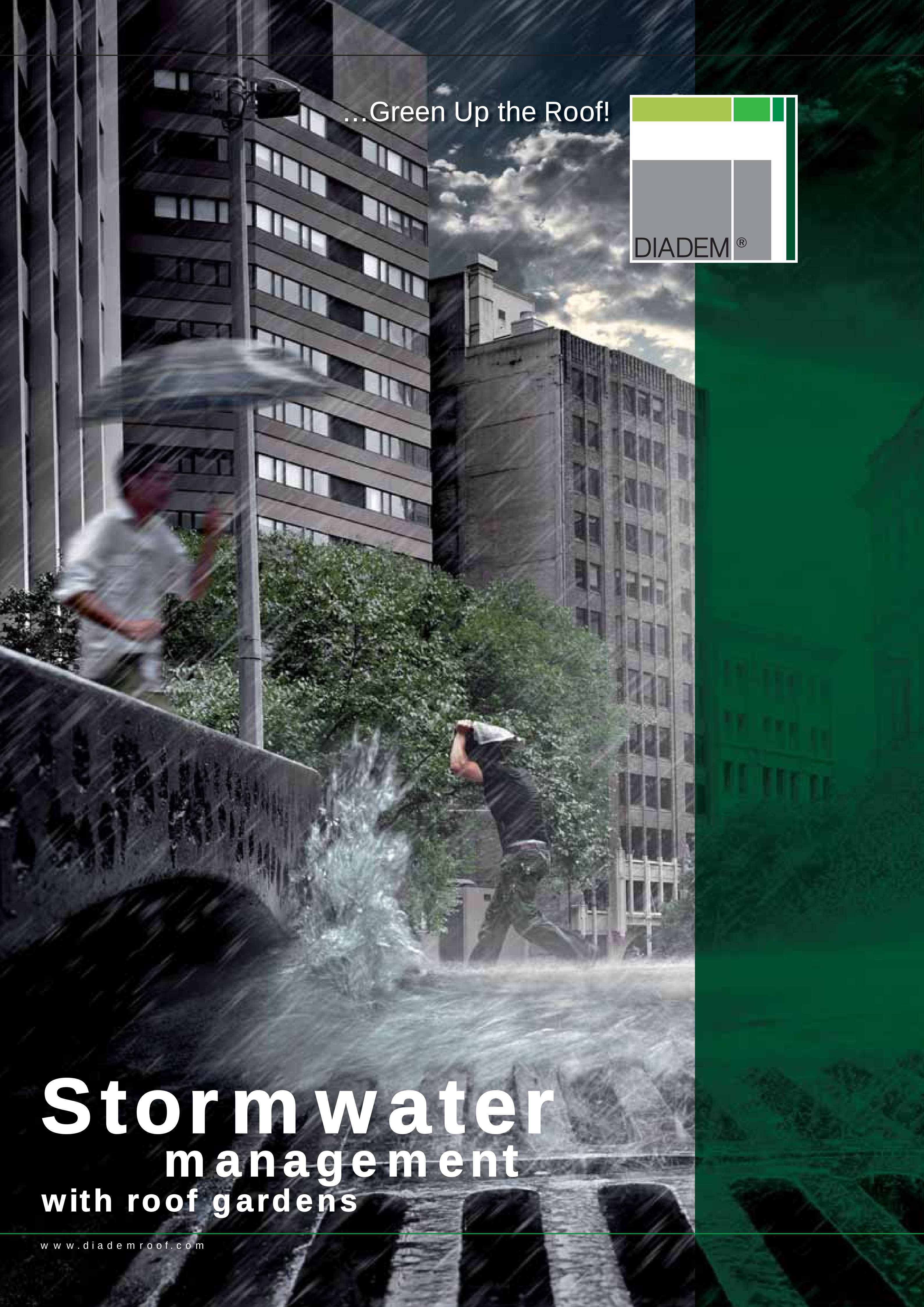

...Green Up the Roof!

DIADEM®

# Stormwater management with roof gardens

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# Stormwater management with roof gardens



☐ In addition to their other numerous benefits, green roofs can offer a smart solution to the new problem of sudden large volumes of rainwater. This article explains the background and offers a case study that shows how a green roof can provide a cost effective alternative to rebuilding inadequate drainage systems.

