

# Water and Environment Support

in the ENI Southern Neighbourhood region

## Explore the Potential of Natural Water Retention Measures (NWRM) at the catchment scale

### Activity No.: N-W-JO-2



### Stakeholders' Consultation Workshop

21 December 2021 (From 10hr to 14:00hr)

Hotel Landmark, Amman-Jordan

Presented by: Dr. D. ZARRIS, WES Non – Key Expert

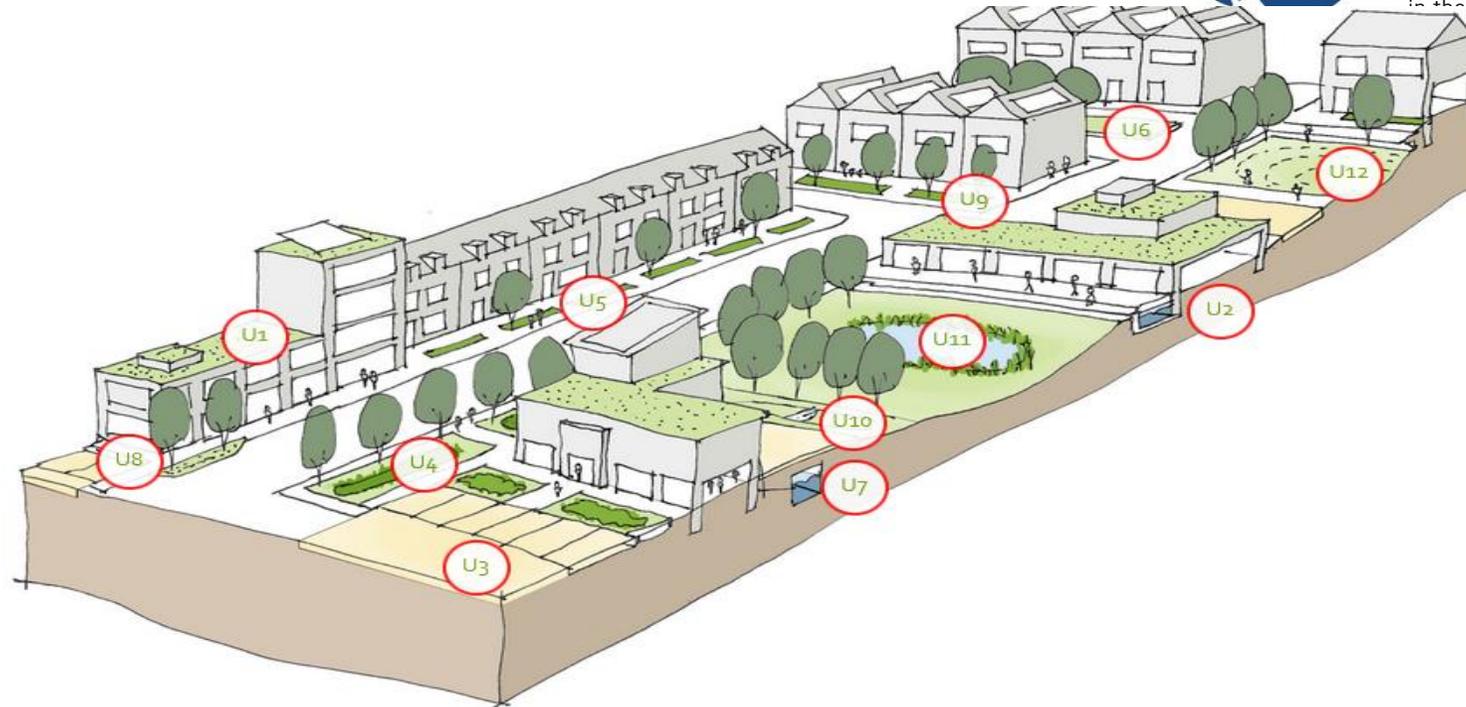


# Review of Natural Water Retention Measures in Urban Areas



**Water and Environment Support**

in the GML Southern Neighbourhood region



U01	<a href="#">Green Roofs</a>
U02	<a href="#">Rainwater Harvesting</a>
U03	<a href="#">Permeable surfaces</a>
U04	<a href="#">Swales</a>
U05	<a href="#">Channels and rills</a>
U06	<a href="#">Filter Strips</a>
U07	<a href="#">Soakaways</a>
U08	<a href="#">Infiltration Trenches</a>
U09	<a href="#">Rain Gardens</a>
U10	<a href="#">Detention Basins</a>



# Natural Water Retention Measures (NWRMs)



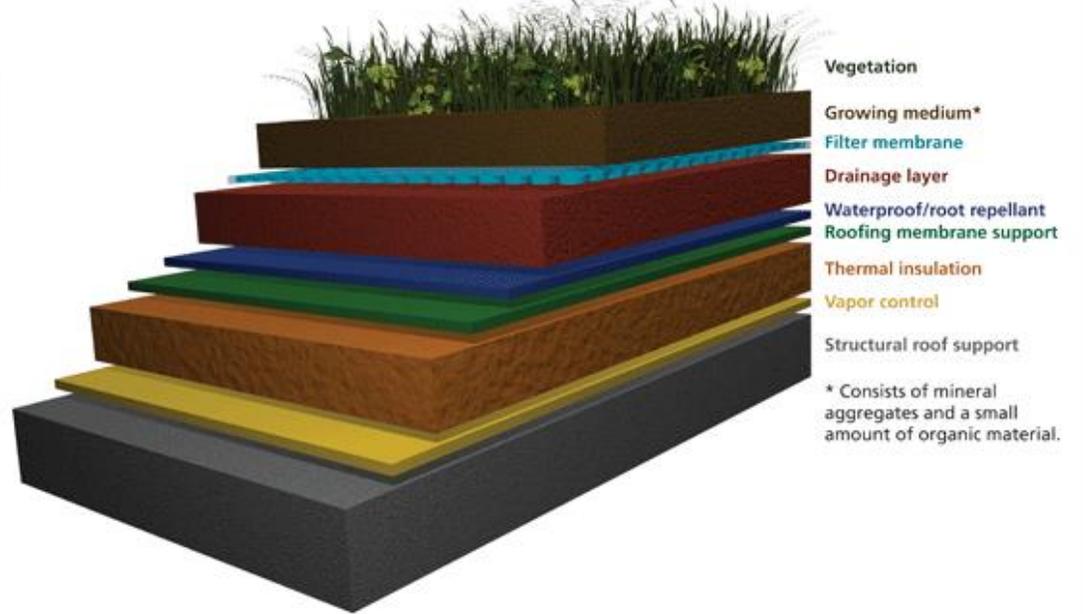
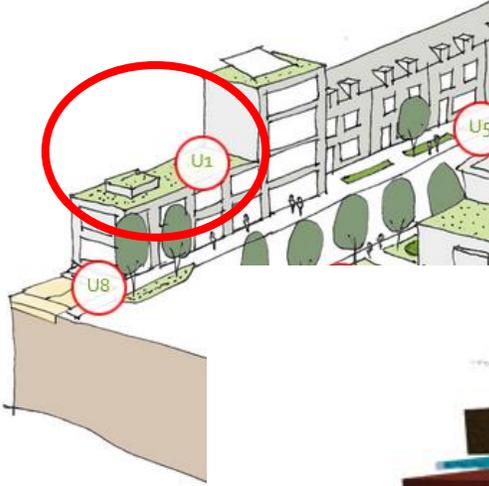
Water and Environment Support

## 1. Green Roofs

### Definition:

A green roof is a layer of vegetation planted over a waterproofing system that is installed on top of a flat or slightly-sloped roof. Green roofs are also known as vegetative or eco-roofs.

Potential restrictions relating to high temperatures and dry weather, which provides challenges for vegetation maintenance, although these can potentially be overcome through irrigation (preferably using water stored from runoff from the green roof) and careful choice of drought tolerant vegetation.



- U01 Green Roofs
- U02 Rainwater Harvesting
- U03 Permeable surfaces
- U04 Swales
- U05 Channels and rills
- U06 Filter Strips
- U07 Soakaways
- U08 Infiltration Trenches
- U09 Rain Gardens
- U10 Detention Basins



## Green roof energy and water related performance in

R. Fioretti<sup>a</sup>, A. Palla<sup>b,\*</sup>, L.G. Lanza<sup>b</sup>, P. Principi<sup>a</sup>

<sup>a</sup> Department of Energetics, Marche Polytechnic University, Via Breccie Bianche 1, Ancona, Italy

<sup>b</sup> Department of Civil, Environmental and Architectural Engineering, University of Genova, Via Montallegro 1, 16145 C

### ARTICLE INFO

**Article history:**  
Received 30 October 2009  
Received in revised form  
16 February 2010  
Accepted 1 March 2010

### Keywords:

Proceedings of the 11th International Conferen

- Stovin et al (2012) found over a 29% for a 2 year event and 15% experimental site in the Mediterranean climate (Scotland, UK. 2008.).

### ABSTRACT

Performance of vegetated roofs are investigated in the urban environment, due to their recognised environmental benefits. A review of related worldwide experiences is reported. The study performed within the specific climatic context of the Mediterranean climate. Results are provided from two case studies, located in the urban environment, monitored green roofs on top of public buildings. T



## Water and Environment Support

Urban Northern Neighbourhood region

Climate by Fioretti  
They concluded  
that although reduced

Palla, A., Lanza, L.G.,  
Environment, 45(8):

Water control  
Recent peak  
Mediterranean climate."

but reducing to  
era. "A green roof  
in Edinburgh,

**Table 7**

Events observed at the green roof of the University of Genova (Italy) for the whole green roof during the second phase of the monitoring campaign and percentage of retained volume and peak flow reduction.

Event [yyyy/mm/dd]	Rain depth [mm]	Flow peak [l/s]	Retained volume [%]	Peak reduction [%]
2007/05/26	9	No outflow	100	100
2007/05/28	12.4	No outflow	100	100
2007/06/01	42.4	0.02	99	99
2007/06/05	41.2	1.31	41	87
2007/08/08	13.2	No outflow	100	100
2007/08/09–10	14	<0.01	95	98.7
2007/08/20	15.2	<0.01	95	99.9
2007/08/21	32.6	0.04	96	99
2007/09/27	28.6	0.02	99	99.6
2007/11/21	8	No outflow	100	100
2007/11/22–23	138.2	1.27	9.5	79
2008/01/4–5	32.8	0.1	70	76
2008/01/11–12	41.4	0.6	15	87
2008/01/16	40.4	0.9	4.6	78
2008/02/04	30.4	0.8	51	70
2008/03/9–10	23.2	0.16	81	94
2008/04/9–11	55	0.1	93	96
2008/04/21	25.4	0.62	23	46
2008/06/17	35.6	1.2	19	77
Mean	–	–	68	89
Dev. Std.	–	–	37	15



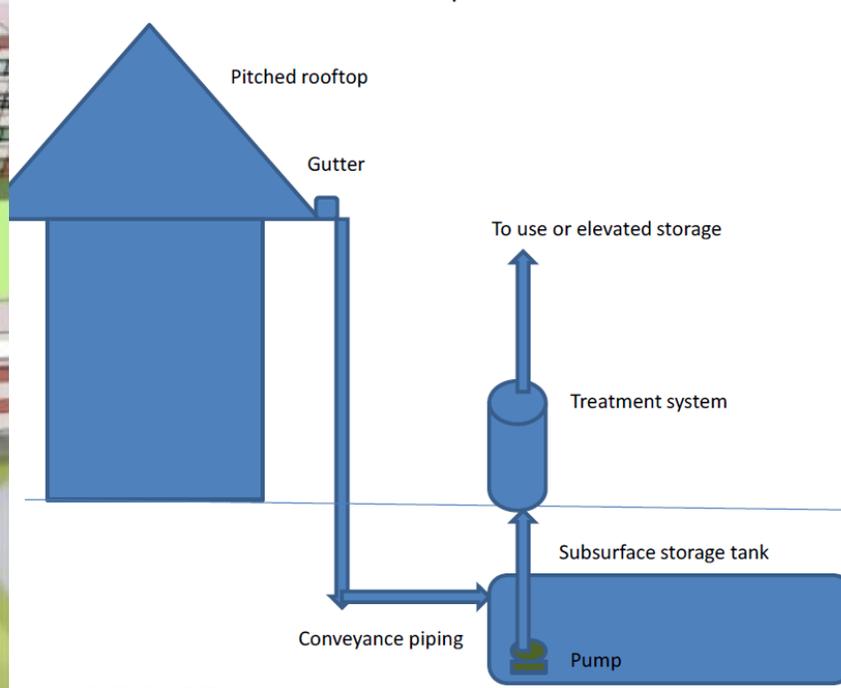
# Natural Water Retention Measures (NWRMs)



Water and Environment  
in the CNL Southern M...

