Water and Environment Support
in the ENI Southern Neighbourhood region

Risque de sédimentation des réservoirs et mesures d'atténuation en faveur de la durabilité en Tunisie
Activity No.: N-W-TN-2

Atelier de Consultation Nationale

18 Sep 2023, Hotel Golden Tulip El Mechtel, Tunis

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

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This Project is funded by the European Union

Review of Natural Water Retention Measures in Urban Areas

Water and
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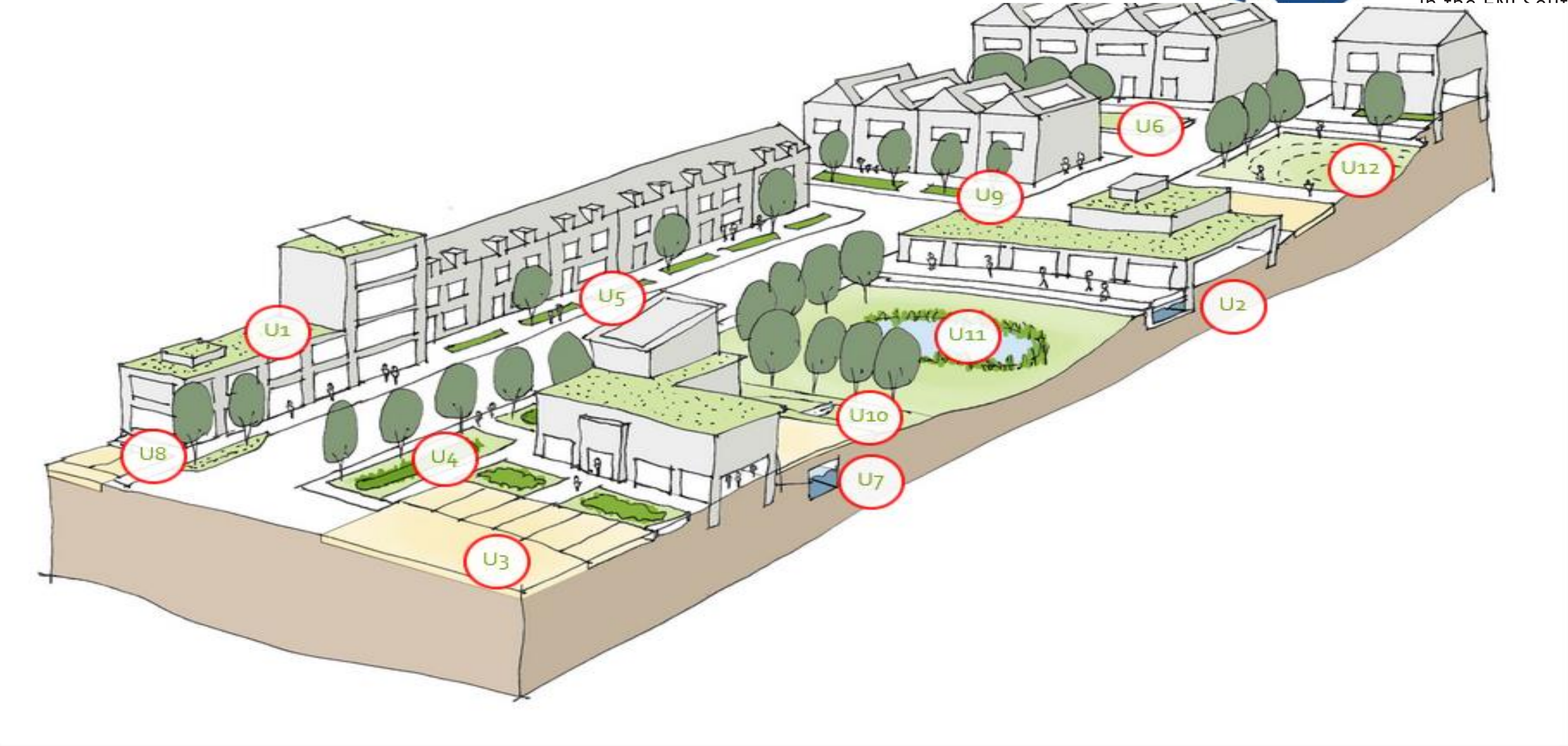
in the ENI Southern Neighbourhood region



U01	Green Roofs
U02	Rainwater Harvesting
U03	Permeable surfaces
U04	Swales
U05	Channels and rills
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U07	Soakaways
U08	Infiltration Trenches
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Natural Water Retention Measures (NWRMs)

Water and
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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.