Research into rain in London by the Lloyd's Emerging Risk Team and the Climate Change Risk Management consultancy found that rainy days of over 45 mm per day - heavy enough to pose a safety risk - have become more frequent. A day with 45mm rainfall had a 30-year return period before 1960, and now has less than a 6-year return period of occurrence. During a heavy rainstorm on 2 July 2011 in Copenhagen 150mm of rain fell in less than two hours. That is 150 litres – a bath full of water – for each square metre that the old, worn and narrow cross-section town sewage network had to handle.

It is no coincidence that the Copenhagen Climate Adaptation Plan of 2011 places extraordinary focus on the problem of sudden and extreme heavy rainfall in towns, the extreme volume of water it delivers in a short space of time and the possible solutions for this. Thus, while the total amount of precipitation in Europe shows a slight decrease, the occurrence of sudden, extreme heavy rainfall is noticeably higher. One of the most important characteristics of green roofs is that a significant part of the rainwater falling onto their surface is retained and over and above the saturation level the excess water flows into the downfall pipes and slows its entry into the sewage systems. Therefore a much lower amount of water enters the otherwise very much overloaded sewage system and the timing of these avoids the peak flows. When planning drainage systems for roofs this feature of green roofs is often not taken into account, even though it may lead to a marked reduction in building costs.

This report provides help with these calculations and gathers together the most relevant guidelines and regulations in the field. Green roofs can provide a solution for the water drainage problems of existing buildings too. In our case study, we demonstrate the rainwater retention quality of green roofs – based on an article written by Judit Horváthné Pintér, a building insulation engineer.

## ☐ Starting point

The Facility Manager informed us that during heavy rains the existing water drainage outlets were not able to cope with the precipitation accumulating on the roof, so the water stayed on the roof. According to the Technical Manager, the problem was not simply with the roof outlets, but that the diameter of the internal and external rainwater drainage pipes of the building was not adequate to carry the rainwater away.

## ☐ Calculation

The size of the building rooftop surface: 108 m × 96 m = 10 368 $m^2$. The slope of waterproofing surface is determined mainly by the roof structure. The water catchment area for one outlet is 12 m × 24 m = 288 $m^2$. There were 36 outlets with a diameter of 100 mm and 80 mm. Calculations were made to check whether the built-in drainage diameter was adequate. The sizing formula is:

$$Q = r_{(D,T)} \times C \times A \times \frac{1}{10000},$$

where

$Q$ = rate of flow of rainwater entering the drain [ $l/s$ ]

$r_{(D,T)}$ = 300 [ $l/(s \times ha)$ ]

$C$ = 0.9 (Hungarian Standard specifies 0.9 runoff coefficient, according to EN12056 this value would be 1.0)

A = 288 $m^2$

In Hungary, the design rainfall rate is 159-274 litre/(sec x ha). We calculate with the highest rounded figure: 300 litre / (sec × ha). Completing the formula we get a result of Q = 7.8 l/s. However, a 100 mm diameter pipe channels 4.5 l/s rain flow (see EN 1253 Standard above), so in order to drain 7.8 l/s water one drain is not sufficient for the given area. Instead of 36 drain outlets, 62 100 mm-diameter outlets would be necessary in this case to cover the 108 × 96 m roof surface.

## ☐ Alternative solutions

The first possibility was a complete reconstruction of the water drainage pipe system. This would have meant that the number of drains needed to be doubled, the slope of the flat roof changed, furthermore the building inside would have needed a new drainage system, as well as higher capacity drainage installed in certain places. Increasing the diameter of the existing drain system pipes would also have meant that the drainage system would have had to have been replaced completely. The number of outlets cannot be doubled on a roof structure where the slope is given by the structure itself or where the roof cannot bear the additional weight of a modified slope. Increasing the diameter of the piping system creates operational upheaval within the building, as well as significant extra cost. It was preferable, therefore, to find a solution to the existing rainwater system, without any reconstruction work. The only way would be to reduce the quantity of rainwater entering the drainage system, or rather to slow down the flow speed at peak times of rain. Experimental measurements, professional literature data, as well as various actual installations demonstrate that vegetation installed roofs, or green roofs, retain and store a substantial proportion of the rainfall and during rain peaks therefore significantly delay the water runoff.