## 2. Rainwater Harvesting

Definition:  
Rainwater harvesting involves collecting and storing rainwater at source for subsequent use, for example, using water butts or larger storage tanks. Water butts are the most widely applied and simple rainwater harvesting



# Rainwater Harvesting



**Water and  
Environment Support**  
in the ENI Southern Neighbourhood region

A limitation of rainwater harvesting as an NWRM is that during wet periods, water storage are often full and water use may be low, resulting in little or no attenuation or reduction in outflow rates or volumes. As a result there are differing opinions about the role of rainwater harvesting in providing a water retention function. Tanks can be specifically designed and managed to accommodate storm water volumes, which is likely to be more effective when applied at a larger scale than individual properties. In general, however, rainwater harvesting should be considered only as a source-control component in a SuDS, in combination with other measures, they will contribute to effective and sustainable water management.



# Natural Water Retention Measures (NWRMs)



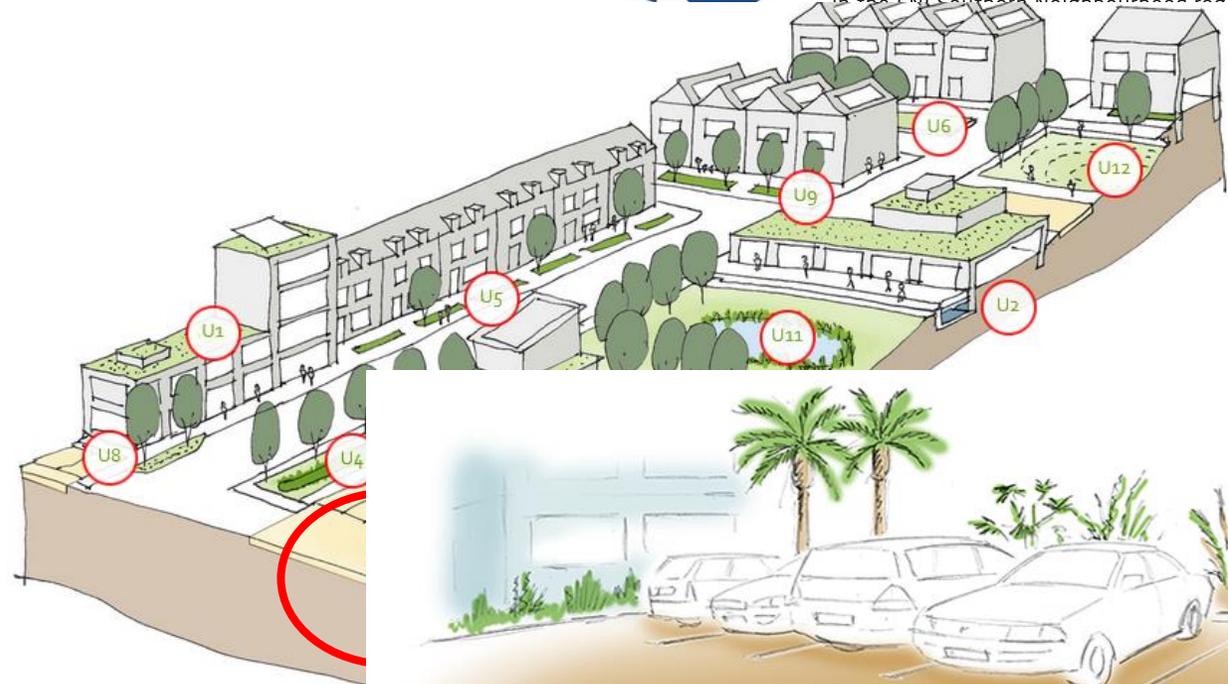
Water and Environment Support  
in the FNI Southern Neighbourhood region

## 3. Permeable Surfaces

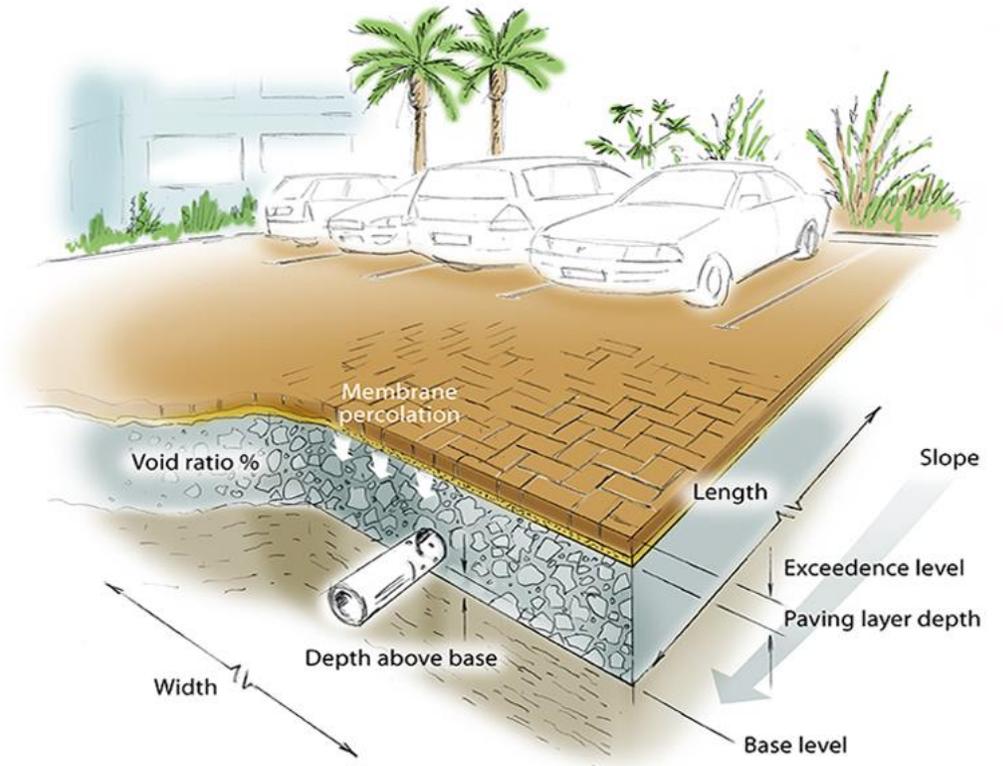
Definition:

Permeable paving is designed to allow rainwater to infiltrate through the surface, either into underlying layers (soils and aquifers), or be stored below ground and released at a controlled rate to surface water. Permeable paving is used as a general term, but two types can be distinguished:

- Porous pavements, where water is infiltrated across the entire surface (e.g. reinforced grass or gravel, or porous concrete and cobblestones)
- Permeable pavements, where materials such as bricks are laid to provide void space through to the sub-base, by use of expanded or porous seals (rather than mortar or other fine particles).



U01	<a href="#">Green Roofs</a>
U02	<a href="#">Rainwater Harvesting</a>
U03	<a href="#">Permeable surfaces</a>
U04	<a href="#">Swales</a>
U05	<a href="#">Channels and rills</a>
U06	<a href="#">Filter Strips</a>
U07	<a href="#">Soakaways</a>
U08	<a href="#">Infiltration Trenches</a>
U09	<a href="#">Rain Gardens</a>
U10	<a href="#">Detention Basins</a>



# Natural Water Retention Measures (NWRMs)



Water and Environment Support  
in the CM Southern Neighbourhood region

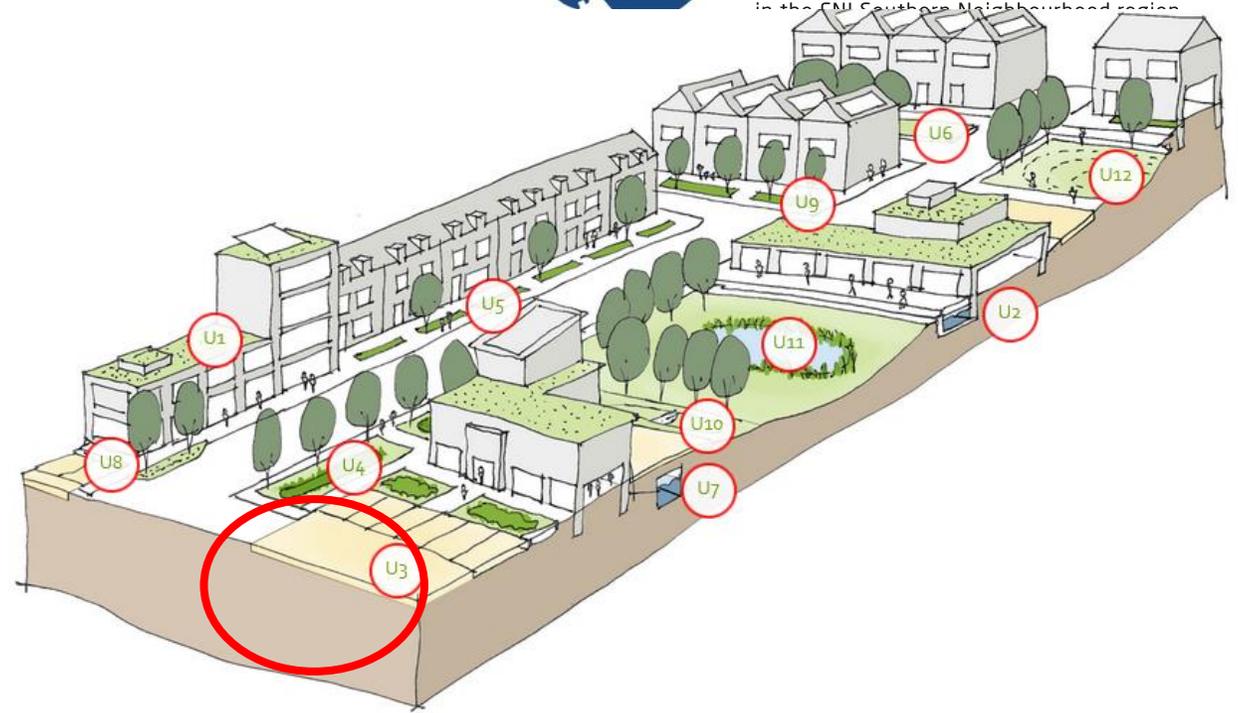
## 3a. Porous Pavements

### Pervious Concrete:

Consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of water through the pavement.