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Building and Environment 45 (2010) 1890–1904

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

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Green roof energy and water related performance in the Mediterranean cli

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ARTICLE INFO

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

Keywords:

ABSTRACT

Performance of vegetated roofs are investigated in terms of their expected benefits for the b
the urban environment, due to their recognised energy and water management potentia
review of related worldwide experiences is reported for comparison purposes. The investiga
performed within the specific climatic context of the Mediterranean region. Full-scale ex
results are provided from two case studies, located in north-west and central Italy, consisting
monitored green roofs on top of public buildings. The attenuation of solar radiation throug

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

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Proceedings of the 11th International Conference on Urban Drainag

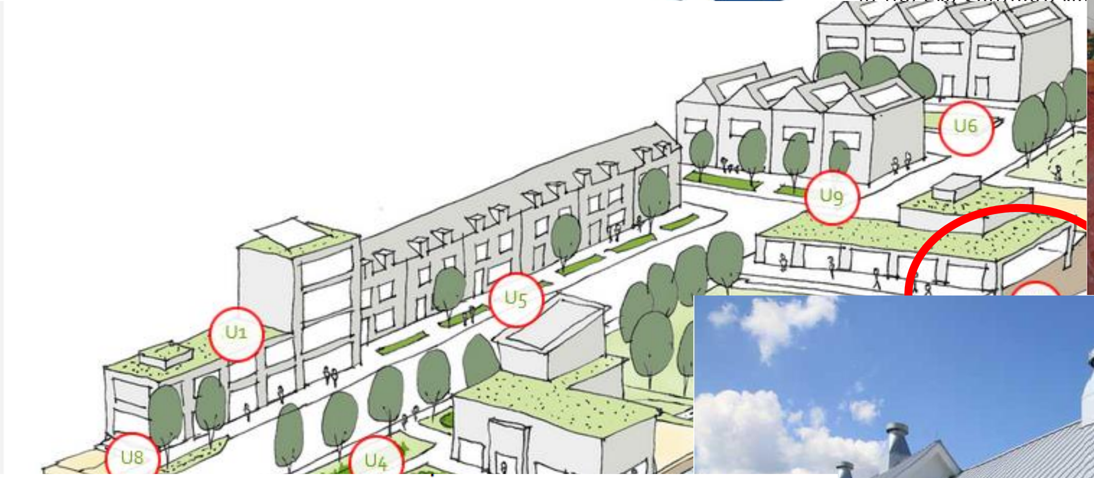
- Stovin et al (2012) found overall 50% cumula
29% for a 2 year event and 15% for a 16 year

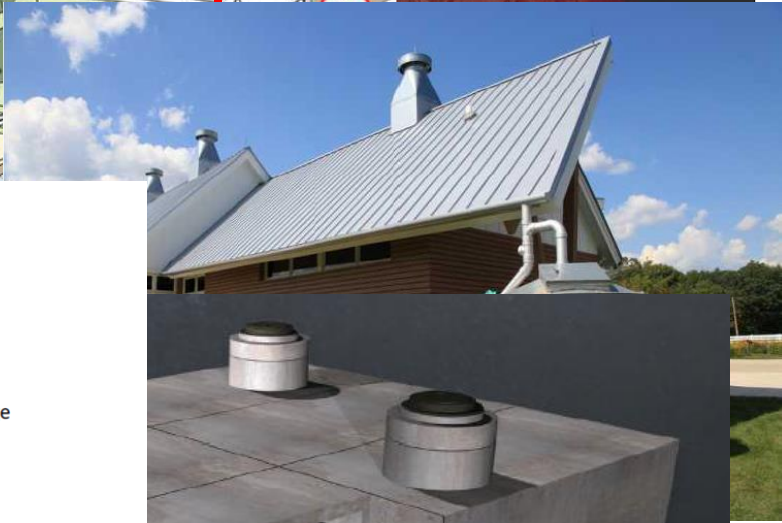
experimental site in the Mediterranean climate." Proceedings of th
Scotland, UK. 2008.).

