof, but is stored in the vegetation.

The other variant is a retention roof or a so-called blue roof that can store up to 100% of the roof water. Retention roofs have a water reservoir under the vegetation layer. Blue roofs only serve as reservoirs and are not combined with a green roof. In the model, this was implemented by disconnecting the roof areas from the sewer system. In the calculation, no water from the roofs reaches the sewer or the surface. In this way, a reduction of the water volume that would otherwise occur via the roof gutter or downpipes on the sample property amounting to approximately 700 m³ takes place. With a roof area of approx. 1.6 ha, this corresponds to a water level of 4.4 cm on the roofs. Another 2000 m³ remain on the rest of the surface. Though blue roofs do not completely relieve critical areas, the positive effects on the surface are noticeable. (see Figure 16)



INITIAL STATE

Figure 17
Comparison of the maximum water levels for the initial state and the "Retention/blue roof" variant

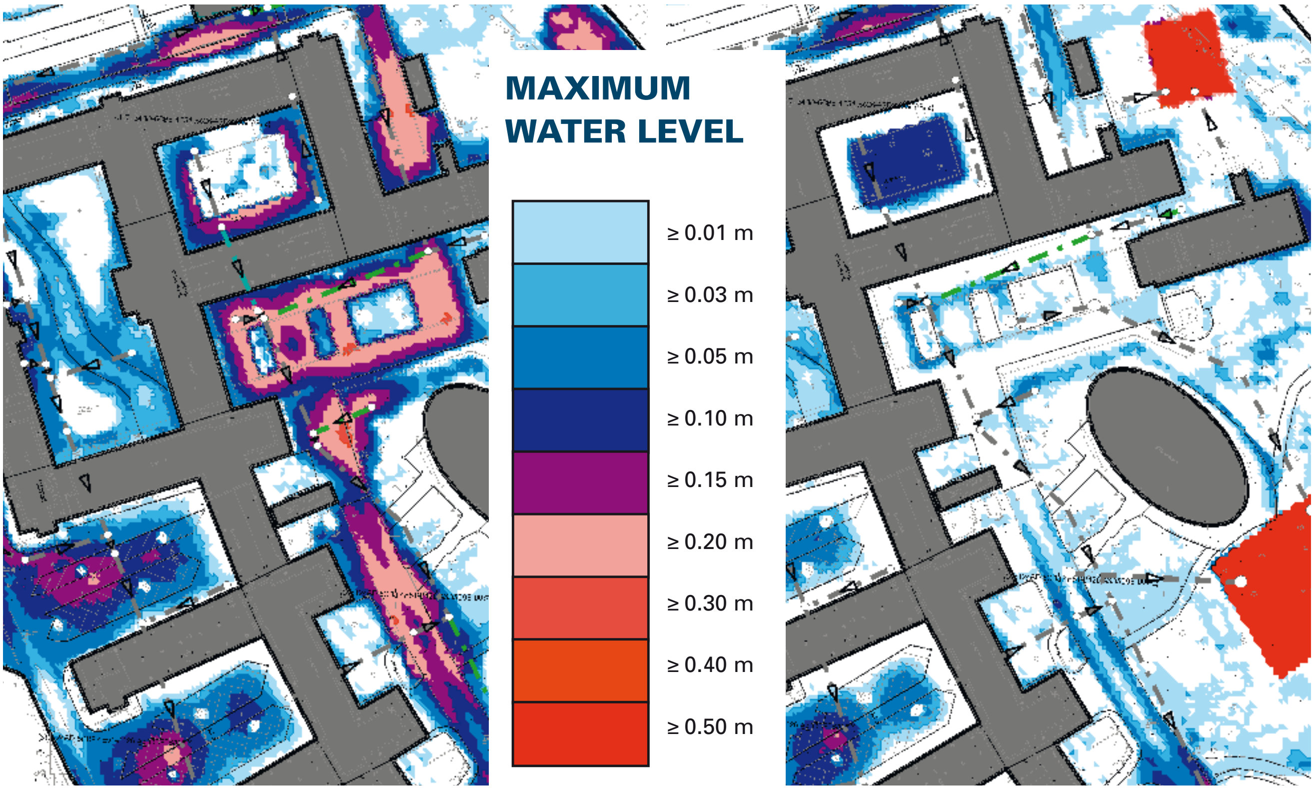
6.5.3 UNDERGROUND STORAGE RESERVOIRS

Assuming that the water completely runs off into the sewer, an underground reservoir for approx. 2640m³ must be sized. According to structural and economic aspects, this is not realistic. As a result, a reservoir with a volume of 500 m³ will be applied to the model for the retention of heavy rainfall. It could also be managed in parts as a non-potable water reservoir and a retention area for heavy rainfall.

Through the installation of the large reservoir (500 m³ in size), a storage volume of approx. 1,300 m³ results in combination with the sewer network. Nonetheless, 2,200 m³ of water remain on the rest of the surface and also on critical areas such as along the buildings.

6.5.4 RETENTION BASINS

Retention basins were integrated in the model for the sample property through the lowering of the ground surface. The retention basis and/or the changes in the incline of the surface produced excellent results in this respect. Particularly in a courtyard where the water was high along the existing structures, the change to the slope of the terrain offered a substantial benefit. The other depressions were filled via open supply lines. In this case, the water level amounts to between 90 and 110 cm. As a result, flooded streets and parking lots can be almost completely drained. The storage volume of all depressions amounts to approx. 1,300 m³. With such a design, a warning would have to be provided at the corresponding areas with high water levels and/or access to the depressions in the event of heavy rainfall would have to be prevented.



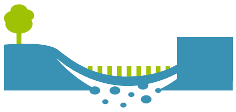
INITIAL STATE **BASINS**

Figure 18
Comparison of the maximum water levels for the initial state and the "Depressions" variant

6.5.5 RETENTION ON THE AREA

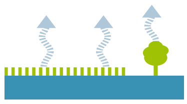
On the model property, it only makes sense to use traffic areas for retaining precipitation water as a complement to other measures. It would be impossible to temporarily store the entire precipitation water on the surface without having to accept substantial restrictions and structural changes. Depressions are present on both access roads on the sample property (towards the parking lot, printing shop and building underpass) where the water accumulates to varying degrees depending on the respective measure.

In the initial variant, the water accumulates there long-term at a level 50 cm and/ or 30 cm . It does not pose a risk to the adjacent structures, but at times blocks the road. In combination with further measures (see maximum variant, Section sponge property- (see maximum variant, Section 6.5.8), however, this only concerns a short-term impairment with water levels that remain over 15 cm for only 30 minutes. With the building underpass, however, the water accumulated in the amount of approx. 20 cm on the road until the end of the calculation. If water levels there were even slightly higher, measures would have to be taken to reduce the water level on the road and keep the access road free for rescue vehicles. This can be achieved by directing the water to underground systems or by changing the road cross-section: On one hand, the road could be adapted so that the water is able to distribute over a larger area and, on the other hand, it could be channelled to suitable areas such as a parking lot.



6.5.6 INFILTRATION

Infiltration has only been investigated in one study (see Section 6.3.2). Due to the differences of the soils, which vary from location to location, infiltration was not considered in the model.



6.5.7 EVAPORATION AND TRANSPIRATION

The evaporation and transpiration was not considered in the analysis as it only plays a subordinate role for the duration of the rainfall. Following heavy rainfall as well as smaller rainfall events, the share of evaporation and transpiration increases with surface measures to bind heavy rainfall. This affects the microclimate long-term and also has an effect during smaller events.

6.5.8 SPONGE PROPERTY (MAXIMUM VARIANT)

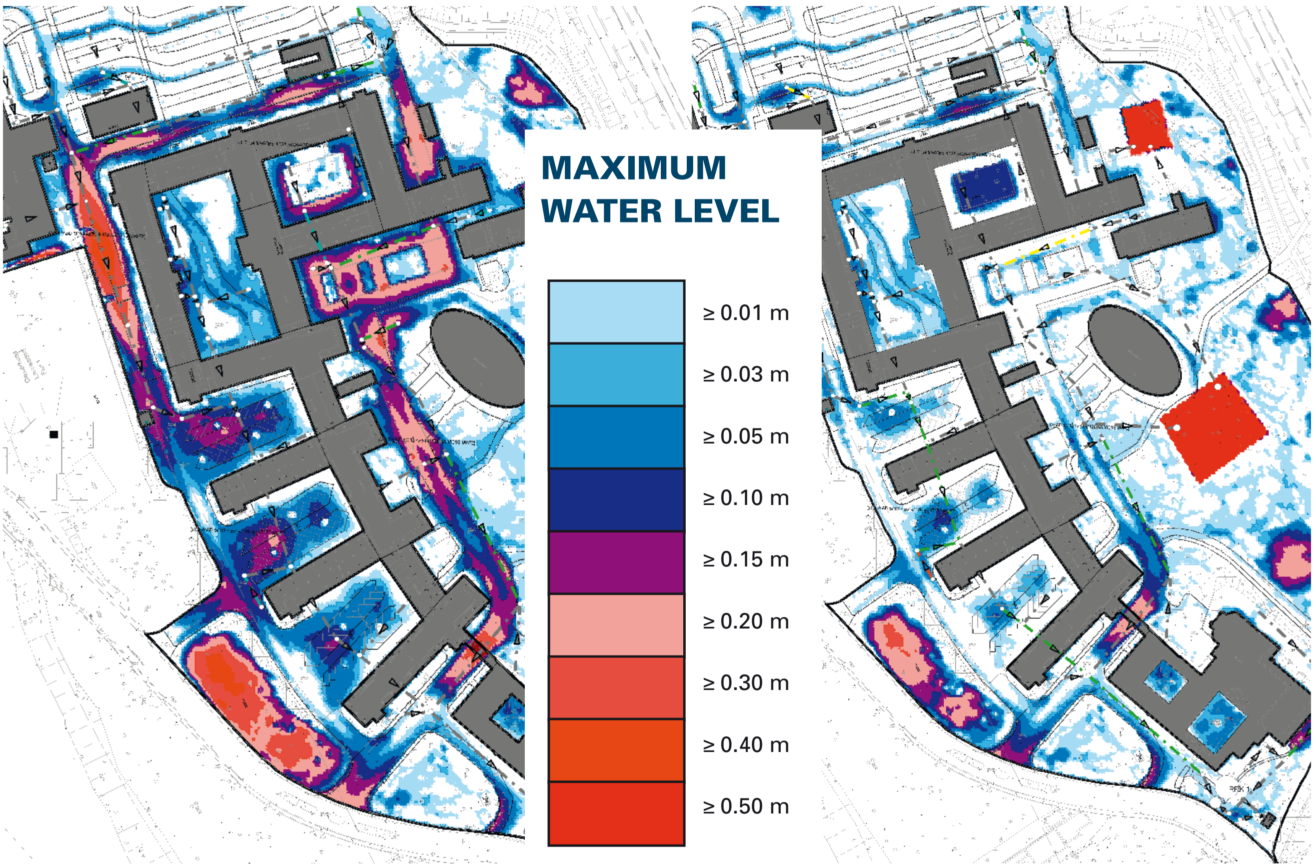
In order to retain the entire rainwater, a variant should be prepared that combines the presented measures so that the water can be stored on the property without damage.