### Porous Asphalt:

Porous asphalt consist large, single-sized aggregate particles with open voids that give the material its porosity and permeability. The large aggregated are bound by asphalt or bitumen. Porous asphalt surfaces are being used on roadways to improve driving safety by removing water from the surface.



U01	<a href="#">Green Roofs</a>
U02	<a href="#">Rainwater Harvesting</a>
U03	<a href="#">Permeable surfaces</a>
U04	<a href="#">Swales</a>
U05	<a href="#">Channels and rills</a>
U06	<a href="#">Filter Strips</a>
U07	<a href="#">Soakaways</a>
U08	<a href="#">Infiltration Trenches</a>
U09	<a href="#">Rain Gardens</a>
U10	<a href="#">Detention Basins</a>

# Natural Water Retention Measures (NWRMs)

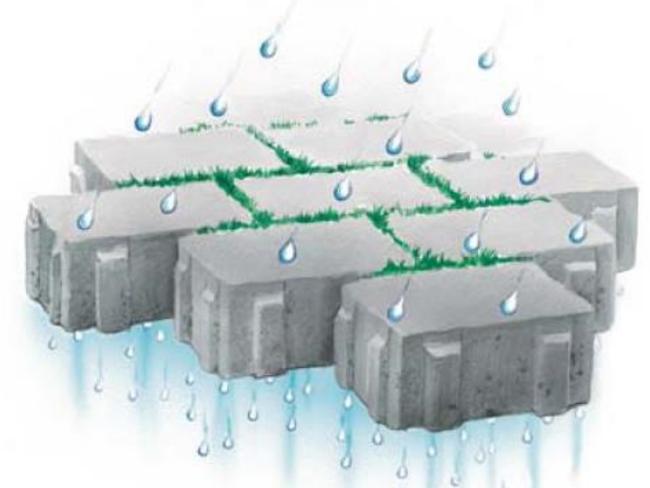
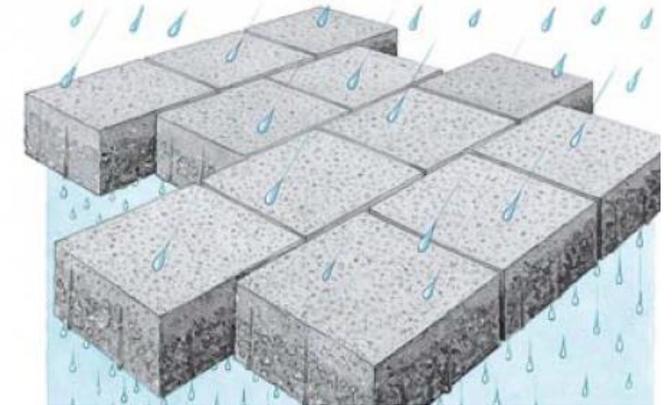
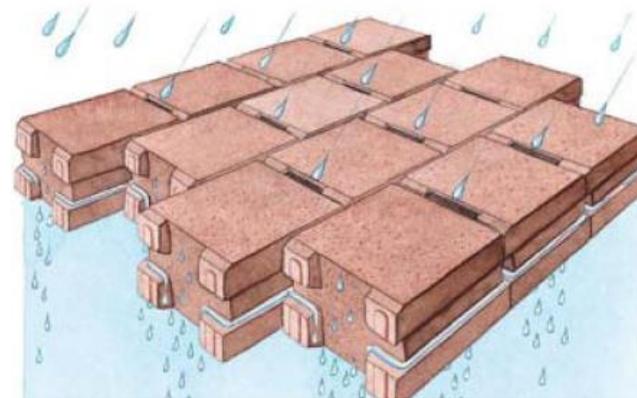


Water and Environment Support

## 3b. Permeable Blocks

The first type consists of concrete pavers with wide joints or apertures to infiltrate the water underground. Pavers with canals on their sides are especially interesting. The joints of these pavers are filled with a permeable mineral material that allows fast water movement. Because of these canals, the pavers need only narrow joints. This feature allows them to be used, for example, around supermarkets with shopping trolleys. Such pavements look very much like traditional pavements.

The second type consists of porous paving-stones with greened apertures. This system is suitable for all areas, where a natural look is desired. The small apertures of 3 cm x 3 cm are filled with a specific substrate that stores water, so that the grass does not dry out during rain-free periods. The open structure of the pavers prevents overheating of the pavement, so the grass has ideal living conditions

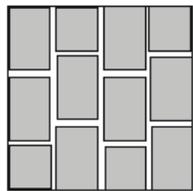
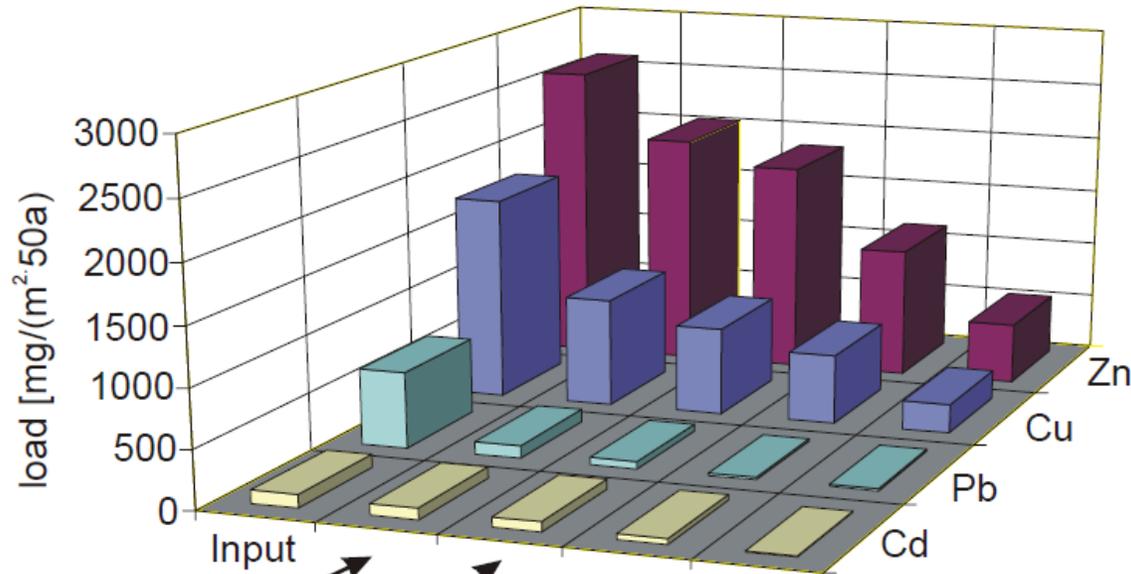
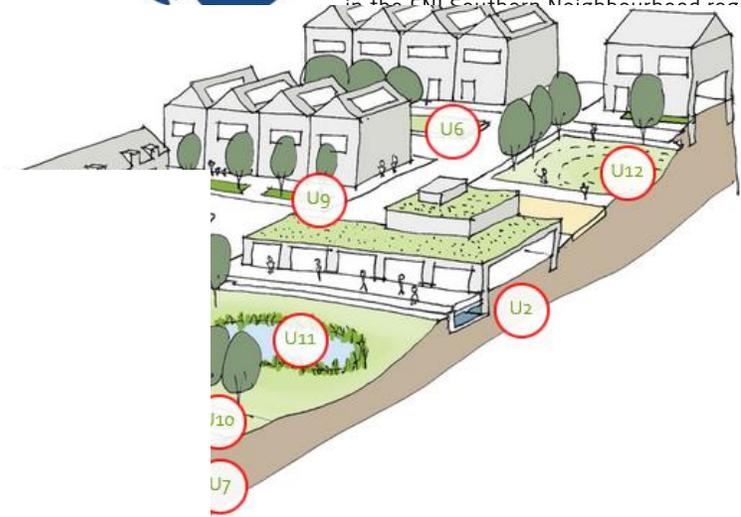


# Natural Water Retention Measures (NWRMs)

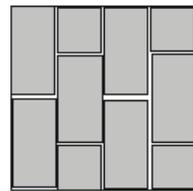


Water and Environment Support  
in the CNL Southern Neighbourhood region

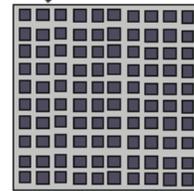
## 3. Permeable Surfaces



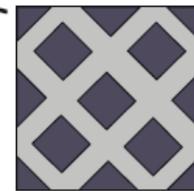
concrete paver with large joints



porous concrete paver



greened concrete paver



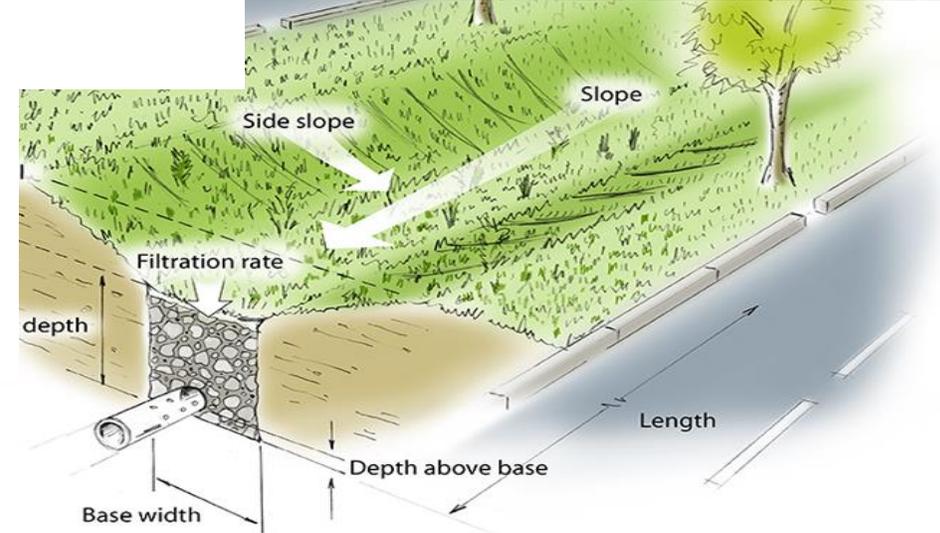
greened concrete paver

# es (NI

The storage volume  $V_S$ , ( $m^3$ ) of a swale is calculated using the following formula:

$$V_S = \left[ \frac{I_{tc,Y}}{3.6 \cdot 10^6} \cdot (A_i + A_s) - \frac{1}{2} k_{h_{sat}} \cdot A_s \right] \cdot 60 \cdot t_c$$

- where :
- $A_i$  = Connected impervious area ( $m^2$ )
  - $A_s$  = Available infiltration area ( $m^2$ )
  - $k_{h_{sat}}$  = Hydraulic conductivity of the soil (m/s)
  - $I_{tc,Y}$  = Rainfall intensity (mm/hr)
  - $t_c$  = Design storm duration (min)



the swale channel  
As a result, swales  
quality of runoff  
particulate pollutant