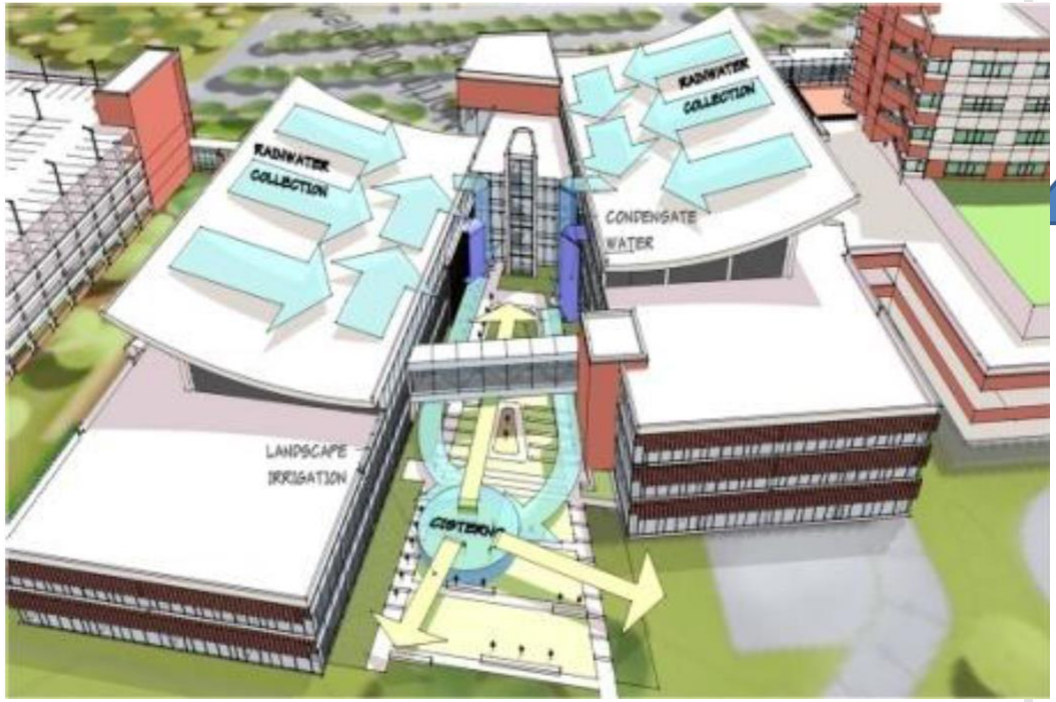
Natural Water Retention Measures (NWRMs)