Depressions were included as a measure on the surface. Retention roofs were used to also reduce flow into the sewer and reduce the burden on the surface. An underground reservoir was also used for water retention. Through the retention of the precipitation on the roofs, the depressions in this combined variant were not filled as high as in the individual variant and could still be scaled down. Due to the lower amount of runoff to the sewer, it no longer fills up to the point of excess head.

The desired result can be achieved with a combination of these measures: 2640 m³ rainwater can be directly retained. The water remaining on the surface is for the most part at uncritical points and does not pose a risk. Further measures, if applicable, are only necessary with respect to problematic points associated with the current situation of the property.

Building protection

Water is still present in a few spots by the buildings despite the combined measures. It must be ensured that the building is protected in these areas. If all entrances have a water and/or pressure-tight design and the walls are sealed, water that remains for short periods of time will not damage the building fabric. Measures such as a change to the slope of the surface, depressions or walls or curbs can also be taken to a small extent. However, this model does not aim to go into such detail. Measures for the protection of buildings are subject to to further evaluation.



INITIAL STATE

MAXIMUM VARIANT

Figure 19
Comparison of the maximum water levels for the initial variant and the "maximum variant"

Table 6: Additional building protection required on the sponge property

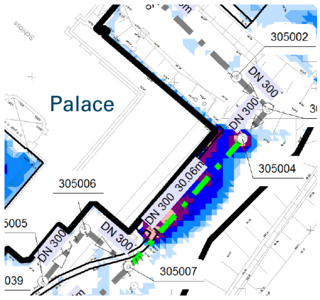
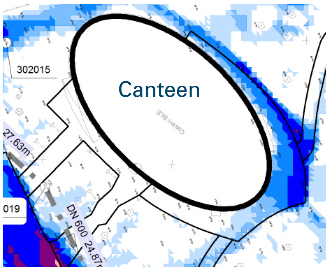
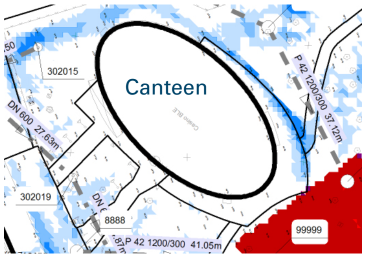
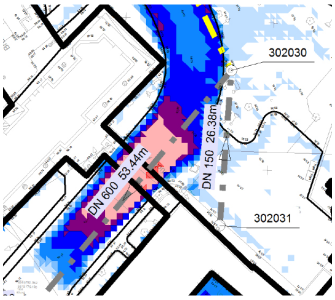
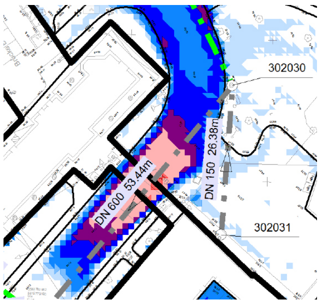
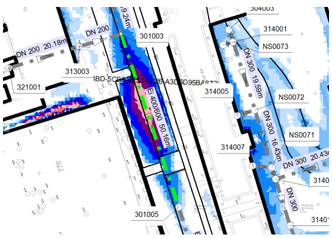
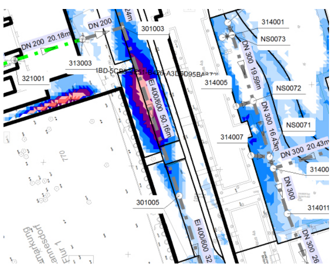
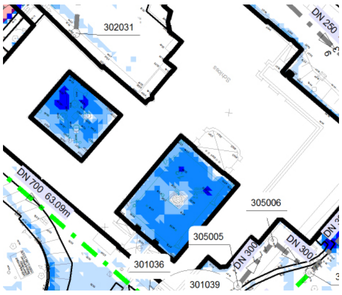
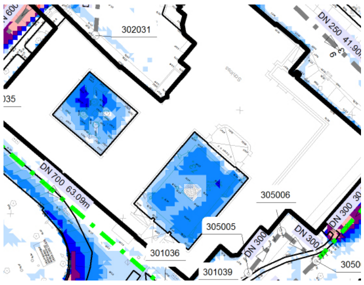
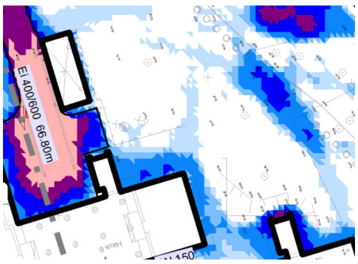
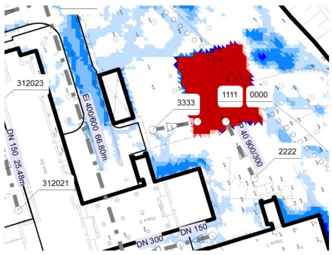
	Known hazardous areas current situation	Hazardous points with the application of combined measures	Possible measures
Ground-level entrance in a depression in the south-east area of the villa (problems have already been experienced here)			Installation of a flood-resistant door or other sealing measures (see Section Structural measures for protecting against heavy rainfall)
Water that has accumulated along the canteen building (high water levels have already been observed)			Hazardous situation associated with a depression mitigated
Water accumulated on the road around the underpass (problems are not known)			Water could be present in the area without damaging the buildings. Passage is restricted with water levels up to 20 cm
Water that has accumulated due to excess head of the sewer system (problems are not known)			Water could be present in the area without damaging the buildings. With water levels just over 15 cm, passage is slightly restricted

Table 6: Additional building protection required on the sponge property			
	Known hazardous areas current situation	**Hazardous points with the application of combined measures**	**Possible measures**
In the courtyards, the water is present along the area with a basement. Depending on the design of the entrances and windows, this may result in problems.			Sealing of ground-level entrances, raised edges for light shafts. The emergency spillway of the roofs should not lead into the courtyard (see Section Structural measures for protecting against heavy rainfall)
Water present by the building. No problems are known.			The risk could be significantly reduced by channelling the water to a depression. As to whether the remaining water level is harmful for the building depends on the design and building fabric

6.6. SUMMARY

6.6.1 TECHNICAL EFFECTIVENESS

For the sample property, up to 2,650 m³ of rain water can be directly retained through the combination of measures (maximum variant). With 350 m³, green roofs have the smallest effect, which can be doubled through the use of retention and/or blue roofs. The underground reservoir can be fully utilised for retention of 500 m³. If it is used as a retention reservoir including use of water, the dimensions must be adapted to keep the retention space the same size for heavy rainfall. With retention of 1,300 m³, retention depressions on this property are the most effective measure. In combination with other measures (maximum variant), only 850 m³ flow to it and could be made to be smaller.

73 % of the precipitation can be retained by structural changes through a combination of all measures. The rest, with a few exceptions, remains on the surface and does not pose any risk of damage to the buildings. The problem areas that continue to exist have already been identified in connection with the actual state and can only be rectified with targeted measures for building protection.

Table 7: Volume bilance of all calculated variants/measures

	Measures					
Volume balance in m³	Initial variant (with sewer)	Underground reservoir	Depres-sion	Retention roof/ blue roof	Green roof	Maxi-mum variant
Rain (total water volume)	3600.00	3600.00	3600.00	3600.00	3600.00	3600.00
Spillage model border	0.00	0.00	0.00	0.00	0.00	0.00
Water on the surface after 2h	2700.00	2280.00	*2700.00	2000.00	2350.00	*1800.00
Surface loss (in particular, infiltration)	0.00	0.00	0.00	0.00	0.00	0.00
Volume of the sewer network m³ that was used	900.00	820.00	900.00	900.00	900.00	600.00
Storage volume (underground)		500.00				500.00
Depression volume			1300.00			850.00
Roof reservoir				700.00	350.00	700.00
Total retention volume	900.00	1320.00	2200.00	1600.00	1250.00	2650.00

* including water stored in the depression

Non-permeable ground has been assumed for all calculations. Instead of the controlled discharge of the stored water, infiltration and/or channelling to an infiltration system is another way to drain the reservoirs. In the event of improved or even good soil conditions, the situation is significantly relieved (see parameter study actual condition). Infiltration systems such as infiltration basins or infiltration trenches were not considered in the model.

6.6.2 LEGAL FEASIBILITY

The following legal assessment reflects the summary of a comprehensive study. The long text is available in the appendix (of the corresponding online publication at www.bbsr.bund.de). Implementation of technical measures

In general, the measures that are technically possible and were described above can be implemented legally. At the same time, different legal instruments must be considered:

- Permits under **water law** at least with respect to infiltration or channelling to water bodies by the intermediate water agency. This is always decisive when the ground water or the water bodies may be affected by the measure.

- **Exemption from the duty to pass on precipitation water** of property owners is an individual municipal instrument. According to which, the obligation to channel the precipitation water into the public sewer system (Section 49 para. 4 LWG NRW in connection with the respective drainage regulations). In general, (subsequent) exemption is voluntary, but must be requested by the property owner and cannot be asserted against his existing (connection) rights.

- **The statute provisions** can create prerequisites, which prescribe the retention of the precipitation on the applicable properties. **Stipulations** in the development plan are, however, only possible in accordance with the strict legal provisions of Section 9 BauGB.