- Uo6 Filter Strips
- Uo7 Soakaways
- Uo8 Infiltration Trenches
- Uo9 Rain Gardens
- Uo10 Detention Basins

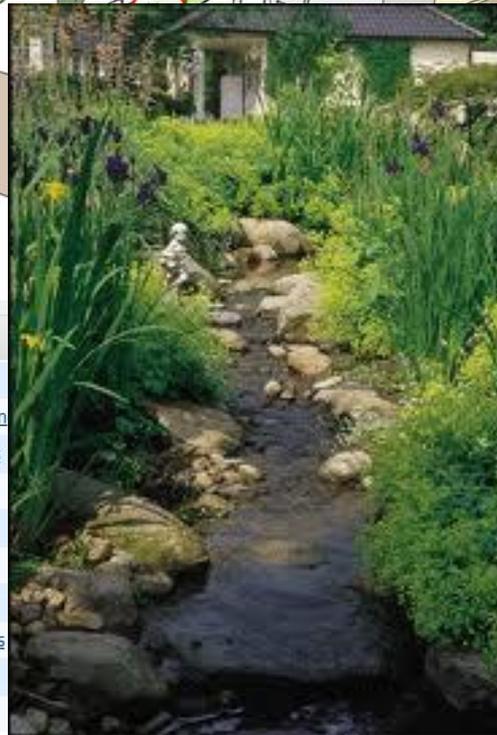
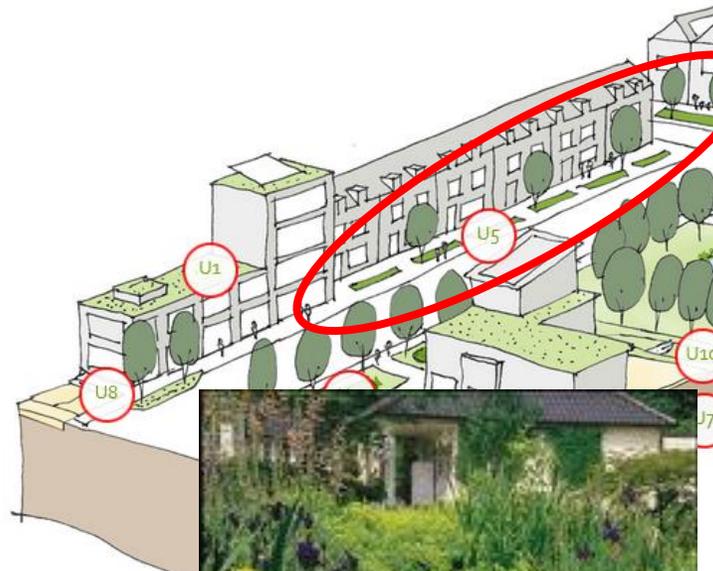
# Natural Water Retention Measures (NWRMs)

## 5. Channel and Rills

### Definition:

Channels and rills are shallow open surface water channels that collect water, slow it down and provide storage for silt deposited from runoff. They can have a variety of cross sections to suit the urban landscape and can include the use of planting to provide both enhanced visual appeal and water treatment.

Channels and rills may be planted, providing a 'green' alternative to conventional drains. They should be planted with native vegetation to be most effective in enhancing biodiversity. They can be incorporated as an element in a network of green areas, thereby creating a green corridor, which is a key issue for the provision of terrestrial habitat. Also control polluted runoff from roofs or balconies wastewater (wash, drainage).

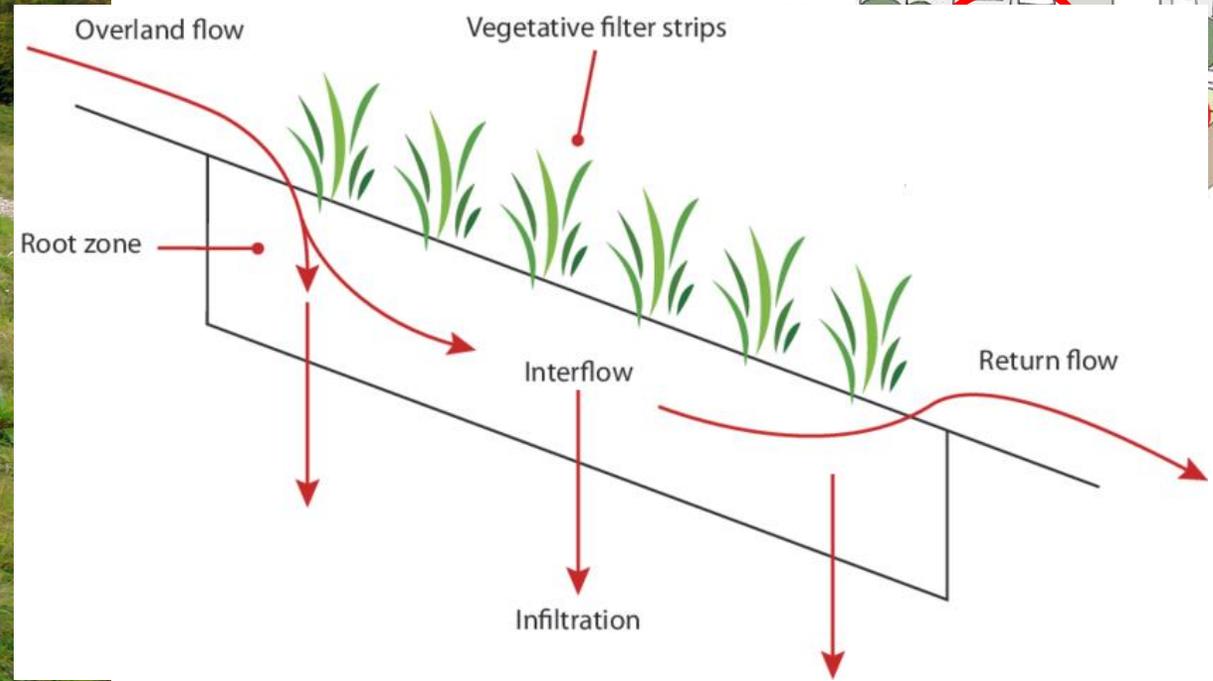
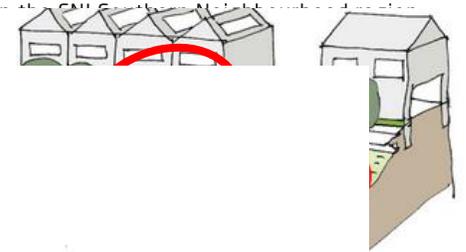


U01	Green Roofs
U02	Rainwater Harvesting
U03	Permeable surfaces
U04	Swales
U05	Channels and rills
U06	Filter Strips
U07	Soakaways
U08	Infiltration Trenches
U09	Rain Gardens
U10	Detention Basins

# Green Roofs (NWRMs)



Water and Environment Support



ways, roof downspouts,

- [Green Roofs](#)
- [U02 Rainwater Harvesting](#)
- [U03 Permeable surfaces](#)
- [U04 Swales](#)
- [U05 Channels and rills](#)
- [U06 Filter Strips](#)
- [U07 Soakaways](#)
- [U08 Infiltration Trenches](#)
- [U09 Rain Gardens](#)
- [U10 Detention Basins](#)

# Natural Water Retention Measures

## 7. Rain gardens

Defi  
Rain  
stor  
inte  
latte



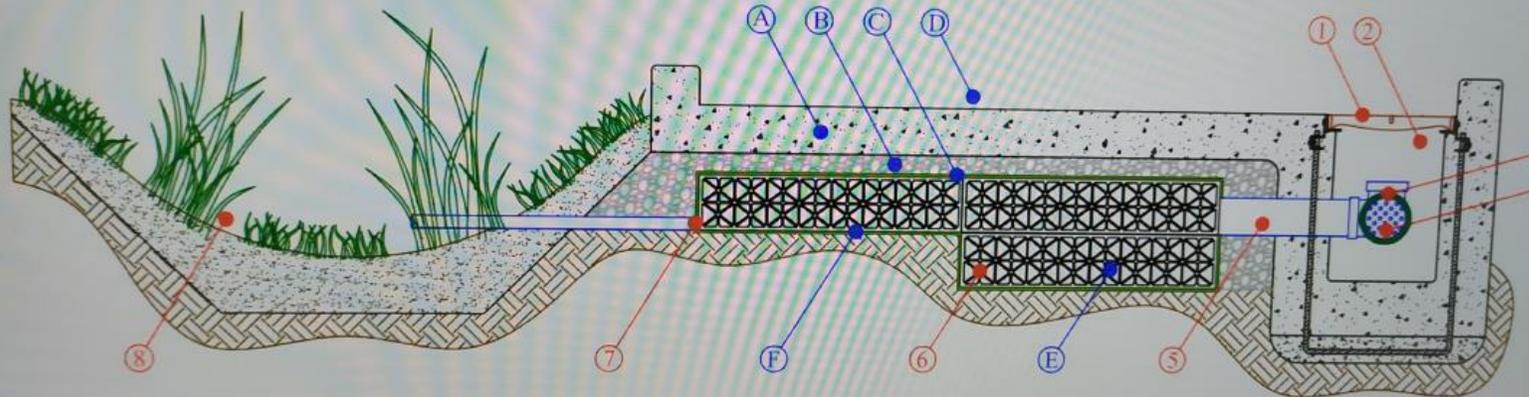
- els and rills
- strips
- ways
- tion Trenches
- ardens
- ion Basins

# Natural Water Retention Measures (NWRMs)

## 8. Soakways

Definition:

Soakways are buried chambers that store surface water and allow it to infiltrate into the ground. They are typically square or circular excavations either filled with rubble or lined with brickwork, pre-cast concrete or polyethylene rings / perforated storage structures surrounded by granular backfill. The supporting structure and backfill substituted by modular geocellular units. Soakways