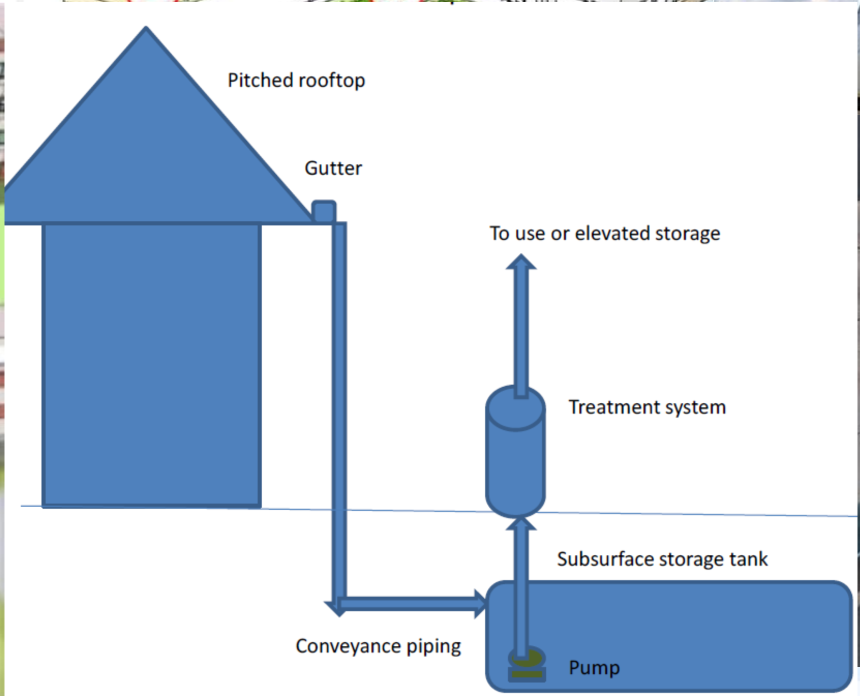
2. Rainwater Harvesting

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

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

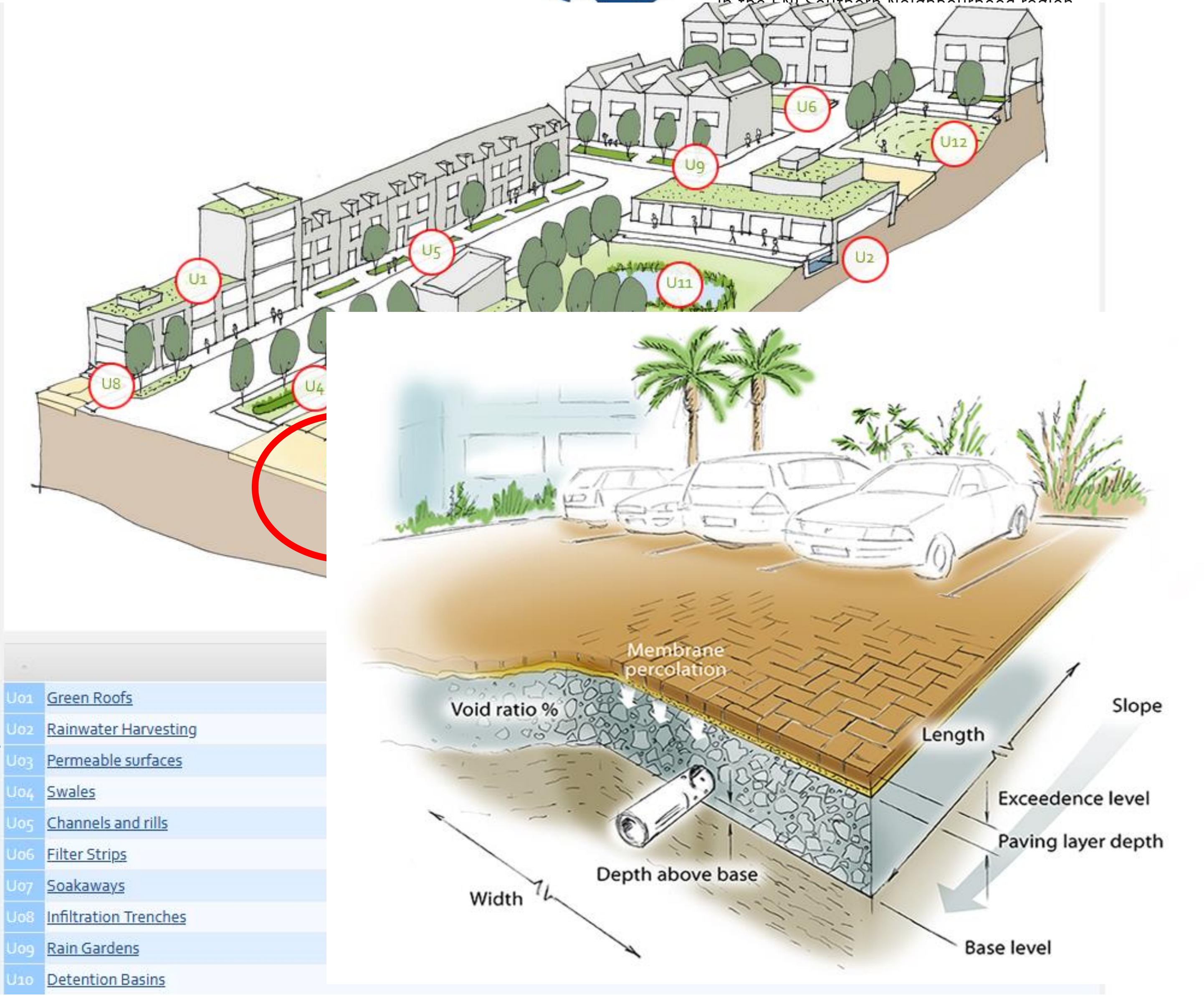
3. Permeable Surfaces

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).