Exemption from the duty to pass on precipitation water: Opportunities and risks

Full exemption from the duty to pass on precipitation water results in the public sewer being relieved hydraulically in that the precipitation water remains on the property and is disposed of. In return, the resident does not have to pay fees for precipitation water.

In general, in order to have noticeable effects on the utilisation of the sewer, larger areas must be disconnected. If this is possible and feasible, expensive measures targeting the water management infrastructure can be avoided as a result.

However, it is difficult to strategically steer voluntary initiatives towards exemption. On one hand, it is possible that the owners of the properties, which are to be disconnected, do not want this to happen and do not apply for exemption. On the other hand, there is a risk of setting so-called precedent cases. This means that, in the future, property owners, who, in the view of the wastewater system operator, have no interest in doing so, will and wish to also allow the precipitation water to remain on their properties.

There is also another obstacle: Through the increasing number of disconnections from the public sewer system, the costs for the public sewers will be carried by a smaller number of connected parties, which may lead to an increase in fees over the long term. As a result, disconnecting from the public wastewater facility is associated with the (long-term) avoidance of investments in the public sewer system.

A residual risk on the part of the municipality must also be considered to the extent the retention of the precipitation water on the property does not function properly. Though the municipality is no longer responsible for disposing of the precipitation water as it is the responsibility of the property owner, the municipality, as the party responsible for the disposal of wastewater, has approved and gone along with the disconnection of the property and leaving the precipitation water on the property. To this extent, secondary responsibility and a liability risk remain.

Possibilities under building planning law for pushing ahead measures in connection with new developments and the existing one

New developments and existing building zones must be distinguished from one another with respect to the implementation of the measures:

In the event of new developments, there are generally more legal possibilities than with existing developments as planning is not yet complete. As a result, it is possible in this case to adopt stipulations with respect to the areas for the disposal of precipitation water within the legal limits of Section 9 BauGB in the development plan and create a corresponding provision as a result. Finally, individual exemptions from the duty to pass on precipitation water can be granted to individual property owners as well as tips and advice on protecting buildings.

With the existing development, measures for retaining precipitation water on the property can be ideally implemented by creating incentives for the property owners.

The fact that the property design, use of the property and the building itself fall under a so-called grandfather clause in these cases is problematic. This means that the property owner may rely upon the existing use of his property. Though such a grandfather clause no longer exists in wastewater legislation, changes are generally possible and can be implemented, Nonetheless, it is difficult to subsequently implement such measures. For example, the legal system of Section 49 para. 4 LWG NRW is created such that individual exemptions generally only occur at the request of the property owner and not at the request of the municipality. As a result, the property owner has a connection right, which it cannot simply be denied. Furthermore, the municipality must ensure that its sewer network is sufficiently utilised. Lastly, the variants of the disposal of precipitation water are both equally justified; the decentralised disposal of precipitation water will not be given precedence.

The most sensible way to create incentives with existing developments is with savings on charges. If the property owner is informed that, by disconnecting from the public sewer system, he does not have to pay the charge for precipitation water or only in part in the event of partial use or infiltration, he will most likely be prepared to submit an application for exemption.

Effects of the Hochwasserschutz-gesetz II (Flood Control Act)

The implementation of the Hoch-wasserschutzgesetz II brought three key changes in the area of heavy rainfall prevention:

- *Flood source areas* have been introduced as of 05 January 2018 (Section 78 d WHG). These are areas where, in the event of heavy rainfall or melting snow, above-ground runoff can occur in a short time, which can result in a risk of flooding in above-ground water bodies and consequently a substantial risk to public safety. The criteria for characterising and classifying such areas can be defined by the legal ordinance of the federal state where there is a labelling duty for these areas in the development plan. The goal is to improve or preserve the natural capacity of the soil for natural water infiltration and retention, particularly by removing ground sealing and by sustainably reforesting suitable areas.

- Furthermore, as of 05 January 2018, special obligations to obtain a permit apply in the flood source areas (Section 78 d para. 4 WHG). According to which, duties to obtain a permit apply for the construction or significant modification of physical structures in outdoor areas including ancillary facilities and other areas of 1500 m² or more, the construction of new roads, the removal of forest or the conversion of forest to another type of use and the conversion of grassland to arable land.

- Finally, new possibilities for stipulations in development plans already come into effect on 06 July 2017. Pursuant to Section 9 para. 1 no. 16 BauGB, water areas and areas for water management can now be defined as well as areas where certain structural or technical measures have to be defined in connection with the construction of physical structures, which serve to prevent or reduce damage caused by flooding including damage caused by heavy rainfall Likewise, the type of these measures and areas, which must be reserved on a building plot for the natural infiltration of water from rainfall, can be defined in order to prevent, in particular, damage from flooding including damage caused by heavy rainfall.

Suggestions regarding legislative initiatives

In general, the existing laws already offer numerous possibilities and options, which provide for the disposal of precipitation water and precautions for heavy rainfall.

The following suggestions may serve solely as impulses for future discussions and must be examined in depth before devising corresponding legislation:

- Pursuant to Section 5 para. 2 WHG, every person who could be affected by flooding is obligated, to the extent possible and reasonable for them, to take suitable measures to protect against the consequences of flooding and to keep damage to a minimum. According to this, every property owner has a duty to protect himself against flooding. As the flooding of properties as the result of heavy rainfall events does not, however, represent classic flooding according to the legal definition, it would make sense to also expand and clarify further the general duty of care to the flooding of properties on the basis of heavy rainfall events.

- Some municipalities already create maps for heavy rainfall events on the basis of flood hazard maps. The creation of such heavy rainfall hazard maps is possible in a legal respect and will continue to spread through the flood source areas that are to be introduced as of 05 January 2018. There is therefore no further need for regulation in this respect.

- At the level of the federal state, there is the possibility of creating funding programmes for heavy rainfall precautions, in particular for retention measures.

- In municipal law, there are already sufficient possibilities for providing for and devising the disposal of precipitation water. In this respect, municipalities should define stipulations in development plans (particularly based on the new stipulation possibilities of Section 9 para. 1 no. 16 BauGB). The possibility for exemption from the duty to pass on precipitation water according to the stipulations of federal state law should be provided for in the drainage statute. Furthermore, own statues regarding the disposal of precipitation water (Section 44 para. 2 LWG NRW or statutes on the devising process Section 86 BauO NRW) can be created, which provide for the disposal of precipitation water on properties. In this way, e.g. statutes can be implemented, which specifically provide for the infiltration of precipitation water or statutes on the devising process, which require green or blue roofs. Furthermore, the creation of "multifunctional retention areas", which retain precipitation water in different ways, could also be considered.

COST ANALYSIS

Sample invoices list the costs of the measures for binding heavy rainfall. In this respect, the creation of basins and infiltration trenches is particularly efficient with comparatively low costs per cubic metre of rainwater that is retained. Finally, around 70 % of the precipitation of a 100-year event can be retained on the sample property used in the model at half the cost.

07 COST ANALYSIS

An indicative cost analysis was performed for the described measures. The unit prices from the Baupreislexikon (building price lexicon) (July 2017, query for Wuppertal) were used for this. The following (favourable) conditions were assumed:

- Flat terrain
- Uncontaminated soil (Z0 / landfill class 0)

For the measures involving soil excavation, the removal of 20 cm of top soil was calculated. The removal of the excavated soil from the property is also considered, but may be more expensive with contaminated soils. The site equipment for excavation was accounted for in the standard price. The costs were determined for a retention volume between 10 m^3 and 1000 m^3. A mass discount was accounted for as a percentage.

In order to render the costs for all measures for comparison, the retention was standardised using cubic metres.

If one relates solely the construction costs to the resulting retention volume, the depression is the most cost-effective measure for retaining the rainwater. A water head of 30 cm is assumed for the calculation. With lower water heads, the price per cubic metre increases with a lower retention volume and decreases slightly with larger volumes.

Table 8: Indicative estimated values for the construction costs incurred per cubic meter of water retained

	Costs per cubic metre retained [€/m^3]
Green roof	800 - 1000
Retention roof	500 - 560
Storage reservoirs/ tanks/ infiltration module	280 - 310
Blue roof	240 - 260
Infiltration module (gravel)	200-220
Retention basin	120 - 140

In the case of infiltration trenches, one must differentiate between gravel trenches and infiltration modules. In a gravel trench, the water is directed to the gravel layer where infiltration takes place. An percentage of 30 % was used as a basis for the cost estimate. With infiltration modules, the water is directed to finished modules with a capacity of up to 90 %.

There are different types of green and/or retention roofs with different retention potentials per square metre [m²/m³]. In general, with the green roof, the production costs [€/m²] are lower, but retention roofs achieve more retention volume per square metre so that the production costs are again more affordable in relation to the retention volume achieved with the retention roof than with the green roof. With costs of €50 to 80 and retention volumes of no more than 160 l/m², €600 to €1,000 per m³ of retention volume result. This is a significantly higher price compared to the depression and other measures. However, it should also be considered that the room under a roof is used for an entirely different economic purpose than the space eunder a depression such that these measures make sense where there interior space is close together and space restrictions on the property (also in an economic respect), this holds all the more true if the positive effects are applied to other environmental potential.

In Figure 20, the costs and the retention volumes achieved are listed together in order for the sample property starting with the most affordable variant - the depression. As a result, it becomes clear that 2/3 of the retention volume can be achieved at 1/3 the cost if sufficient space is available. Or vice-versa: The last 10 % of the retention volume is associated with relatively high costs (1/3 of the total costs).

As a result, 70% of the precipitation volume (in the case of the calculated 100-year event) can be retained on the sample property for approx. 1/3 of the cost. With these measures, more frequent heavy rainfall can be completely retained e.g. in the event of a 50-year event. As mentioned above, special conditions must be in place in this respect. The situation is entirely different in more confined areas.

In summary, it can be stated that, for the retention of the precipitation volumes and management of extreme events without damage, a combination of retention measures and measures to protect buildings is the most cost-efficient strategy.