## ☐ The solution – green roof as a technical necessity

The standards recommend about 0.3 for a runoff coefficient of the green roof. A con-

## Current EU standards and explanations for calculation

The EN 1253 harmonised standard clearly defines the minimum flow rates capacity of water drainage systems for both gravity drainage and vacuum drainage systems. (chart 1.)

|  | Gravity system | Vacuum system |
|---|---|---|
| Drainpipe diameter (mm) | Flow rates* (l / s) | Flow rates* (l / s) |
| DN50 | 0,9 | 4,0 |
| DN70 | 1,7 | 12,0 |
| DN100 | 4,5 | - |
| DN125 | 7,0 | - |
| DN150 | 8,1 | - |
| * If adequate water pressure is achieved | | |

chart 1. Source: Edited by author based on EN 1253 standard

The professional literature uses the so called ‘runoff coefficient’(marked as „C“, or previously „Ψ“), which defines for various types of surfaces the percentage of precipitation that flows towards the roof’s collection drainage points without delay. Subtracting the flow rate of the drainage system from the measured rainfall gives the quantity of rainwater that remains of the roof, the amount that is stored there. The EN 12056-3 harmonised standard defines the runoff coefficient for green roofs with various heights of growing media and plants. Equally the FLL guidelines, considered the guiding principle for green roof building worldwide – “Guideline for the Planning, Execution and Upkeep of Green-Roof Sites” , Richtlinie für die Planung, Ausführung und Pflege von Dachbegrünungen, 2008 – also describe the runoff coefficients of green roofs. (chart 2.)

| Course depth | Types of DIADEM® greenroof systems | Runoff coefficient (according to EN 12056-3 standard) | Runoff coefficient (according to FLL guidelines, up to 5 degree slope)* | Recommended guidelines for runoff coefficient calculations |
|---|---|---|---|---|
| 2-4 cm | DIADEM®-50 | 0,5 | 0,7 | FLL |
| 4-6 cm | | | 0,6 | FLL |
| 6-10 cm | | | 0,5 | EN 12056 / FLL |
| 10-15 cm | DIADEM®-150 | 0,3 | 0,4 | FLL |
| 15-25 cm | DIADEM®-350 | | 0,3 | EN 12056 / FLL |
| 25-50 cm | | | 0,2 | EN 12056 |
| above 50 cm | DIADEM®-750 | | 0,1 | EN 12056 |
| *FLL guidelines include the runoff coefficient of roofs with a slope of more than 5 degrees | | | | |

chart 2. Source: Edited by author of article.

| T | 0,5 | | 1,0 | | 2,0 | | 5,0 | | 10,0 | | 20,0 | | 50,0 | | 100,0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D | hN | rN | hN | rN | hN | rN | hN | rN | hN | rN | hN | rN | hN | rN | hN | rN |
| 5,0 min | 3,5 | 116,9 | 5,2 | 173,5 | 6,9 | 230,0 | 9,1 | 304,8 | 10,8 | 361,4 | 12,5 | 418,0 | 14,8 | 492,7 | 16,5 | 549,3 |
| 10,0 min | 5,8 | 96,4 | 8,0 | 133,5 | 10,2 | 170,4 | 13,2 | 219,3 | 15,4 | 256,2 | 17,6 | 293,2 | 20,5 | 342,1 | 22,7 | 379,1 |
| 15,0 min | 7,2 | 79,5 | 9,8 | 108,3 | 12,3 | 137,2 | 15,8 | 175,3 | 18,4 | 204,2 | 21,0 | 233,0 | 24,4 | 271,2 | 27,0 | 300,0 |
| 20,0 min | 8,0 | 67,0 | 10,9 | 91,2 | 13,8 | 115,4 | 17,7 | 147,4 | 20,6 | 171,6 | 23,5 | 195,7 | 27,3 | 227,7 | 30,2 | 251,9 |
| 30,0 min | 9,1 | 50,4 | 12,5 | 96,3 | 15,9 | 88,2 | 20,4 | 113,1 | 23,8 | 132,0 | 27,1 | 150,8 | 31,6 | 175,8 | 35,0 | 194,6 |
| 45,0 min | 9,8 | 36,2 | 13,8 | 50,9 | 17,7 | 65,7 | 23,0 | 85,1 | 27,0 | 99,8 | 30,9 | 114,5 | 36,2 | 134,0 | 40,1 | 148,7 |
| 60,0 min | 10,1 | 27,9 | 14,5 | 40,3 | 18,9 | 52,6 | 24,8 | 68,9 | 29,3 | 81,3 | 33,7 | 93,6 | 39,6 | 109,9 | 44,0 | 122,2 |
| 90,0 min | 11,4 | 21,1 | 16,0 | 29,7 | 20,7 | 38,3 | 26,8 | 49,6 | 31,4 | 58,2 | 36,0 | 66,8 | 42,2 | 78,1 | 46,8 | 86,7 |
| 2,0 h | 12,5 | 17,3 | 17,2 | 24,0 | 22,0 | 30,6 | 28,3 | 39,3 | 33,1 | 45,9 | 37,8 | 52,6 | 44,1 | 61,3 | 48,9 | 67,9 |