# Natural Water Retention Measures (NWRMs)

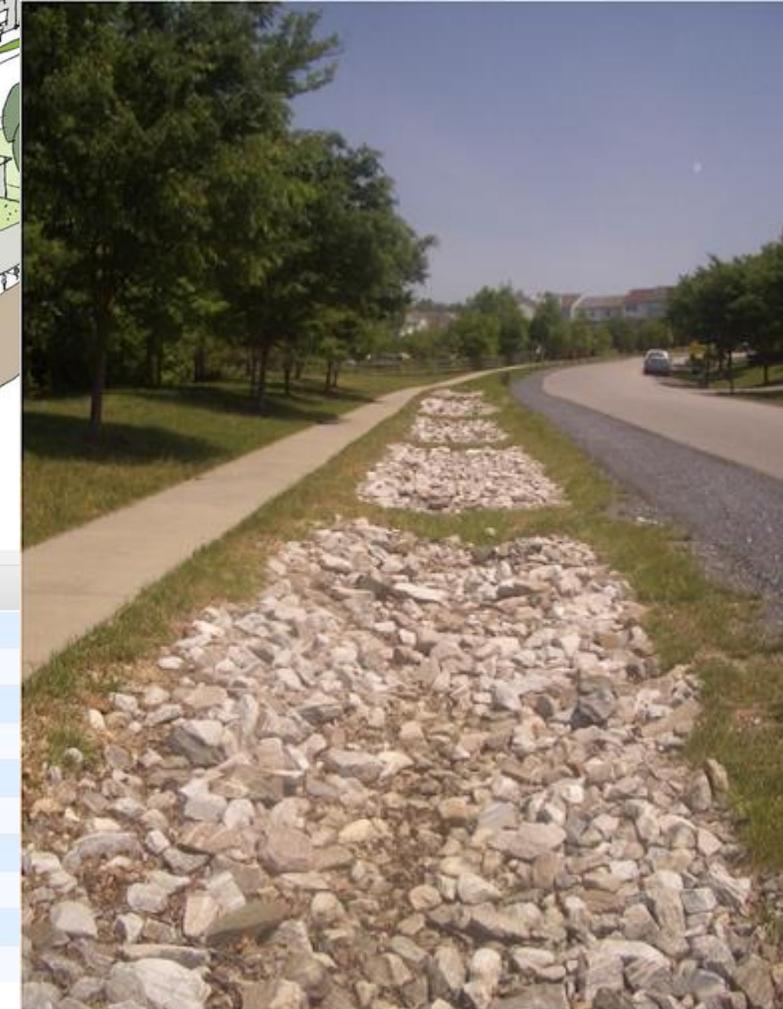
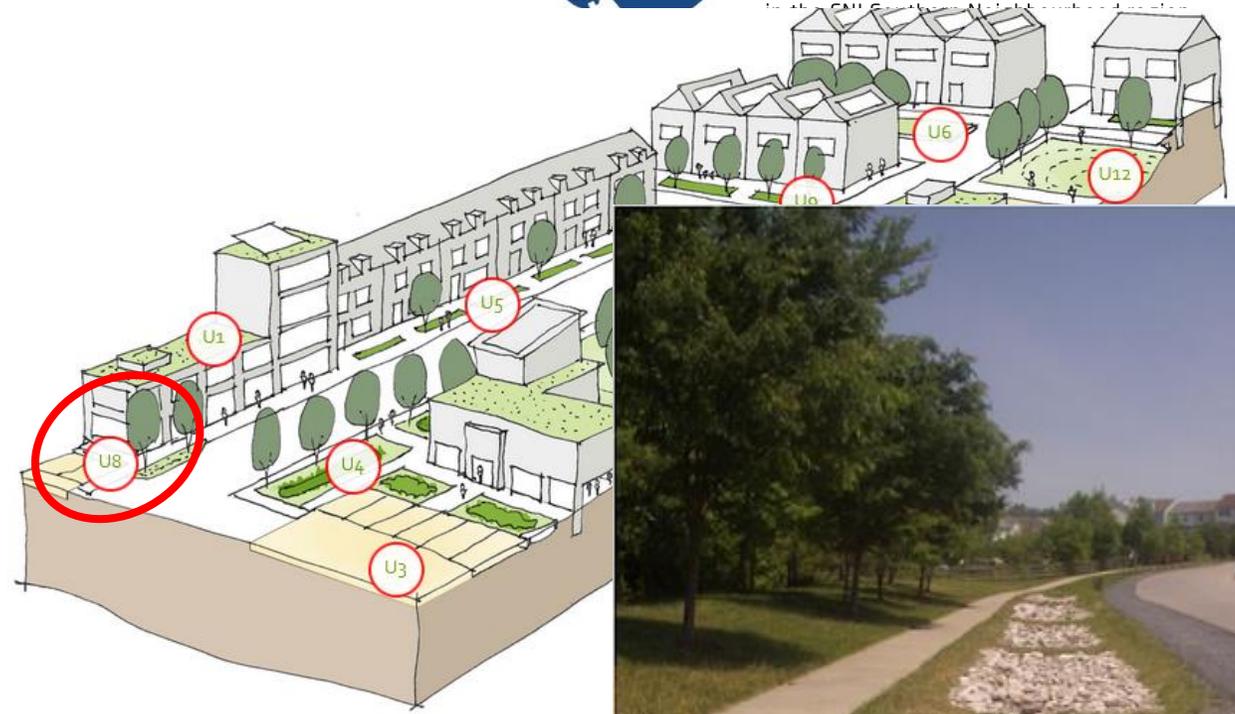


Water and Environment Support

## 9. Infiltration trenches

Definition:

Infiltration trenches are shallow excavations filled with rubble or stone. They allow water to infiltrate into the surrounding soils from the bottom and sides of the trench, enhancing the natural ability of the soil to drain water. Ideally, they should receive lateral inflow from an adjacent impermeable surface but point source inflows may be acceptable with some design adaptation.



Filter strips.

# Natural Water Retention Measures (NWRMs)



Water and Environment Support

## 10. Subsoil Infiltration Trenches

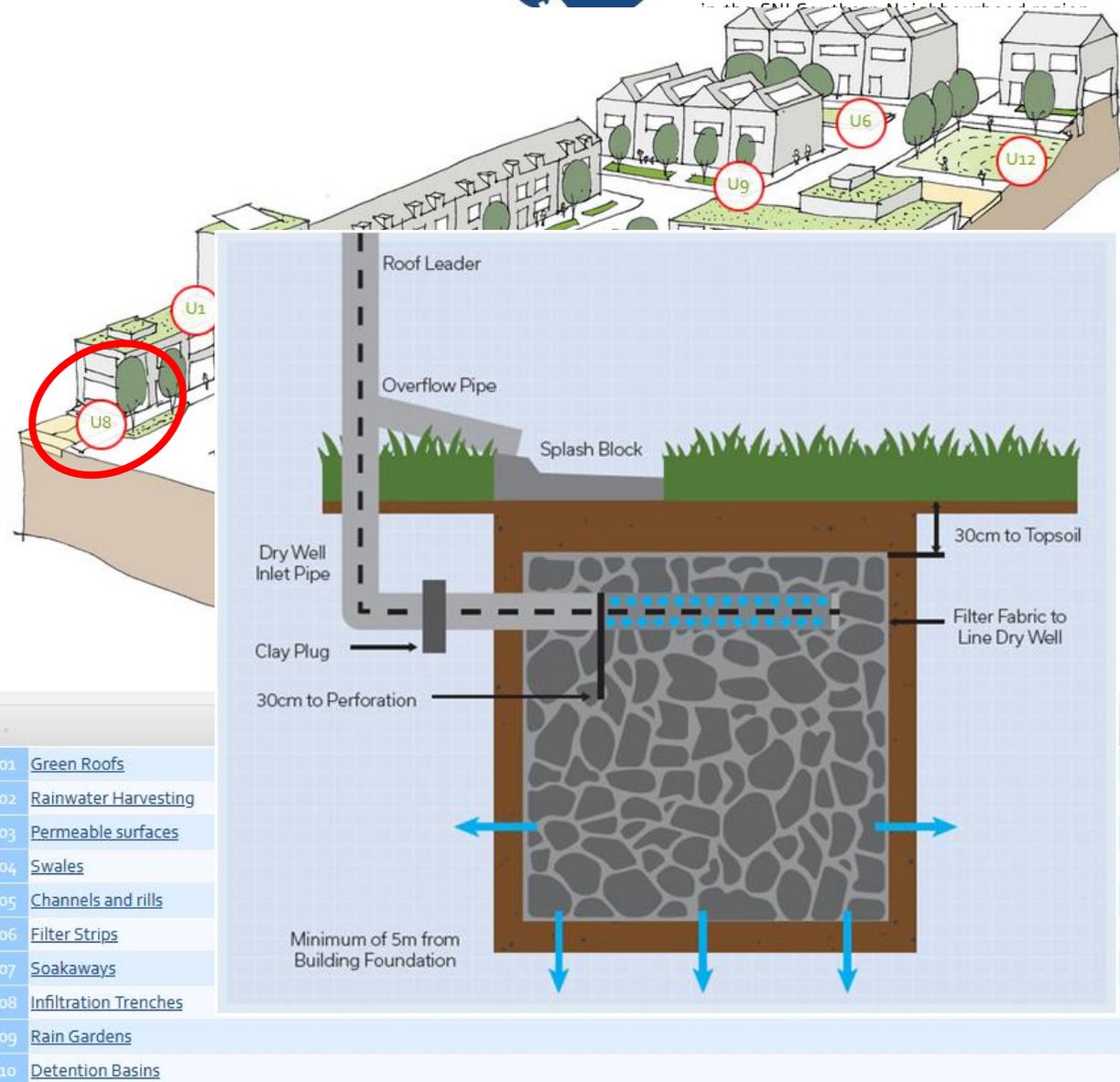
Definition:

Infiltration is provided by a permeable artificially-constructed gravel filter trench, which is covered by shallow soil or by pavements. The pore volume of the gravel allows for substantial storage capacity. When retention is the main purpose of the trench, runoff is either infiltrated from the reservoir into the underlying and surrounding soil, or is collected by perforated pipes and routed to a throttled outflow facility.

The percolation trench should be filled with crushed stone or gravel. This system is especially effective for soils with low hydraulic conductivity and for hot climates. Most of the runoff is infiltrated, so it is very effective in supporting groundwater recharge, for example to decrease salinity. The system can easily be combined with infiltration swales. Goal of the design is to determine the cross-section and length of the infiltration trench. The hydraulic conductivity has to be significantly larger than  $1 \cdot 10^{-6}$  m/s.