RELATION TO THE RETENTION VOLUME
on the sample property

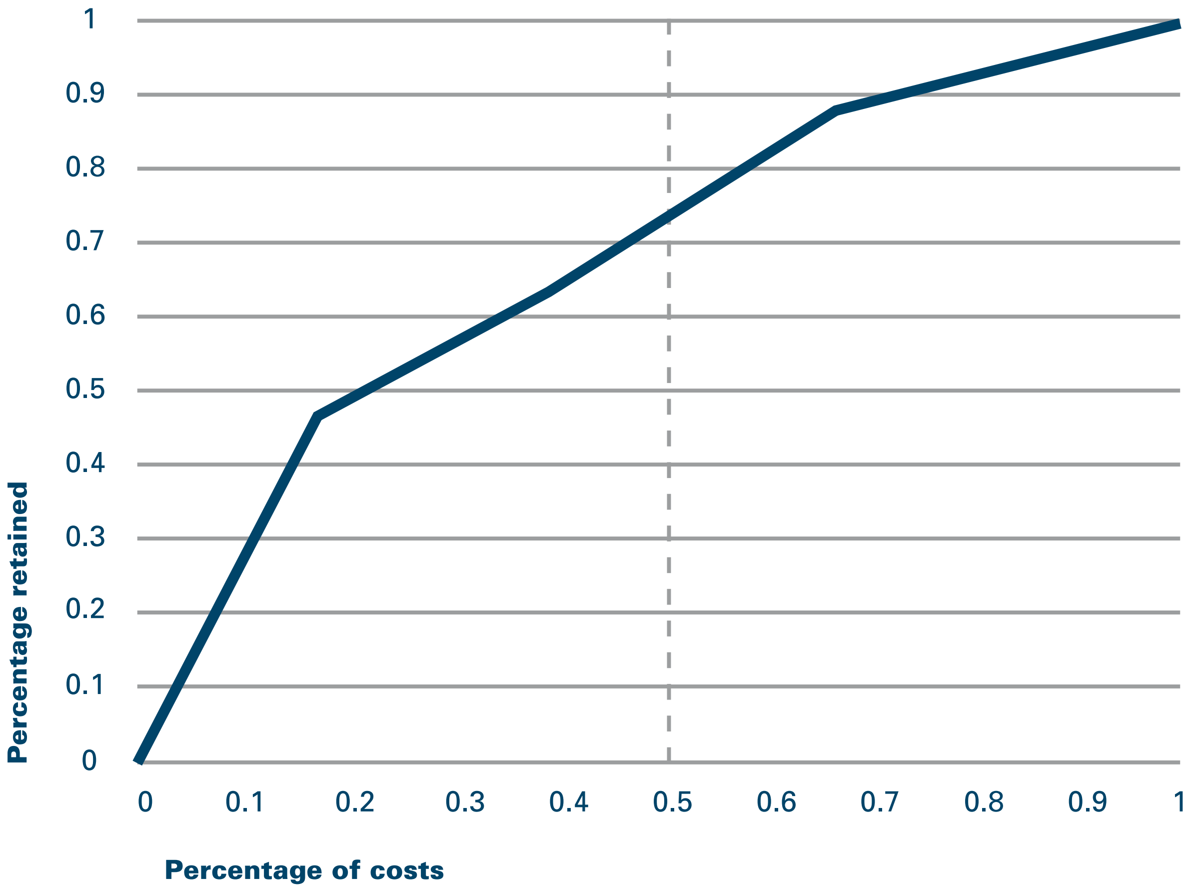


Figure 20
Proportion of costs to retention volume on the sample property

RECIPROCAL EFFECTS OF THE MEASURES

The measures for binding heavy rainfall also have positive effects on the environment. As a result, reduced sealing has a positive effect on the microclimate; the increased infiltration of water promotes the replenishment of ground water and the use of the precipitation water, for example, in gardens reduces the use of potable water.

08 RECIPROCAL EFFECTS OF THE MEASURES ON OTHER ENVIRONMENTAL POTENTIAL

The proposed measures for protecting against the effects of heavy rainfall often have positive effects on other environmental potential such as e.g. the microclimate, the replenishment of ground water or biodiversity on a property.

8.1 MICROCLIMATE

The described reduction of sealing and the use of green roofs has a positive effect on heat stress and the natural water balance. Through reduced runoff, the water remains on the surface longer as well as in the topmost layers of the soil where it can evaporate. Green areas and roofs can release up to 90 % of the water into the atmosphere through evaporation (Uni Freiburg, 2013). Cooling through evaporation has a positive effect on the microclimate and reduces the accumulation of heat on the property. However, green roofs only contribute to cooling if the plants are supplied with sufficient water. Roofs that have dried out have virtually no effect during hot spells (MKULNV, 2011). Open water areas cool to a lesser degree than areas with vegetation; as a result, blue roofs have a smaller positive effect on the microclimate (Pfoser, et al., 2013). All other unsealed, planted areas have the same effect.

8.2 GROUND WATER

The infiltration of water promotes the replenishment of ground water, which is generally severely limited due to excessive sealing. Expansive infiltration systems have a more positive effect than systems in individual spots. In the case of systems in individual spots, almost all water occurring is infiltrated more or less in a single spot, which may result in the level of ground water increasing significantly around the spot where the water is channelled.

Another advantage of expansive, above-ground infiltration systems is evaporation and transpiration via the soil layers and plants.

8.3 BIOVITALITY

More green areas create more habitat for animals and areas permitting plant rooting, which has a positive effect on the biodiversity of the property.

8.4 WATER CONSUMPTION

The water reservoirs and tanks can also have a positive effect on environmental potential in that the water collected is used further – for example, as non-potable water in the home for the washing machine and toilet or for garden cultivation. The use of fresh water is reduced as a result. The use of water for garden cultivation also includes the advantages of infiltration as well as evaporation and transpiration. In general, water can only be used from closed reservoirs.

8.5 FURTHER ENVIRONMENTAL POTENTIALS

Greening buildings (roofs and façades) as well as the general removal of sealing and greening of areas has been found to have a positive effect on the air quality. In addition to photosynthesis, a number of plants also have positive effects when it comes to binding particulate matter. There another research project will be conducted at the BBSR regarding the exact effects.

Greening buildings also protects the building cladding against negative environmental effects such as excessive heat, storm and hail.

EVALUATION

Every possible measure incurs other costs and offers different effects with respect to protecting against heavy rainfall as well as positive effects on the environment. Evaluation matrices in the form of tables compare these measures so that they can be compared.

09 EVALUATION OF THE MEASURES

The measures were analysed according to costs and benefits. The feasibility, which has effects on other environmental potential as well as costs (based on the cost analysis – costs per cubic metre retained), was evaluated. Furthermore, a second matrix (cf. Table 10) showed the conditions under which the maximum effectiveness of the individual measures can be achieved. Depending on the infiltration capacity of the soil, the slope of the terrain and the degree of sealing, the measures have different levels of effectiveness. The maximum effectiveness of the individual measures provides estimated values as to what percentage of the heavy rainfall can be retained by them. The values concern the entire property and the total volume of the rain. Depending on the respective boundary condition associated with the property, this maximum effectiveness is reduced accordingly.

Table 10 indicates the percentage the individual measures account for with respect to the overall objective. In the evaluation of the feasibility (cf. Table 9), the following trends emerge:

- Retention in the soil particularly with favourable soil conditions with a high infiltration capacity,
- Retention in the area particularly on flat terrain,
- Technical measures and the use of roofs are always possible, but significantly more costly.

The following table illustrates the evaluation of the measures according to feasibility and effect and/or benefit on the basis of a sponge property permitting transferability to other properties. Depending on the infiltration capacity of the soil, it evaluates the slope of the terrain and base area coefficient, the feasibility, the positive effect on other environmental potential as well as the costs for the respective measures.

Table 9: Evaluation matrix

Effects / Measures	Feasibility						
	Soil infiltration capacity			Slope of the terrain			Sealing base are
	excellent (10-20mm/h)	moderate (5-10mm/h)	poor (5-0mm/h)	flat	low	high	0.2 -0.5
Retention with the structure:							
Green roof	o	o	o	o	o	o	++
Retention roof	o	o	o	o	o	o	++
Blue roof	o	o	o	o	o	o	++
Storage reservoirs /tanks	o	o	o	++	++	+	++
Depressions (without infiltration)	o	o	o	++	x	--	++
in the area /traffic areas	o	o	o	++	-	--	+
in the sewer (existing development)	o	o	o	++	x	-	o
Retention in the soil (natural):							
Surface infiltration (removal of sealing)	++	+	--	++	+	-	+
Retention in the soil (structural):							
Infiltration basin	++	+	--	++	x	--	++
Swale-infiltration trench system	+	x	-	++	x	-	++
Infiltration trench	+	x	-	++	+	+	++
Shaft infiltration	x	x	-	++	++	++	++

Legend

Feasibility/ benefit	--	-	x	+	++	o
	very difficult/ very limited	difficult/ limited	neutral	easy/high	very easy/ very high	no effect

with respect to ea coefficient		BENEFIT environmental potential			COSTS
0.5-0.8	0.8-1	Heat*	Ground water	Bio diversity	Construction
++	++	++	o	+	--
++	++	++	o	++	-
++	++	x	o	o	x
+	+	depending on use			--
x	--	+	o	x	++
++	++	o	o	o	x**
o	o	o	o	o	x**
x	--	++	++	++	++
x	--	+	++	+	++
x	--	+	++	x	+
+	x	o	+	o	-
+	+	o	-	o	--

Costs	--	-	x	+	++	o
	very high	high	reasonable (high)	low	very low	no effect

* Cooling of the microclimate produced by evaporation

** lower to the extent what is present can be used without modification

Table 10: Effectiveness of the individual measures (estimated values)

Effects / Measures	maximum effectiveness (individual measures)	Reduction factors: Soil infiltration capacity – excellent (10-20mm/h)	moderate (5-10mm/h)	poor (5-0mm/h)	Slope of the t – flat	low
Retention with the structure:						
Green roof	25%*	o	o	o	o	o
Retention roof	40%*	o	o	o	o	o
Blue roof	50%*	o	o	o	o	o
Storage reservoir / tanks	15%	o	o	o	1.0	0.7
Depressions (without infiltration)	75%	o	o	o	1.0	0.5
in the area /traffic areas	50%	o	o	o	1.0	0.5
in the sewer (existing development)	25%	o	o	o	1.0	0.8
Retention in the soil (natural):						
Surface infiltration (removal of sealing)	50%	1.0	0.50	0.00	1.0	0.
Retention in the soil (structural):						
Infiltration basin	90%	1.0	0.80	0.50	1.0	0.
Swale-infiltration trench system	50%	1.0	0.60	0.20	1.0	0.
Infiltration trench	25%	1.0	0.50	0.10	1.0	0.
Shaft infiltration	20%	1.0	0.40	0.00	1.0	0.