chart 3. Source: KOSTRA-DWD, Deutscher Wetterdienst – www.dwd.de Town tested: Buxtehude

According to EN 12056-3 standard the runoff coefficient of flat non-load-bearing roofs with warm roof systems is 1,0, which means that the entire amount of precipitation falling on the roof surface flows into the drain pipes without any delay. The EN 12056 standards also define which design rainfall rate is to be used for sizing calculations of rainwater outlets. This means that the design rainfall rate is the amount of rain falling in a 5-minute storm event with a return period of once in 5 years, marked ($r_{(D,T)}$, where $D$=5 minutes, $T$=5 years). The meteorological institutes of various countries measure this design rainfall rate for a given area either in mm (See example chart 3. hN column, as precipitation rate) or *l / (s × ha) (See example chart 3. rN column, as rain intensity, where s = second; ha = hectare).*

The formula used for water amount to be carried in the drainage pipes uses precipitation intensity, which is a *l / (s × ha)* value. Based on the precipitation rate, the following formula can be used to calculate precipitation intensity:

$$rN_{(D,T)} = hN_{(D,T)} \times \frac{166{,}67}{D_{(min)}},$$

where

$rN_{(D,T)}$ = precipitation intensity (according to KOSTRA chart designations)
$hN_{(D,T)}$ = precipitation rate (according to KOSTRA chart designations)
$D_{(min)}$ = time, duration of event in minutes
$T$ = frequency of event in years

According to the above, the drainage pipe sizing is calculated as follows:

$$Q = r_{(D,T)} \times C \times A \times \frac{1}{10000},$$

where

$Q$ = rate of flow of rainwater entering the drain (*l/s*)
$r_{(D,T)}$ = precipitation intensity
$C$ = runoff coefficient
$A$ = roof surface area ($m^2$), or roof surface area for one drain pipe

trol calculation was performed to determine whether the existing drains would be sufficient if a green roof covered the building. Taking the previously described formula with a change in the runoff coefficient:

$$Q = r_{(D,T)} \times C \times A \times \frac{1}{10000},$$

where

$Q$ = rate of flow of rainwater entering the drain [ *l/s* ]
$r_{(D,T)}$ = 300 [ *l / (s×ha)* ]
$C$ = 0,3
A = 288 $m^2$

Assuming the 300 litre / (sec × ha) rainfall, the newly calculated rate of Q = 2.6 l/s flow value and the current 100mm diameter pipes with a flow capacity of 4.5 l/s, we can state with a high degree of certainty that the existing rainwater drainage system would not only be adequate, but even have over 70% spare capacity. The drainage water load is reduced by two thirds, so water congestion around the roof drain outlets is not expected. In this case study the green roof was in effect a technical necessity, since it avoided a reconstruction of the rainwater-drainage system and any internal construction work so the normal course of business would not be disturbed.