LDK Consultants Engineers & Planners SA  
CONSULTANTS

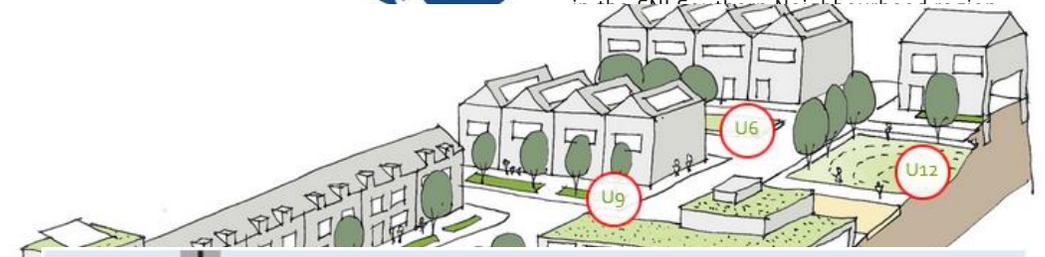


# Natural Water Retention Measures (NWRMs)



Water and Environment Support

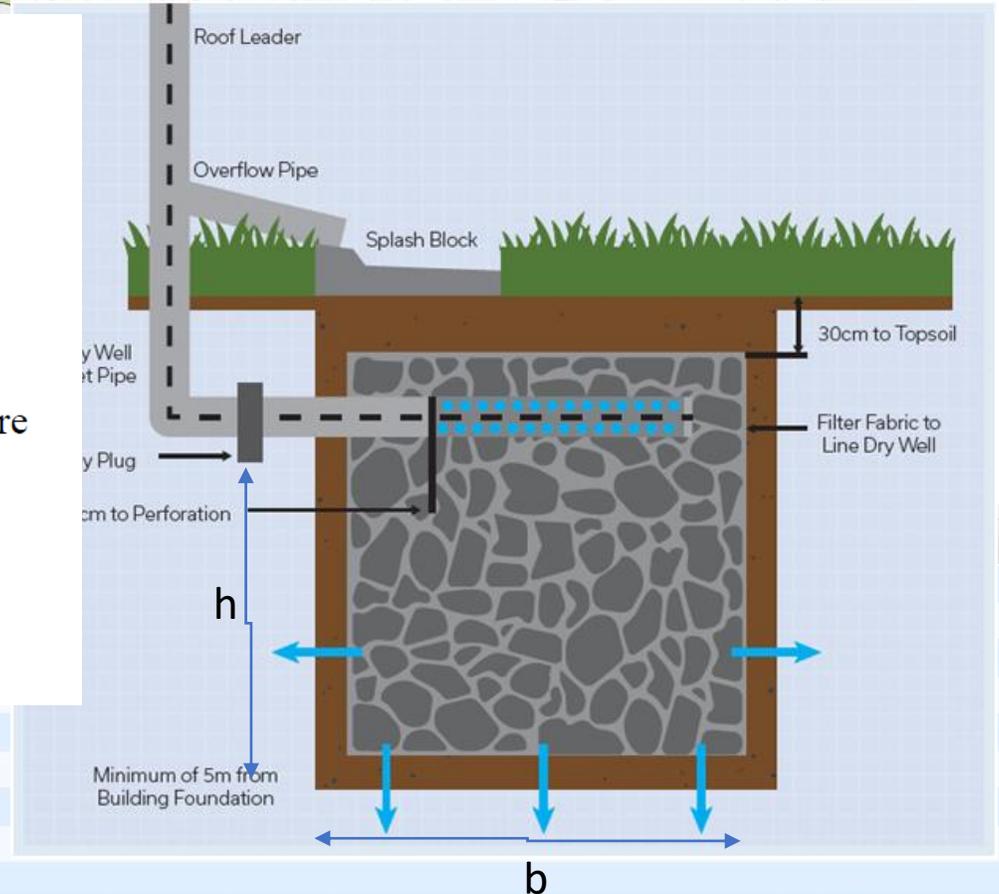
## 10. Subsoil Infiltration Trenches



$$L = \frac{A_i \cdot I_{tc,Y} \cdot 60 \cdot t_c}{\left[ b \cdot h \cdot s_g + \left( b + \frac{h}{2} \right) \cdot 60 \cdot t_c \cdot \frac{k_{hsat}}{2} \right] \cdot 3.6 \cdot 10^6}$$

where :

- $A_i$  = Connected impervious area ( $m^2$ )
- $b$  = Base width of trench (m)
- $s_g$  = Storage coefficient, corresponding to the porosity, or relative pore volume of the gravel filling, (-).
- $h$  = Usable trench height (m)
- $I_{tc,Y}$  = Rainfall intensity (mm/hr)
- $k_{hsat}$  = Hydraulic conductivity of the soil (m/s)
- $t_c$  = Duration of the design storm (min.)

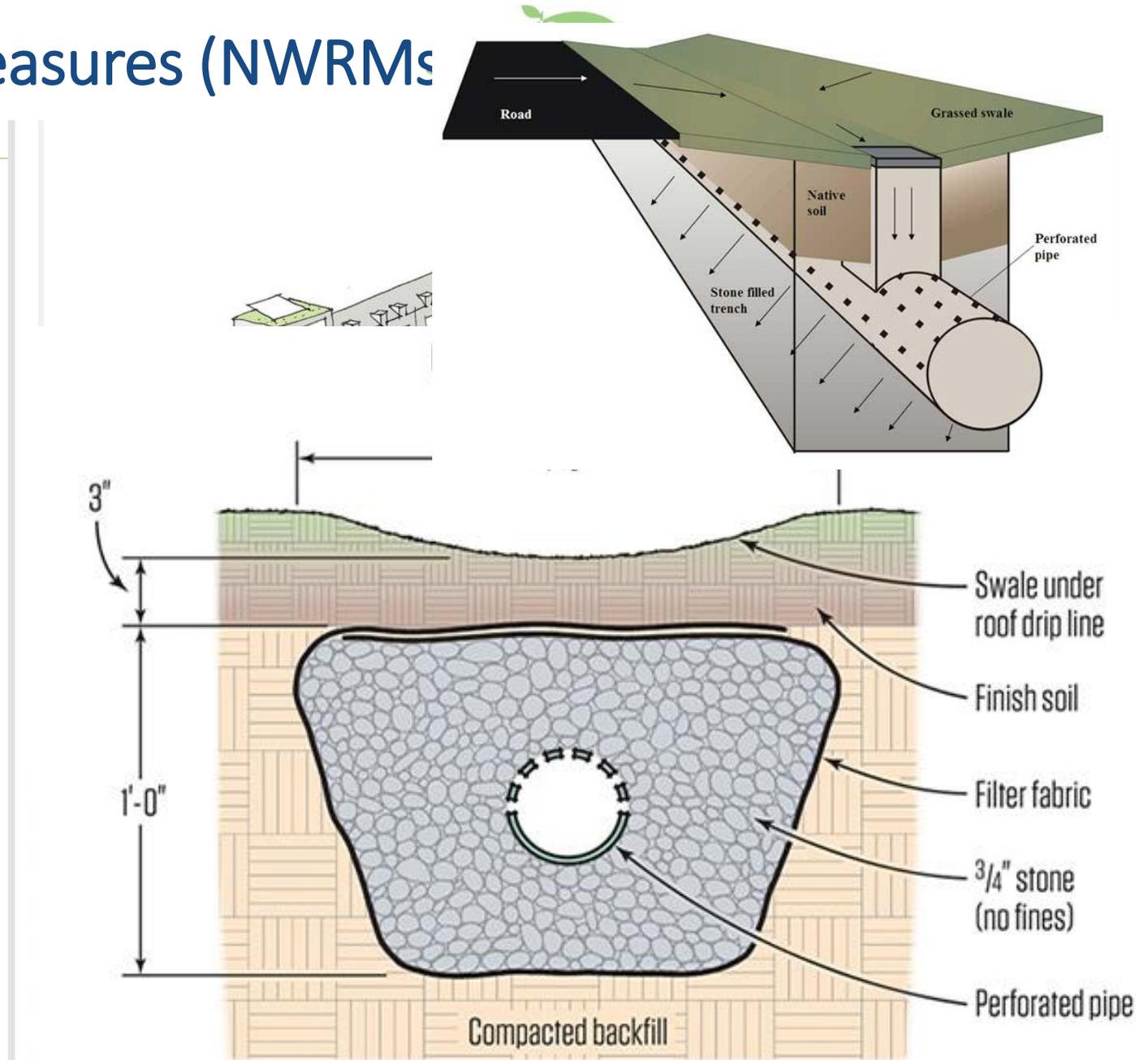


- U05 Channels and rills
- U06 Filter Strips
- U07 Soakaways
- U08 Infiltration Trenches
- U09 Rain Gardens
- U10 Detention Basins

# Natural Water Retention Measures (NWRMs)

## 11. Subsoil Infiltration Pipes

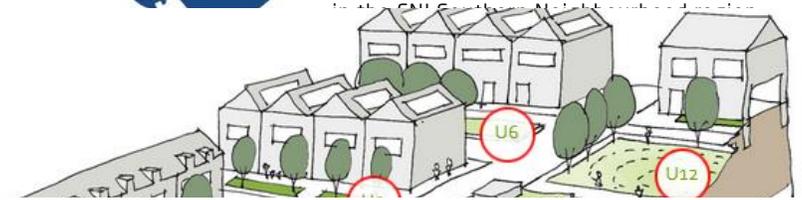
**Definition:**  
Infiltration into the ground can be performed by a perforated pipe, which is covered by shallow topsoil or traffic used pavements like roads or car parks. The pipe volume gives substantial storage capacity. Pipes with different diameters can be used. Parallel pipes or star-shaped pipes can be arranged to increase the infiltration capacity. Underground pipes require installation of special inlets to prevent coarse sediments and oil/grease from clogging the soil around the pipe.



# Natural Water Retention Measures (NWRMs)



Water and Environment Support



## Ground Gutter

First, the storage coefficient for the pipe and the surrounding gravel must be determined:

$$s_{tot} = \frac{s_g}{b \cdot h} \left[ b \cdot h + \frac{\pi}{4} \left( \frac{1}{s_g} \cdot d_i^2 - d_o^2 \right) \right]$$

where :

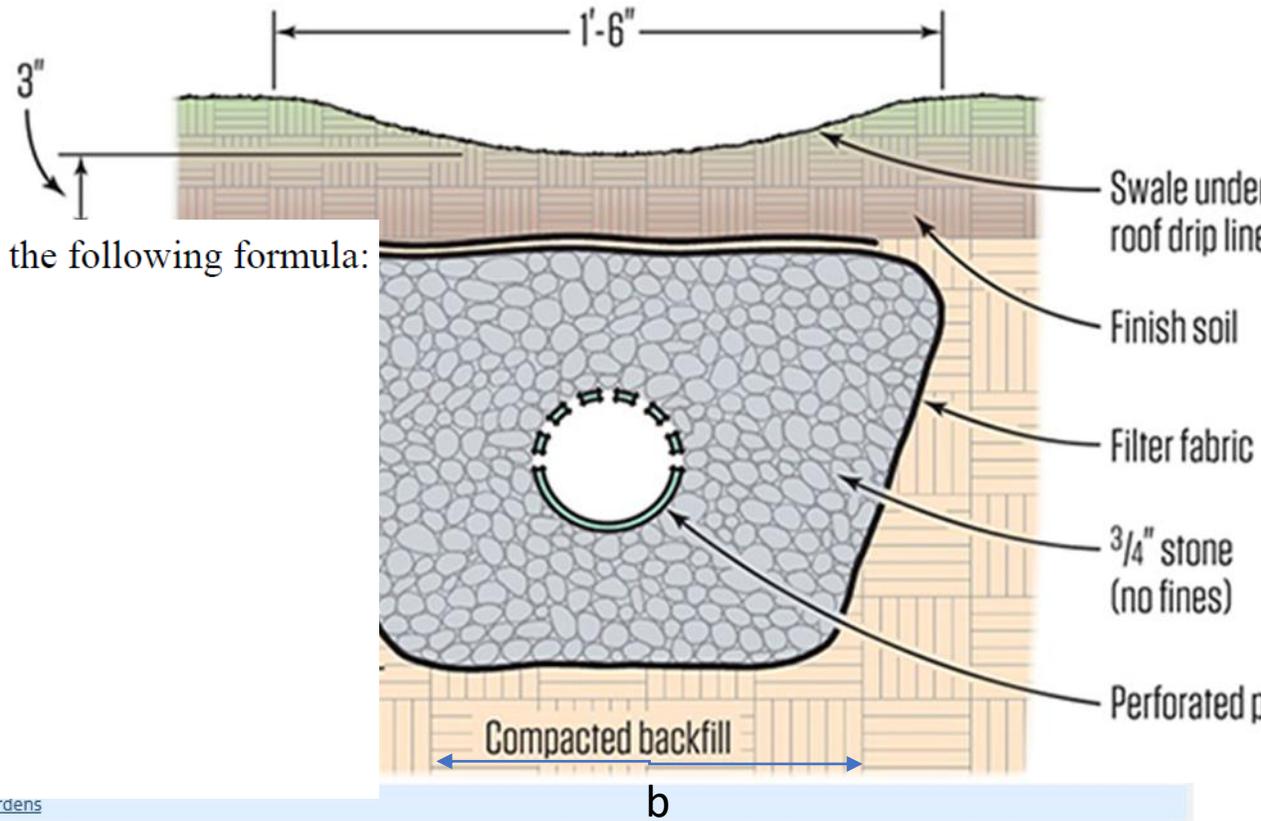
- b = Base width of trench (m)
- h = Usable trench height (m)
- s<sub>g</sub> = Storage coefficient of surrounding gravel, corresponding to the porosity or relative pore volume of the surrounding gravel
- d<sub>i</sub> = Inner diameter of the pipe (m)
- d<sub>o</sub> = Outer diameter of the pipe (m)