errain		Sealing with respect to base area coefficient		
	high	0.2-0.5	0.5-0.8	0.8-1
	O	0.35	0.65	1.00
	O	0.35	0.65	1.00
	O	0.35	0.65	1.00
5	0.50	1.00	0.50	0,50
0	0.10	1.00	0.75	0.00
0	0.00	1.00	0.75	0.50
0	0.50	1.00	1.00	0.50
.50	0.00	1.0	0.65	0.10
.50	0.10	1.0	0.50	0.00
.60	0.40	1.0	0.80	0.00
.80	0.60	1.0	0.80	0.40
.80	0.60	1.0	1.00	1.00

*Assumption: 50% of the sealed areas are roof areas

Example:

Assuming that the surface infiltration and/or the effectiveness of removing sealing for a property with excellent infiltration capacity, a gentle slope and a base area coefficient of 0.6 are to be estimated. The maximum effectiveness of this measure amounts to 50 %. This means that, ideally, 50 % of the water falling on the property during a heavy downpour can be retained. The excellent infiltration capacity does not result in a reduction in the effectiveness. The slope, however, reduces the effectiveness by a reducing factor of = 0.5. The degree of sealing of the property also reduces the effectiveness by 0.65. As a result, surface infiltration in the example has a maximum effectiveness of:

For this example, it can also be assumed that only approximately 1/6 of the heavy rainfall that falls on this property can be retained due to the sealing of the area.

Finally, the feasibility and costs according to Table 9 show that this measure, due to the good infiltration capacity of the soil, can be classified as *very easy*, as *easy* due to the gentle slope and *neutral* due to the average base area coefficient. At the same time, the environmental potential of heat, ground water and biodiversity on the property are utilised very effectively and the measure is very cost-efficient.

$$\mathbf{W}_{\text{Surface infiltration}} = 50\ \% * 1 * 0.5 * 0.65 = 16.25\ \%$$

SUMMARY

The climate is changing and heavy rainfall will also occur to an increased extent in the future. To prevent damage caused by such events, there is a series of effective measures, which can already be implemented today in a relatively cost-efficient manner and, in particular, in a legally compliant manner.

10 SUMMARY

There is no question that the climate will change. Various forecasts predict that extreme weather events such as storms, droughts, cold spells as well as heavy rainfall will become more frequent in the future. The urban climate effect amplifies the impact of such events. Due to the high percentage of sealed areas in urban centres, significantly more water reaches the sewers and is unable to run off in the event of heavy rainfall. Flooding and damages to developed areas.

In order to counteract the effects of extreme events, possible concepts were developed in the German Strategy for Adaptation to Climate Change (DAS, 2008). The term "Sponge City" has been mentioned in various national climate adaptation strategies and studies. Internationally, this term is most well known in China. Due to rapid urbanisation and poor water management, the need for action is particularly great there. "Sponge City" refers to the principle of channelling less water on the surface and disposing of it in sewers, but instead storing it and using it. The principle of the sponge city is described as a form of natural rain water management and as a means for cool cities.

This principle was applied to a property in this project. Due to the resulting flooding protection, improved microclimate, an improvement of the landscape and, if applicable, lower charges for rain water and the lower consumption of potable water, the effects are also positive for individual properties. Peak runoff is also reduced in the public network through decentralised rain water management and water retention. Through the integration of reservoirs and intensifying total infiltration as well as evaporation and transpiration, runoff will become virtually zero during the event and the water balance of the property will once again be closed to the natural water balance.

Redesigning a property as a sponge property has a positive effect in terms of vulnerability and resilience. To extent to which heavy rainfall affects the building fabric on a property is critically dependent on the construction, the location including topography, the landscape, the degree of sealing, the soil characteristics as well as the intensity and duration of the rainfall. Particularly the use of unsuitable building materials can cause damages to take on disastrous proportions due to the accumulation or ingress of water. Simple measures to protect buildings can significantly reduce or event prevent damages from flooding.

The model calculations have shown that the different measures of a sponge property exhibit different levels of effectiveness. Though a combination of such measures may also not be able to completely mitigate existing hazardous areas such that protection of buildings must always be ensured in addition to the water retention measures on the property. The scope of measures to protect buildings can also be significantly reduced as the result of retention.

There is a variety of possibilities for creating a sponge property with varying degrees of efficiency and, depending on the characteristics of the property, they are more or less easy to implement. Decisive factors are the infiltration capacity of the soil, the percentage of built-up area as well as the slope of the property.

At the same time, nearly all measures for the retention of precipitation water also have effects on other environmental potential. Increased evaporation and transpiration contributes to the cooling of the microclimate; infiltration improves the replenishment of groundwater. The natural water balance is once again approached.

A sponge property also offers benefits for the different stakeholders. On one hand, the owner improves the value of his property with these measures while protecting against flooding and improving the microclimate. On the other hand, the municipality benefits from the reduced, controlled and delayed discharge of the water into the public network. Peak runoff is reduced in the event of heavy rainfall where excess head and flooding of other areas can be avoided. If multiple property owners in a city act in accordance with this principle, the positive effect can extend to the entire city and/or the respective urban district.

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APPENDIX

1. DEFINITION OF WASTEWATER WHEN DOES RAINWATER BECOME WASTEWATER?

Pursuant to Section 54 para. 1 no. 2 WHG, among others, wastewater is the water that collectively runs off of built-up or paved areas (precipitation water).

Therefore, as soon as rainwater comes into contact with paved surfaces, it becomes wastewater in a legal sense. If it comes into contact with unpaved surfaces (e.g. farmland, meadows, forest), it is referred to as unconfined runoff.

Though there is essentially no general duty under public law to protect a residential area against unconfined runoff[1], the city and/or municipality generally does not have to define measures against unconfined runoff or influent water in planned or unplanned building zones (Sections 30, 34 BauGB) or in outdoor areas under zoning law (Section 35 BauGB) if these hazards are foreseeable and manageable for the affected party.[2]

The party building within the hazardous area of e.g. areas that are used for agriculture where there is a threat of influent surface water must protect himself against such hazards and/or take action under civil law against the neighbour on whose property the water comes from.

To this extent, the duty to disposal of wastewater of the city and/or municipality also does not apply in the case of unconfined runoff from agriculture areas (e.g. farmland, meadows) as this only concerns wastewater pursuant to Section 56 WHG in conjunction with Section 48 LWG NRW.[3]

It is problematic if unconfined runoff e.g. runs onto a public road and then onto a private property where it causes damage. It is questionable as to whether this water becomes rainwater - that is wastewater - which the municipality is responsible for disposing of. This has not yet been clarified in case law. In general, the precipitation water in the sense of Section 54 para. 1 no. 2 WHG is only at hand if it comes into contact with a paved surface for the first time as rain and collectively runs off from there.[4]

[1] cf. Upper Administrative Court of Hamm, decision of 18 February 2008 – 5 U 115/07-. [2] cf. BGH, decision of 18 February 1999 – III ZR 272/965-.
[3] Administrative Court of Aachen, decision of 22 September 2014 -7 K 1260/13-. [4] cf. OVG NRW, decision of 17 February 2017 -15 A 687/15- regarding a gravel area.

2.
LEGAL CLASSIFICATION OF MEASURES FOR RAINWATER RETENTION

2.1
WHICH MEASURES FOR THE RETENTION OF RAINWATER ON THE PROPERTY ARE AT ALL POSSIBLE FROM A LEGAL STANDPOINT?

In general, all technical measures are possible, for example:

- surface infiltration/treatment
- Infiltration via corresponding systems e.g. infiltration systems, depression/ drainage channel systems,
- Roof greening or blue roofs,
- rainwater utilisation systems/tanks,
- priv. detention basins such as a pond on the property in connection with controlled discharge,
- priv. sewer with controlled discharge.

However, a permit under water law from the water authority is required for measures affecting the ground water (in particular, infiltration measures) depending on the local situation (e.g. water conservation area).[5]

channelling precipitation water to a neighbouring property is not possible as this is already prohibited under civil law and the neighbour also does not have to tolerate this (Section 27 para. 1 NachbG NRW (NRW Neighbour's Right Legislation).

This is dealt with differently if unconfined runoff (upstream/ downstream landowner problem, Section 37 WHG) is concerned and the upstream land owner does not change the runoff of the water in a negative manner. In this case, the downstream land owner must tolerate the runoff of the upstream property.

[5] OVG NRW, decision of 24 February 2017 -15 B 49/17-; OVG NRW, decision of 21 December 2016 -15 A 2917/15-; Queitsch KStZ (Kommunale-Steuer-Zeitschrift) 2017, p. 46 et seqq.

2.2
HOW DO THE RESPECTIVE MEASURES DIFFER IN A LEGAL SENSE?

Measure	Implementation
Surface infiltration/ treatment	• Section 55 para. 2 WHG in conjunction with federal state law e.g.: • Sections 44 para. 1, 49 para. 4 LWG NRW: Exemption in individual cases (prerequisites: permit under water law from the intermediate water authority + declaration of exemption (from the municipality) from the duty to pass on wastewater pursuant to Section 48 LWG NRW)
Infiltration via systems	• Section 55 para. 2 WHG in conjunction with Federal State Law e.g.: • Sections 44 para. 1, 49 para. 4 LWG NRW: Exemption in individual cases (prerequisites: permit under water law from the intermediate water authority + declaration of exemption from the duty to handover wastewater issued by the municipality pursuant to Section 48 LWG NRW) • Section 65 para. 1 BauO NRW: exempted undertaking
Roof greening	• Statutory provision • In individual cases at the request/institute authority and spillover to the public sewer required
Rainwater utilisation system/ tanks	• Statutory provision • In individual cases at request/institute authority • spillover to the public sewer required • Use of the precipitation water for garden irrigation possible without a permit under water law (cf. Section 49 para. 4 sentence 3 LWG NRW)
Private retention with controlled discharge into a public sewer	• Statutory provision • Building permit • Institute authority • Spillover to the public sewer

Surface infiltration/treatment

Section 44 para. 2 LWG NRW: Definition of infiltration of precipitation water by means of a separate statute on the disposal of precipitation water [6]

Section 49 para. 4 LWG NRW: Possibility for exemption from the duty to pass on precipitation water (Section 48 LWG NRW) at the request of the property owner to the extent a permit under water law from the intermediate water agency is in place and the municipality has issued a declaration of exemption.[7]

The criteria for the issue of a permit under water law will vary as they are highly dependent on the local situation (interior area, development plan, outdoor area, type and nature of use etc.), the property size and the infiltration situation on the property; this is a decision of the intermediate water agency based on an individual case.