### Green roof as a rainwater reservoir

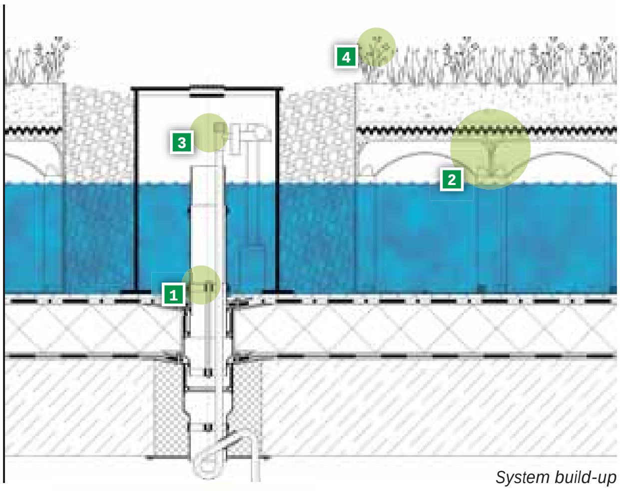
Climate change has resulted in a large increase in the occurrence of extremely heavy rainfall even though the total amount of precipitation shows a slight decrease. The figures and studies above show the extent of the rainwater falling on the green roofs that is retained within the growing medium as a reservoir. The amount that is not utilised by the vegetation is subsequently and slowly released into the drainage system. The water flow from the green roof is already filtered and to a degree, it becomes cleaned water, therefore the cleaning/filtering work undertaken by the sewage system may well be reduced.

**In summary...**

... the technical aspects of the green roof's rainwater-retaining property offer a powerful additional incentive for both property owners and local authorities to consider this type of solution.

DIADEM® Marshtop

# DIADEM®
## Marshtop




*System build-up*

### Application

This system is applicable for all intensive roof garden types as long as the structural elements and types of vegetation have been selected to meet the criteria set for roof top reservoir irrigation systems within the scope of green roof technology. Flooded roofs are ideal for marshy gardens, increasing the ecological value of green roofs. Over and above the ecological benefits, the thermal properties of the building also improve significantly. In combination with a complex water management system, the DIADEM® Marshtop operates in a self-sustaining manner without the need for further water replenishment.

### Water management system

The DIADEM® Marshtop possesses significant water retention and evaporation properties thereby reducing the strain on the sewage system, helping the natural circulation of water, capitalising on the ecological usage of precipitation and reducing the urban heat island effect. The essence of the system is that the roof surface acts as a water basin and only the surplus water flows away from the roof. The excess water is then channelled and collected in rainwater harvesting tanks acting as compensation sources for the quantity lost due to evaporation.

System requirements:

- Roof constructed to zero falls, or constructed with screed to falls in a stair-step pattern
- Outlet with rooftop reservoir irrigation unit
- Automatic water level regulator
- Drainage board with adequate capacity
- Root resistant waterproofing
- Roof constructed to meet sufficient load-bearing capacity

With appropriate planning the system can be designed to provide water flow for fire pumps.

### 1 Outlets

The DHA-110-D roof outlet with clamping collar ensures uniform water level on the waterproofing with the aid of a height-adjustable extension flange found inside the outlet. The height of the extension flange can be adjusted according to need.

### 2 Storm water retention

The DIADRAIN-150 system is designed so that its depth is in direct proportion to the amount of annual precipitation and the water retention requirements of the project for achieving appropriate water attenuation. The height of the system may vary according to the local environmental requirements. Our expert team will assist you with the appropriate calculation.

### 3 Water replenishment

The KSR+W inspection box with built-in water level regulator made of stainless steel regulates the replenishment of water when falling below the required minimum level thereby resulting in optimal water circulation.

### 4 Habitat

Maintaining a constant, uniform water level on the waterproofing creates ideal conditions for a wet habitat and some colonies with unique species of flora and fauna.

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Sources: *Green roof as buffer reservoir* written by Judit Horváthné Pintér, building insulation engineer (extract, May 2008, www.muszakilapok.hu) • *East London Extreme Rainfall Importance of granular data*, Lloyd's emerging risks team report

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