The second step is to calculate the length of percolation pipe L (m) using the following formula:

$$L = \frac{A_i \cdot I_{tc,Y} \cdot 60 \cdot t_c}{\left[ b \cdot h \cdot s_{tot} + \left( b + \frac{h}{2} \right) \cdot 60 \cdot t_c \cdot \frac{k_{hsat}}{2} \right] \cdot 3.6 \cdot 10^6}$$

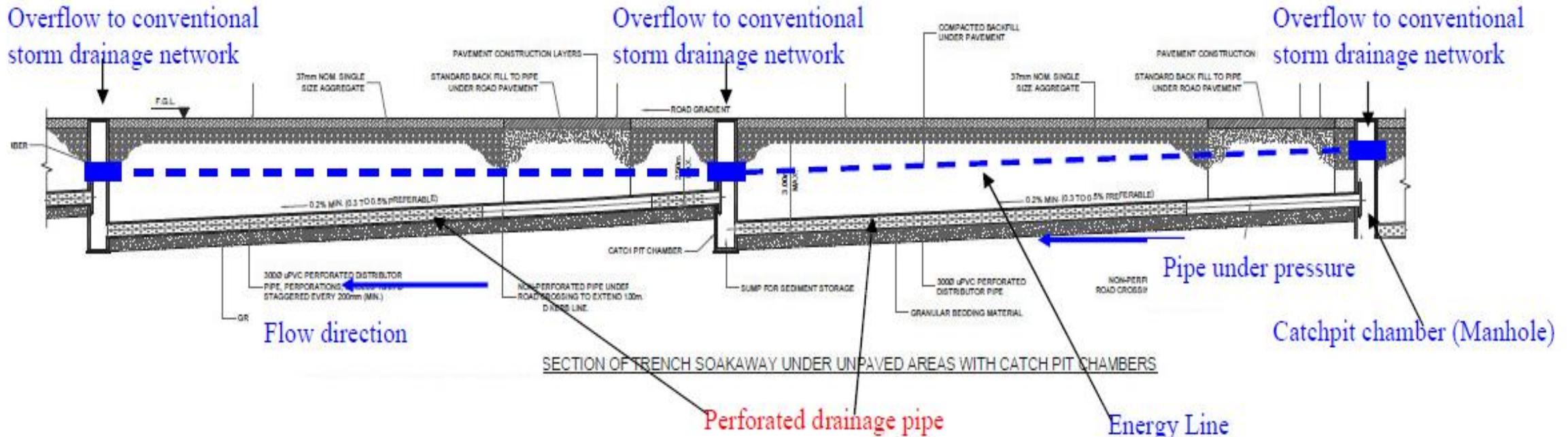
where :

- A<sub>i</sub> = Connected impervious area (m<sup>2</sup>)
- I<sub>tc,Y</sub> = Rainfall intensity (mm/hr)
- = Water conductivity of the saturated zone (m/s)
- t<sub>c</sub> = Duration of the design storm (min.)





## 11. Subsoil Infiltration Pipes as Conventional Stormwater Drainage



# Natural Water Retention

## 12. Detention Basins

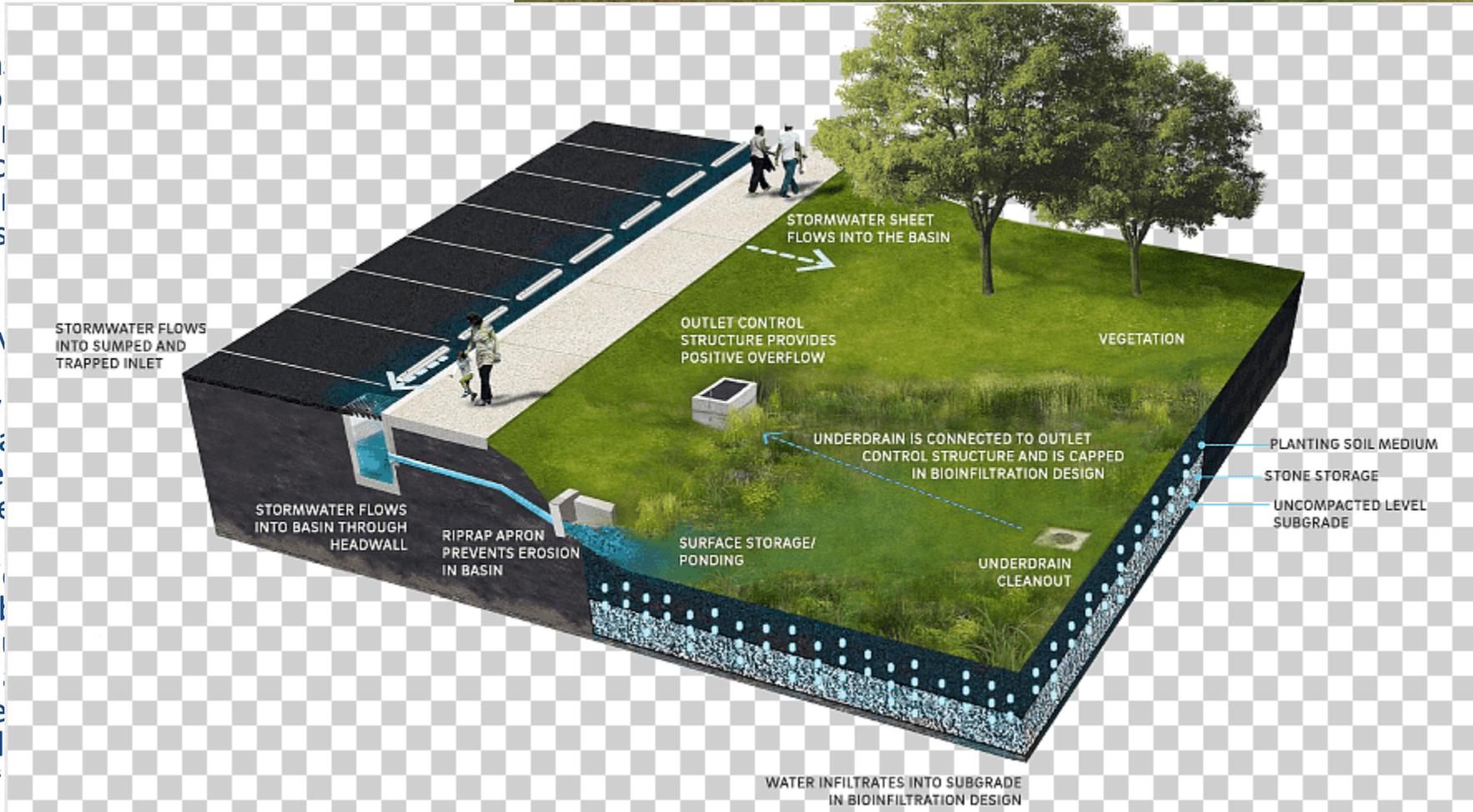
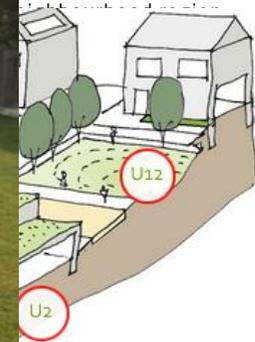
Definition:  
Detention basins hold runoff from settling of sediment. Water may be slowly released through an outlet control structure. Detention basins

Detention basins in periods of heavy rain (e.g. recreation), ancillary amenity fields, recreation areas, planted with trees for visual appearance.

There are no regional detention basins. They can be used to reduce mosquitoes because they drain relatively quickly. If they are completely empty, there is no standing water to become established.



Plant Support



# Natural Water Retention Measures

## 13. Retention Ponds

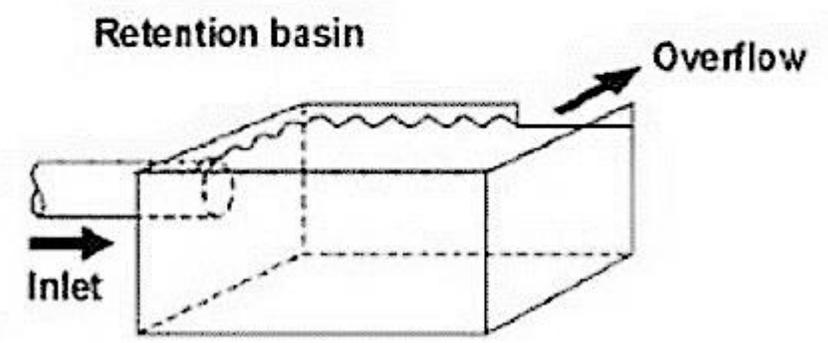
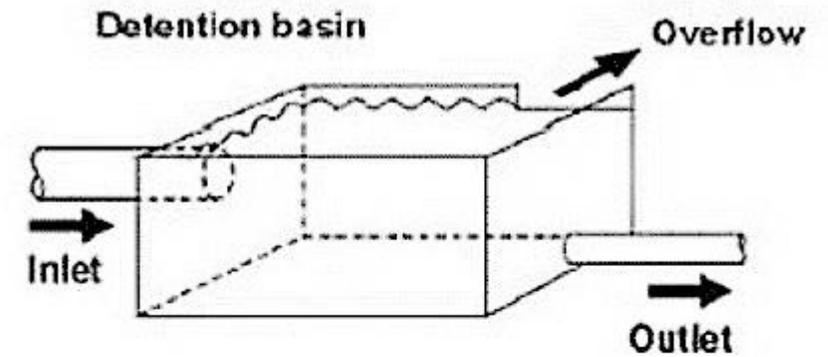
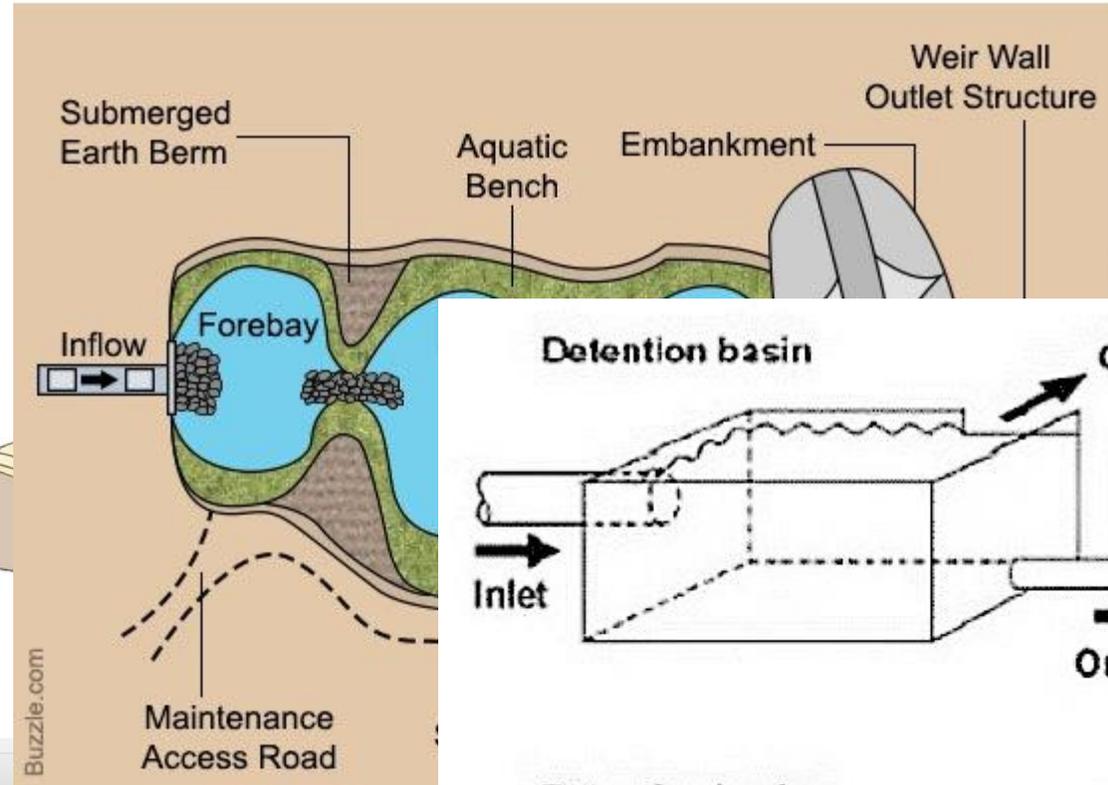
### Definition:

Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. They are created by using an existing natural depression, by excavating a new depression, or by constructing embankments. Existing natural water bodies should not be used due to the risk that pollution events and poorer water quality might disturb/damage the natural ecology of the system.

Retention ponds can provide both storm water attenuation and water quality treatment by providing additional storage capacity to retain runoff and release this at a controlled rate. Ponds can be designed to control runoff from all storms by storing surface drainage and releasing it slowly once the risk of flooding has passed. Runoff from each rain event is detained and treated in the pond. The retention time and still water promotes pollutant removal through sedimentation, while aquatic vegetation and biological uptake mechanisms offer additional treatment. Retention ponds have good capacity to remove urban pollutants and improve the quality of surface runoff.



### Design of a Retention Pond



- Uo1 [Green Roofs](#)
- Uo2 [Rainwater Harvesting](#)
- Uo3 [Permeable surfaces](#)
- Uo4 [Swales](#)
- Uo5 [Channels and rills](#)
- Uo6 [Filter Strips](#)
- Uo7 [Soakaways](#)
- Uo8 [Infiltration Trenches](#)
- Uo9 [Rain Gardens](#)
- Uo10 [Detention Basins](#)

# Natural Water Retention Measures (NWRMs)



Water and Environment Support

## 14. Infiltration Basins

### Definition:

An infiltration basin is a facility constructed within highly permeable soils to provide temporary storage of stormwater runoff. Infiltration basins may have an emergency type spillway but typically do not have a structural outlet to discharge runoff. Instead, outflow from an infiltration basin is through the soil of the basin. An infiltration basin may also be combined with an extended detention basin to provide additional runoff storage for both stormwater quality and quantity management

Infiltration ponds are used typically for small drainage areas and are feasible where the soil has adequate permeability and the maximum water table and/or bedrock elevation is sufficiently low.

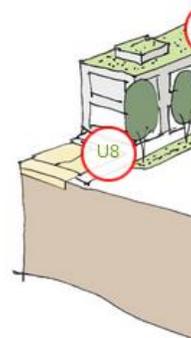
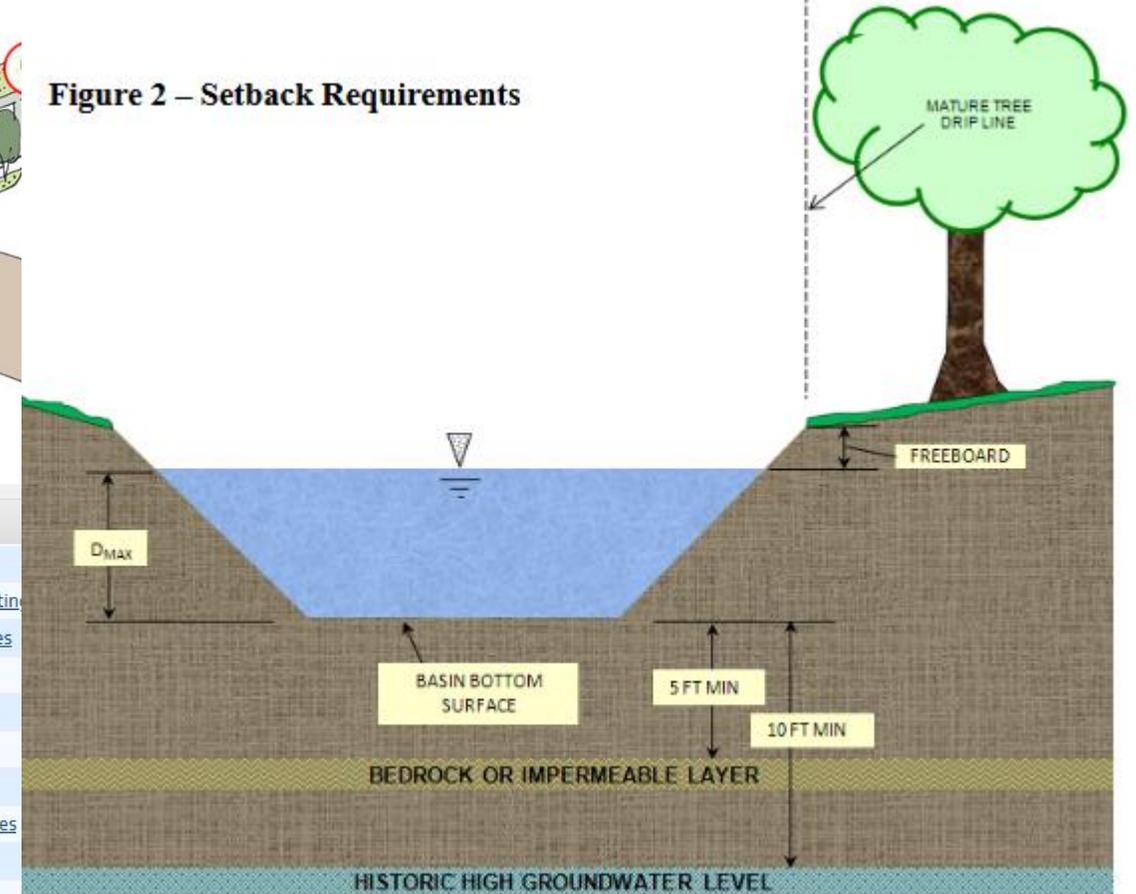


Figure 2 – Setback Requirements



- Uo1 Green Roofs
- Uo2 Rainwater Harvesting
- Uo3 Permeable surfaces
- Uo4 Swales
- Uo5 Channels and rills
- Uo6 Filter Strips
- Uo7 Soakaways
- Uo8 Infiltration Trenches
- Uo9 Rain Gardens
- Uo10 Detention Basins

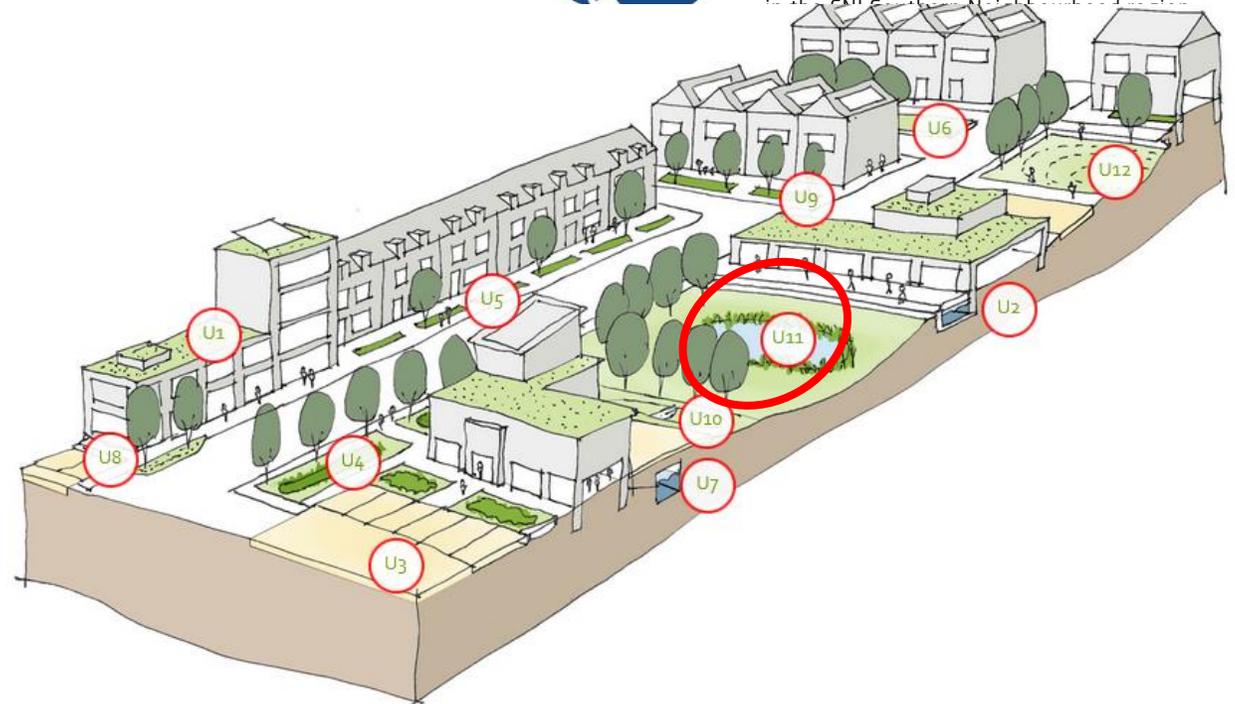
# Natural Water Retention Measures (NWRMs)



Water and Environment Support

## 14. Infiltration Basins

- Soil textures that are recommended for infiltration basins, requires a minimum soil infiltration rate of 13 mm/hour or greater, which include loam, sandy loam, loamy sand, and sand.
- A maximum allowable drain time, requires that the infiltration must fully drain the design runoff volume within 72 h.
- A maximum allowable depth ( $d_{max}$ ) constraint for infiltration basins,  $d_{max}=f \cdot T_p$ , where  $f$  is the final infiltration rate of the basin area in mm/hour,  $T_p$  is the maximum allowable ponding time in hours.
- Infiltration basin bottom must be as level as possible to uniformly distribute runoff for infiltration.



U01	<a href="#">Green Roofs</a>
U02	<a href="#">Rainwater Harvesting</a>
U03	<a href="#">Permeable surfaces</a>
U04	<a href="#">Swales</a>
U05	<a href="#">Channels and rills</a>
U06	<a href="#">Filter Strips</a>
U07	<a href="#">Soakaways</a>
U08	<a href="#">Infiltration Trenches</a>
U09	<a href="#">Rain Gardens</a>
U10	<a href="#">Detention Basins</a>



**Water and  
Environment Support**  
in the ENI Southern Neighbourhood region

Thank you for your attention!