The municipality may issue a declaration of exemption at its discretion; the evaluation will occur by weighing the legal, technical and economic prerequisites. To the extent e.g. a sewer for precipitation water is located on the property, the municipality requires no further argument to refuse the request for exemption as the sewer connection is only a variant of local rainwater disposal in the sense of Section 55 Abs. 2 WHG.[8]

Infiltration via corresponding systems

Section 44 para. 1 LWG NRW or Section 49 para. 4 LWG NRW as above.

Generally, no building permit is required as this concerns an undertaking not requiring a permit pursuant to Section 65 para. 1 BauO NRW.

Roof greening

In general, the possibility of roof greening can generally be provided for by the municipality.

However, it must be determined from the very beginning how much water the greened roof can absorb because, in the event of extreme rainfall events, the greenedroof area reaches its saturation point and is therefore unable to absorb the entire precipitation water. In any case, a spillover to the sewer is required in order to rule out flooding damages to neighbouring properties if the roof greening is no longer able to absorb rainwater.[9]

Rainwater utilisation systems/tanks,

A by-law of the municipality is recommended for a system solely for utilising rainwater (e.g. collection and use of rainwater for flushing toilets and/or the washing machine). Used rainwater must be made available to the public sewage system as wastewater. A spillover of the rainwater utilisation system to the public sewer is, however, required to rule out any flooding damage to neighbouring properties if the rainwater utilisation system is no longer able to hold rainwater.[10]

Also collecting rainwater with subsequent use for garden irrigation constitutes use of the precipitation water, which in generally can be permitted on the basis of a request vis-à-vis the municipality if this is provided for in the local by-laws. As to whether a permit under water law from the intermediate water authority may be necessary must be evaluated in individual cases. A need for evaluation could result in an individual cases e.g. based on the degree of contamination of the precipitation water.

Private retention basins/pond with controlled discharge into the public sewer

For this, approval by the municipality is required (on the basis of a provision in the drainage statute, building permit or institute authority); generally a spillover to the public sewer is also required in this case.[11]

In general, the municipality may, however, only demand retention with controlled discharge if this is either prescribed on the basis of by-laws or the measure is reasonable and appropriate for the property owner (that is, there is no solution that is equally suitable on a technical level or a more economical solution). The construction of public rainwater retention basins on private areas would only work with a corresponding contract with the property owner and the entry of security in the land register (Section 1018 BGB (German Civil Code)).

Furthermore, it is absolutely imperative that the municipality observe, with respect to the aspect of building planning law, that a development plan must be based on a development concept (with respect to wastewater), according to which the incoming precipitation water can be disposed of without any damage to health and the property of the parties affected by the plan inside and outside of the planning area. [12]

A development plan, which does not sufficiently consider surface drainage, can even be deemed invalid during the consideration phase due to an error. [13]

In terms of fees, it must also be observed with respect to all retention measures where a spillover to the sewer must be created that in these cases, the municipality provides reduced service to the property owners compared to the other parties liable to pay the fees such that this could affect the rainwater fee. However, the municipality must enact a valid statute of fees so that, on the basis of this statute, it is obligated to collect the respective fees. The rule of law (Art. 20 para. 3 GG) and the principle of equality (Art. 3 para. 1 GG) and/or the principle of fairness of fees rule out that usage fees are collected in divergence to to legal and statutory provisions. The waiver of fees is therefore generally impermissible.[14]

[6] cf. Queitsch in: Queitsch/Koll-Sarfeld/Wallbaum, LWG NRW, Kommentar (Commentary), Section 44 LWG NRW marginal number 35 et seqq.

[7] OVG NRW, B.v. 24 February 2017 -15 B 49/17-; OVG NRW, decision of 21 December 2016 -15 A 2917/15- ; Queitsch KStZ 2017, p. 46 et seqq.

[8] cf. OVG NRW, decision of 16 June 2016 -15 A 1068/15-; OVG NRW, decision of 25 April 2016 -15 B 189/16-; OVG NRW, decision of 31 July 2015 -15 A 2604/14-; OVG NRW, decision of 05 March 2014 -15 A 1901/13-; OVG NRW, decision of 18 October 2013 -15 A 1319/13-; Queitsch, KStZ 2015, p. 81 et seqq. (p. 87).

[9] OVG NRW, decision of 16 June 2016 -15 A 1068/13-; OVG NRW, decision of 30 September 2016 -15 A 2112/15-; OG NRW, decision of 25 April 2016 -15 B 189/16-; OVG NRW, decision of 31 July 2015 -15 A 2604/14-; OVG Lüneburg, decision of 04 April 2017 -9 LB 102/15.

[10] OVG NRW, decision of 16 June 2016 -15 A 1068/13-; OVG NRW, decision of 30 September 2016 -15 A 2112/15-; OG NRW, decision of 25 April 2016 -15 B 189/16-; OVG NRW, decision of 31 July 2015 -15 A 2604/14-; OVG Lüneburg, decision of 04 April 2017 -9 LB 102/15.

[11] OVG NRW, decision of 16 June 2016 -15 A 1068/13-; OVG NRW, decision of 30 September 2016 -15 A 2112/15-; OG NRW, decision of 25 April 2016 -15 B 189/16-; OVG NRW, decision of 31 July 2015 -15 A 2604/14-.

[12] Cf. BVerwG (Federal Administrative Court), decision of 21 March 2002 – 4 CN 14/00 ; BayVGH, decision of 11 February 2014 – 1 N 10/2254 - ; Mitschang/Reidt in: Battis/Krautzberger/Löhr, BauGB , Kommentar (Commentary), Section 9 BauGB margin no. 79.

[13] Cf. BayVGH, decision of 11 February 2014 – 1 N 10/2254 -; OVG Koblenz, decision of 08 March 2012 – File reference: 1 A 10803/11 - ; Mitschang/Reidt in: Battis/Krautzberger/Löhr, BauGB , Kommentar (Commentary), Section 9 BauGB margin no. 79.

A contractually agreed fee waiver therefore results in a breach of a statutory requirement so that in general, such a contract is void.[15]

According to case law, an exception to the rule that fee waivers are impermissible is only possible if the party liable to pay the fee, who has or is to pay less, provides quid pro quo as compensation for the reduced wastewater fee with respect to the fee budget.[16]

The quid pro quo provided in this respect must be adequate. General benefits for the municipality do not constitute adequate quid pro quo in this context. This must concern quid pro quo, which benefits the fee budget and consequently all other parties liable to pay fees so that all other such parties liable to pay fees are not disadvantaged in connection with the fee assessment due to the granting of reduced fee rate with respect to the favoured party liable to pay a fee.[17]

However, it is also possible that a flat-rate deduction is defined in a statute with respect to the precipitation water fee (e.g. for green roofs), which considers the reduced discharge of the wastewater and consequently results in savings with respect to the wastewater fee on the part of the property owner. Likewise, a fee deduction is possible with retention (delayed discharge) if costs are shown to have been saved for other parties liable to pay fees, which could be inherent in the wastewater fee. Such savings can e.g. exist in that the sewer does not have to be made larger on the property due to the retention measure.

At the same time, however, it must also always be considered that, according to OVG NRW, it is the task of the municipality to enlarge a public sewer whose capacity is insufficient.[18] In the process, it is to be assumed in principle that a municipality must take action if it determines on the basis of a calculation performed today that the public mixed water sewer, which was built e.g. 40 years ago, does not have a sufficient size on the basis of current findings.[19]

2.3 WHICH REQUIREMENTS DOES THE RAINWATER HAVE TO FULFIL IN THE EVENT OF INFILTRATION?

For the infiltration of the precipitation water in an individual case (not already provided for by the statute), it is necessary in accordance with Section 55 para. 2 WHG that this version of removal only comes into consideration if no provisions under water law or interests of water law contradict it (so-called triad of legal barriers). [20]

Furthermore, on the basis of the respective federal state law such as in North Rhine-Westphalia, it is required in addition to exemption from the duty to pass on precipitation water (Section 48 LWG NRW) in accordance with Section 49 para. 4 LWG

[14] cf. BVerwG, decision of 21 October 1983 -8 C 174.81-; OVG NRW, decision of 22 January 2016 -9 A 1042/13-; OVG NRW decision of 24 July 2013 -9 A 1290/13-.

[15] cf. BVerwG, decision of 21 October 1983 -8 C 174.81-; OVG NRW, decision of 22 January 2016 -9 A 1042/13-; OVG NRW decision of 24 July 2013 -9 A 1290/13-.

[16] cf. BVerwG, decision of 18 April 1975 –VII C 15.73; OVG, decision of 22 January 2016 -9 A 1042/13-; OVG NRW, decision of 24 July 2013 -9 A 1290/13; OVG NRW, decision of 22 December 1971 –II A 38/70-.

[17] OVG, decision of 22 January 2016 -9 A 1042/13-; OVG NRW, decision of 24 July 2013 -9 A 1290/13.

NRW. For this, the intermediate water agency must grant a permit under water law and the municipality must issue a declaration of exemption.[21]

For the technical assessment of the infiltration capacity, the DWA A 138 and DWA M 153, among others, apply as technical regulations.

[18] OVG NRW, decision of 17 April 1012 -15 A 1407/11-; OVG NRW, decision of 16 November 2011 -15 A 854/10-; Queitsch: "Maßnahmen und Finanzierungsinstrumente zur Vorsorge gegen Katastrophenregen (Measures and Financing Instruments for Precautions against Catastrophic Rainfall Events") in. UPR 7/2015, p. 249 et seq. (252).

[19] Queitsch: "Maßnahmen und Finanzierungsinstrumente zur Vorsorge gegen Katastrophenregen" (Measures and Financing Instruments for Precautions against Catastrophic Rainfall Events") in. UPR 7/2015, p. 249 et seq. (252).

[20] Cf. Queitsch in: Queitsch/Koll-Sarfeld/Wallbaum, LWG NRW, Kommentar (Commentary), Section 49 LWG NRW marginal number 38 et seqq.; 46 et seqq.; OVG NRW, decision of 24 February 2017 -15 B 49/17-; OVG NRW, decision of 21 December 2016 -15 A 2917/15- ; Queitsch KStZ 2017, p. 46 et seqq.

[21] cf. VG Arnsberg, decision of 17 August 2009 -14 K 1706/09 and 14 K 3002/08-; OVG NRW, decision of 16 June 2016 -15 A 1068/15-;.
OVG NRW, decision of 25 April 2016 -15 B 189/16; OVG NRW, decision of 05 March 2014 -15 A 1901/13-; OVG NRW, decision of 08 October 2013 -15 A 1319/13-.

3. SEPARATE CHANNELLING OF THE PRECIPITATION WATER

3.1 WHICH PREREQUISITES MUST BE IN PLACE FOR CHANNELLING TO A SEPARATION SYSTEM, PARTICULARLY WITH RESPECT TO CONTAMINATION (SEPARATION DECREE)?

Degree of contamination	Need for treatment
uncontaminated precipitation (unpolluted)	No prior treatment
Slightly contaminated precipitation water (slightly polluted)	Generally requires treatment with exceptions
Heavily contaminated precipitation water (polluted)	In general, collection and channelling to a sewage works Exemptions under strict prerequisites

According to Item 2.2 of the separation degree,[22] the following applies:

Uncontaminated (= unpolluted) precipitation water (category I of annex 1 to the separation decree) can generally be channelled to above-ground water bodies without prior treatment. This also applies if the discharge point into the flowing water body is in the water conservation area (and/or water catchment area) or the course of the flowing water body runs through water protection zones as long as the respectively defined regulation on protected areas does not stipulate otherwise. According to Items 14.1 and 15 of the "Erlass zur Niederschlagswasserbeseitigung "(Decree on the Disposal of Precipitation Water" [23] infiltration can occur..

Slightly contaminated (= slightly polluted) precipitation water (category II of the Annex 1 to the separation decree) generally requires treatment in accordance with the stipulations in Sec. 3 and the table in Annex 2 of the separation decree. Central treatment of such precipitation water can be refrained from in individual cases if, based on the land use, only an insignificant contamination with oxygen depleting substances and nutrients and contamination with heavy metals and organic pollutants is to be expected or if comparable decentralised treatment occurs. In general, this applies to

- roof areas in commercial and industrial zones,
- paved surfaces with light vehicle traffic (moving or stationary) e.g. residential streets with parking lots and parking spots, access roads to collective garages; other
- parking lots to the extent the prerequisites of Category III of Annex 1 are not at hand,
- inter-community roads and route connections with low traffic as well as
- yard and traffic areas in mixed, commercial and industrial zones with low vehicle traffic (moving or stationary) with a low number of lorries
- without lorry parking lots with a runoff effect,
- without storage areas with a runoff effect,
- without areas with a runoff effect from category III of annex 1 to the separation decree,
- without production operations,
- without handling of water-polluting substances,
- without other impairments of the precipitation water quality.

Depending on classification to the aforementioned case groups under the same prerequisites as per Item 14.2 in conjunction with Item 15 of the "Erlasses zur Niederschlagswasserbeseitigung (Decree on the Disposal of Precipitation Water", infiltration can occur**.

In general, **heavily contaminated (= polluted)** precipitation water (category III of Annex 1 to the separation decree) must be collected, channelled and allocated to wastewater treatment as per Annex 2 and/or the central treatment plant.

Infiltration is only permitted on an exceptional basis under the conditions of Items 14.3 and 15 of the "Erlasses zur Niederschlagswasserbeseitigung" following prior treatment as per Annex 2 to the separation decree.

3.2 WHAT IS THE BASIS FOR THE SPLIT WASTEWATER FEE AND THE SEPARATION OF CONTAMINATED AND PRECIPITATION WATER?

A public precipitation water sewer as a variant of local disposal of rainwater as per Section 55 para. 2 WHG is only to be built if no provisions under water law, no interests under water law or other public-law provisions contradict it (so-called "triad of legal barriers").[24]

If the precipitation water is heavily contaminated, it can also be discharged via mixed water sewers in the future because it will be purified in the treatment plant then. [25]

[22] of 26 May 2004, MBl. NRW 2004, p. 583. [23] v. 18 May 1998, MBl. 1998, p. 654.
[24] Queitsch in: Queitsch/Koll-Sarfeld/Wallbaum: Kommentar zum LWG NRW (Commentary on LWG NRW), Loseblattsammlung (Loose-leaf Collection), Section 44 margin no. 23.

The separated wastewater fee is prescribed by case law.[26]

4. MEASURES UNDER BUILDING LAW WHAT ROLE DO THE MEASURES PLAY IN THE DEVELOPMENT PLAN?

To the extent areas are planned for an infiltration or retention system from the very beginning, they should be designated in the development plan as open space (that is, areas that are not to be built up).

To the extent rainwater is to be infiltrated in an entire area, this is also to be stipulated in the development plan. As a result, the disposal of the rainwater is provided for in a conclusive manner.

In connection with the stipulation possibilities, however, it must always be considered that they require that this is referred to in soil legislation.[27] This means that only areas where measures for the retention and infiltration of precipitation water can be taken can be stipulated, but not the measure itself.[28] As a result, e.g. no stipulation can be made that rainwater utilisation systems have to be built in a building area.

The stipulation possibility in accordance with Section 9 para. 1 no. 14 BauGB has a high level of practical relevance with respect to areas for the retention and infiltration of precipitation water. Such a stipulation is also permissible on private areas and generally compatible with Art. 14 para. 1 GG.[29] However, the stipulation of the operation of rainwater utilisation systems is not permissible under building planning law as such a stipulation is not referred to in soil legislation.[30] Furthermore, the development plan must be based on a development concept according to which the precipitation water occurring can be disposed without any harm to health and damage to the property of the parties affected by the plan and outside of the plan area.[31] Measures such as the creation of depressions for infiltration or the retention of precipitation water must be defined in accordance with Section 9 para. 1 no. 20 BauGB and can entail stipulations in accordance with Section 9 para. 1 no. 14 and 15 BauGB.[32] A development plan that does not adequately account for the drainage of contaminated water may be invalid due to an error during the consideration phase.[33]

[25] Queitsch, KStZ 2017, p. 46 et seqq.
[26] OVG NRW, decision of 18. 12. 2007 – 9 A 3648/04-; BVerwG, decision of 13. 5. 2008 – 9 B 19.08-; cf. OVG NRW, decision of 11. 7. 2005 –9
A 2002/05 – and decision of 28. 6. 2004 –9 A 1276/02 –; OVG NRW, decision of 5. 2. 2003 –9 B 2482/02.-
[27] cf. BVerwG, decision of 30 August 2001 -4 CN 9/00-;.
[28] BVerwG, decision of 30 August 2001 -4 CN 9/00-.
[29] BVerwG decision of 30 August 2001 – 4 CN 9/00-; VGH Munich U. v. 11 February 2014 – 1 N 10/2254-.
[30] cf. BVerwG, U.v. 30 August 2001 -4 CN 9/00-;.

5. PREREQUISITES AND RISKS IN CONNECTION WITH EXEMPTION FROM THE COMPULSORY CONNECTION AND USAGE REQUIREMENT

5.1 WHAT RISKS EXIST IN CONNECTION WITH EXEMPTION FROM THE COMPULSORY CONNECTION AND USAGE REQUIREMENT? WHAT PREREQUISITES MUST BE FULFILLED FOR THIS TO OCCUR?

The compulsory connection and usage requirement is provided for in the drainage statute and ultimately follows from the comprehensive duty of the municipality to dispose of wastewater (Section 46 LWG NRW) as well as the municipal code of NRW (Section 9 GO NRW). This legal basis allows the municipality to force the property owner to pass on its wastewater.

The compulsory connection and usage requirement is neither subject to a statute of limitation nor forfeiture because the municipality with the duty to dispose of wastewater has to be able to impose the compulsory connection and usage requirement with respect to its public sewage system in order to fulfil its duty to dispose of wastewater and prevent resulting official liability (Art. 34 GG, Section 839 BGB).[34]

At the same time, however, the property owner has a connection and usage right, which means that the municipality is generally obligated to dispose of the wastewater occurring on its property and/or to accept it in the public sewage system. With respect to the aspect of official liability (Art. 34 GG, Section 839 BGB), the municipality must properly fulfil its duty to dispose of wastewater and ensure that no damages from flooding and inundation occur.[35] If a public sewer is too small, it must be enlarged e.g. the municipality has a duty to adapt the capacity. [36]

[31] BVerwG decision of 21 March 2002 – 4 CN 14/00-; regarding the municipal liability in the event of flood damages caused by the spillover of a rainwater retention basin cf. BGH decision of 11 March 2004 – III ZR 274/03-.

[32] in this regard BVerwG U.v. 30 August 2001 -4 CN 9/00-.

[33] OVG Koblenz U. v. 8 March 2012 – 1 A 10 803/11 - ; BayVGH, decision of 11 December 2014 – 1 N 10/2254 -; Mitschang/Reidt in: Battis/Krautzberger/Löhr, BauGB , Kommentar (Commentary), Section 9 BauGB margin no. 79.

[34] cf. OVG NRW, decision of 30 September 2016 -15 A 2112/15; OVG NRW, decision of 16 June 2016 -15 A 1068/15; OVG NRW, decision of 25 April 1016 -15 B 189/16-; Queitsch: “Kommunale Abwasserbeseitigung und die Erhebung von Abwassergebühren" (Municipal Wastewater Disposal and the Collection of Wastewater Fees) in: KStZ 2017 no. 3, p. 46 et seqq. (48).

In accordance with Section 49 para. 4 LWG NRW, two prerequisites must be in place in order to be exempted from the duty to pass on precipitation water:

- a permit under water law from the intermediate water agency and
- a declaration of exemption from the municipality.[37]

The exemption can also occur in part, that is, only partial areas of the property will not be connected to the public sewer. The exemption then applies to these areas. With the declaration of exemption, the duty to dispose of wastewater for the precipitation water (Section 48 LWG NRW) is transferred to the property owner, that is, he is responsible for the disposal of his precipitation water.

There is a risk in connection with the exemption for the municipality e.g. when damage occurs despite the exemption (e.g. on the neighbouring property). If in doubt, it would be checked in this case as to whether the exemption was justified, that is, whether a sufficient evaluation took place in advance to determine that the precipitation water on the property can be disposed of properly. If this is not the case, there is a liability risk on the part of the intermediate water agency and the municipality.[38]

Furthermore, there is also always a financial risk in connection with the exemption of properties from the duty to pass on precipitation water. The properties disconnected from the public sewer system will no longer channel their precipitation water to the public sewer system and therefore also pay no fees for precipitation water. This also means that the costs of the municipality, which are incurred for the disposal of the precipitation water, will be apportioned among fewer properties.

Furthermore, there are often difficulties if the exemption is to be revoked and the duty to dispose of wastewater is to fall back on the municipality. In general, this is only to be considered unproblematic if the permit under water law e.g. is limited in terms of time and is not renewed. In this case, a prerequisite for justified exemption is no longer in place so that the duty to pass on precipitation water comes back into effect. If, however, the municipality wishes to revoke its declaration of exemption, this

[35] Cf. regarding liability: BGH, decision of 18 February 1999 – III ZR 272/96 - ; OLG Dresden, decision of 31 July 2013 – 1 U 1156/11 - ; LG Trier, decision of 21 May 2007 – 11 O 33/06 - ; Rotermund/Krafft, Kommunales Haftungsrecht (Municipal Liability Law), 5th edition 2013, margin no. 935 et seqq.; Queitsch in: Queitsch/Koll-Sarfeld, Wallbaum, LWG NRW, Kommentar (Commentary), Section 46 LWG NRW margin no. 256 et seqq.; margin no. 269 et seqq.

[36] Cf. OVG NRW, decision of 17 April 2012 – 15 A 1407/11; OG NRWW; decision of 16 November 2011 – 15 A 854/10 ; BGH; decision of 05 June 2008 – III ZR 52/07 - ; Rotermund/Krafft, Kommunales Haftungsrecht (Municipal Liability Law), 5th Edition 2013, margin no. 935 et seqq.; Queitsch in: Queitsch/Koll-Sarfeld, Wallbaum, LWG NRW, Kommentar (Commentary), Section 46 LWG NRW margin no. 258

[37] cf. VG Arnsberg, decision of 17 August 2009 -14 K 1706/09 and 14 K 3002/08-; OVG NRW, decision of 16 June 2016 -15 A 1068/15-; OVG NRW, decision of 25 April 2016 -15 B 189/16; OVG NRW, decision of 05 March 2014 -15 A 1901/13-; OVG NRW, decision of 08 October 2013 -15 A 1319/13-

[38] OVG NRW, decision of 16 June 2016 -15 A 1068/13-; OVG NRW, decision of 30 September 2016 -15 A 2112/15-; OVG NRW, decision of 25 April 2016 -15 B 189/16-; OVG NRW, decision of 31 July 2015 -15 A 2604/14-

has not been provided for in the LWG NRW to date. With respect to the municipality's institute authority, however, such a right of revocation can at least be viewed as justified if e.g. proper retention on the property is no longer functional and therefore flooding damage to neighbouring properties or public traffic areas can occur. [39]

Ultimately, there is always the risk of creating so-called precedence cases with respect to the exemption of individual properties from the duty to pass on precipitation water. If a property owner has been exempted, it is often the case that at least the owners of the neighbouring properties also issue a request for exemption from the duty to pass on precipitation water. Determining whether to grant an exemption always occurs on a case-by-case basis, as a result, the neighbour generally is not able to call upon the exemption of the applicable property owner that has already occurred,. If, however, the case and/or the property situation of the neighbour is the identical, that is, if there are no differences whatsoever or only to a marginal extent, the administration must also treat both properties the same based on the principles of equal treatment (Art. 3 para. 1 GG).

[39] Cf. OVG NRW, decision of 24 February 2017 – 15 B 49/17 -; OVG Lüneburg, decision of 04 April 2017 – 9 LB 102/15

5.2 WHEN DOES AN EXEMPTION FROM THE COMPULSORY CONNECTION AND USAGE REQUIREMENT HAVE TO BE GRANTED – WHAT ARE VALID REASONS TO NOT GRANT AN EXEMPTION? WHAT ROLE DOES A BASIC FEE PLAY?

The compulsory connection and usage fee for precipitation water is compatible with Art. 14 GG, creates a social restriction of the property and (also) serves to prevent flooding of neighbouring properties and traffic areas.[40]

Circumstances where a public rainwater sewer, which the municipality has to refinance (see above), is located in front of the applicable priority or the principle of equal treatment is breached (e.g. all properties on the road are connected) goes against granting an exemption.

If there is a basic fee for precipitation water, it may only be paid, according to prevailing opinion, if there is a possibility for discharging it, that is, if a sewer connection is at all present. This applies regardless whether it is in fact also discharged via this connection (that is, also in the event of so-called emergency spillways). If there is no precipitation water connection for the property, there is also no duty to pay a basic fee. However, contradicting views are held in this regard.

5.3 WHICH STATUS PROVISIONS HAVE TO BE DEFINED?

For new building areas, as much as possible should be stipulated in the development plan with respect to the disposal of precipitation water if the compulsory connection and usage requirement is to be diverged from. Legally, the development plan represents a municipal statute in the sense of Section 7 GO NRW. However, it must be observed that a development plan always applies to the entire area and not to individual properties. The exemption criteria are stipulated by law and therefore does not have to be provided for in statutes. In most drainage statutes, however, it is adopted for the sake of clarification.

With respect to the permit for roof greening and rainwater utilisation systems, it is recommended that a provision be adopted in the drainage statute as a legal basis to ensure legal certainty. For example, there is no corresponding provision in the LWG NRW.

[39] Cf. OVG NRW, decision of 24 February 2017 – 15 B 49/17 -; OVG Lüneburg, decision of 04 April 2017 – 9 LB 102/15

[40] OVG Lüneburg, decision of 04 April 2017 -9 LB 102/15-; OVG NRW, decision of 24 February 2017 -15 B 49/17-

6. MAINTENANCE AND CONTROL DUTIES

6.1 WHAT ARE THE DUTIES OF THE PROPERTY OWNER WITH RESPECT TO THE MAINTENANCE OF THE SYSTEMS?

To the extent purely private systems on a property are concerned, the property owner must also see to proper maintenance and repair of these systems. The valid generally accepted rules of engineering apply to this extent (Sections 60, 61 WHG).

If this concerns parts of the public drainage system, they have to be maintained by the municipality. For this, the municipality could exercise its right to enter the private property and the property owner would have to tolerate the work.

6.2 WHICH CONTROL DUTIES DOES THE MUNICIPALITY HAVE?

As soon as the municipality has exempted the property owner from the duty to pass on precipitation water, he is himself responsible for the proper disposal of precipitation water on his property, that is, the municipality no longer has control duties of any kind in this respect. If, however, there is a disturbance affecting the system, it must – solely for the protection of the public sewer system and the protection of the other properties – cooperate in finding a solution, that is, consider whether to revoke the exemption and connect to the public sewer system. This generally occurs in cooperation with the intermediate water agency.

If the system no longer functions properly, the intermediate water agency would have to request that the property owner refurbish it.

If only a partial exemption or a spillover to the public sewer exists (e.g. with in the case of rainwater utilisation systems), the municipality still (at least in part) has the duty to dispose of wastewater such that it must also check whether the channelling of precipitation water functions properly on the whole.

6.3 WHAT HAPPENS IF THE SYSTEMS FAIL? DOES LIABILITY EXIST ON THE PART OF THE MUNICIPALITY?

Based on the above, it follows that the municipality is generally only liable in cases where it either still has the duty to dispose of wastewater entirely or in part or a system concerns a part of the public sewage system. [41]

However, it must be observed that, if an exemption has been granted, the legitimacy of the exemption will generally also be evaluated in the event of damage so that a liability risk also remains in this case (see above).

To the extent precipitation water runs onto neighbouring private properties and damage occurs there, the property owner will be liable for the failure of its system as it is exempted in this case from the duty to pass on precipitation water and by law has the duty to dispose of the wastewater with respect to the precipitation water (cf. in this regard: Section 49 para. 4 LWG NRW).

7.
SUBSIDISATION POSSIBILITY ON THE PART OF THE MUNICIPALITY FOR PRIVATE SYSTEMS

CAN PRIVATE INFILTRATION SYSTEMS BE SUBSIDISED (BY THE MUNICIPALITY) E.G. IN ORDER TO AVOID EXPENSIVE, EXTENSIVE REFURBISHMENT OF THE SEWER IN AN APPLICABLE AREA? CAN LIABILITY DUTIES OF THE MUNICIPALITY BE TRANSFERRED AND/OR EXCLUDED IN THIS CONTEXT?

Subsidisation of private infiltration systems by the municipality in order to avoid refurbishment of the public sewer is generally not possible as the municipality must primarily fulfil its duty to dispose of wastewater duly and in compliance with the law. This also includes operating and maintaining a public sewer in accordance with the generally accepted rules of engineering. If the size of a public sewer is insufficient, the municipality has a duty to adapt its capacity, that is, sewers that are too must, if in doubt, be made to be larger in order to be able to handle all precipitation water from the properties.[42]

Furthermore, so-called system liability (e.g. Section 2 Haftpflichtgesetz (Liability Law)) is prescribed by law and cannot be transferred or even excluded.

[42] OVG NRW, decision of 16 November 2011 – 15 A 854/10 and 15 A 2228/09 –; OVG NRW, decision of 17 April 2012 -15 A 1407/11-; OVG NRW,
decision of. 24 February 2017 -15 B 49/17-; cf. BGH, decision of 21 June 2007 - III ZR 177/06-.