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Natural Water Retention Measures (NWRMs)

Water and
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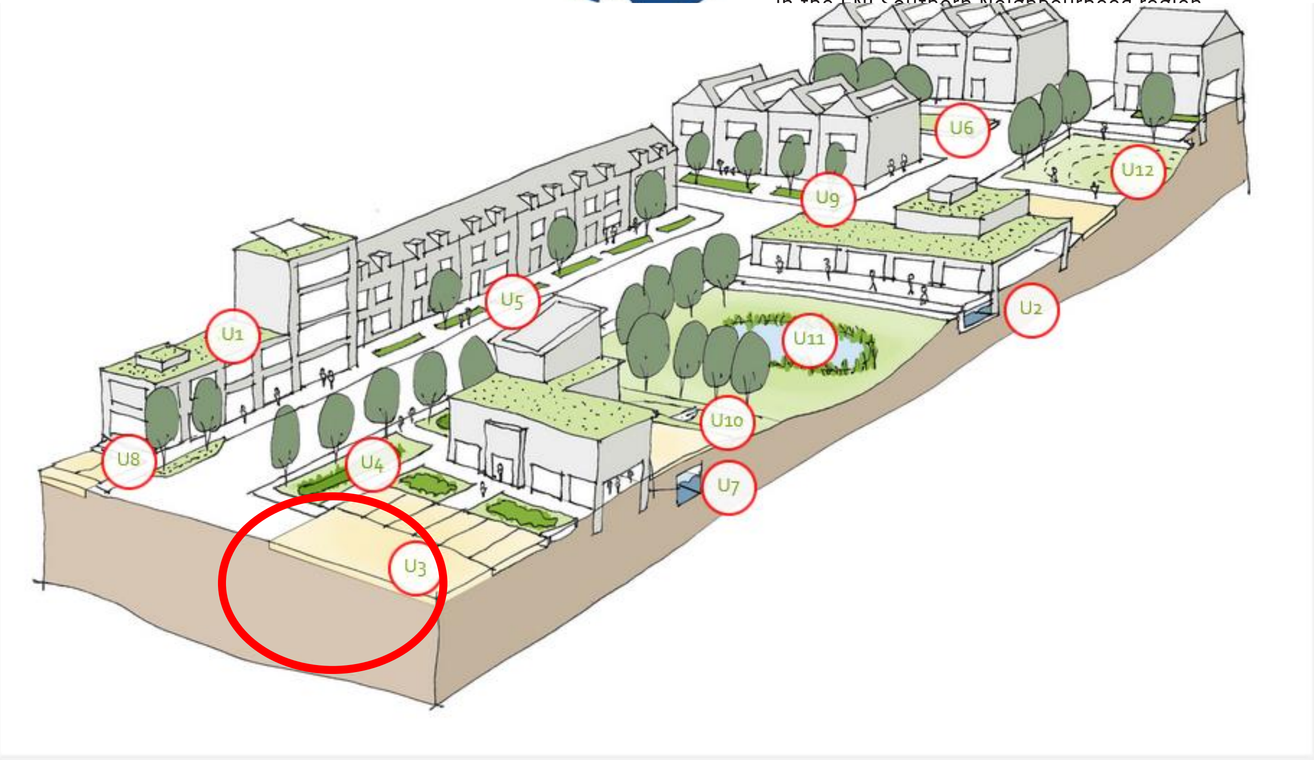
in the ENI Southern Neighbourhood region

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	Green Roofs
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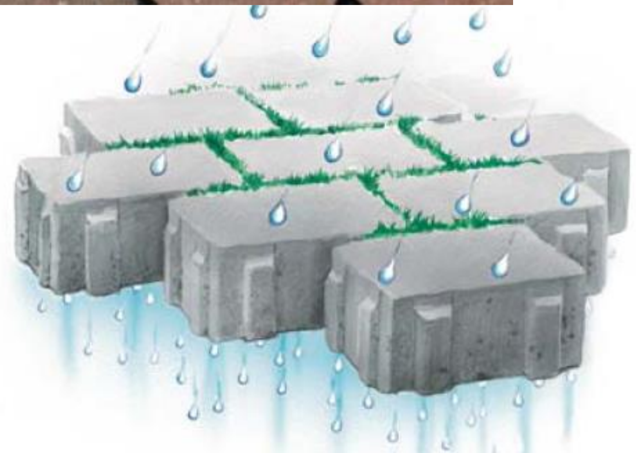
Natural Water Retention Measures (NWRMs)

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 over-heating of the pavement, so the grass has ideal living conditions



U08 Infiltration Trenches
U09 Rain Gardens
U10 Detention Basins

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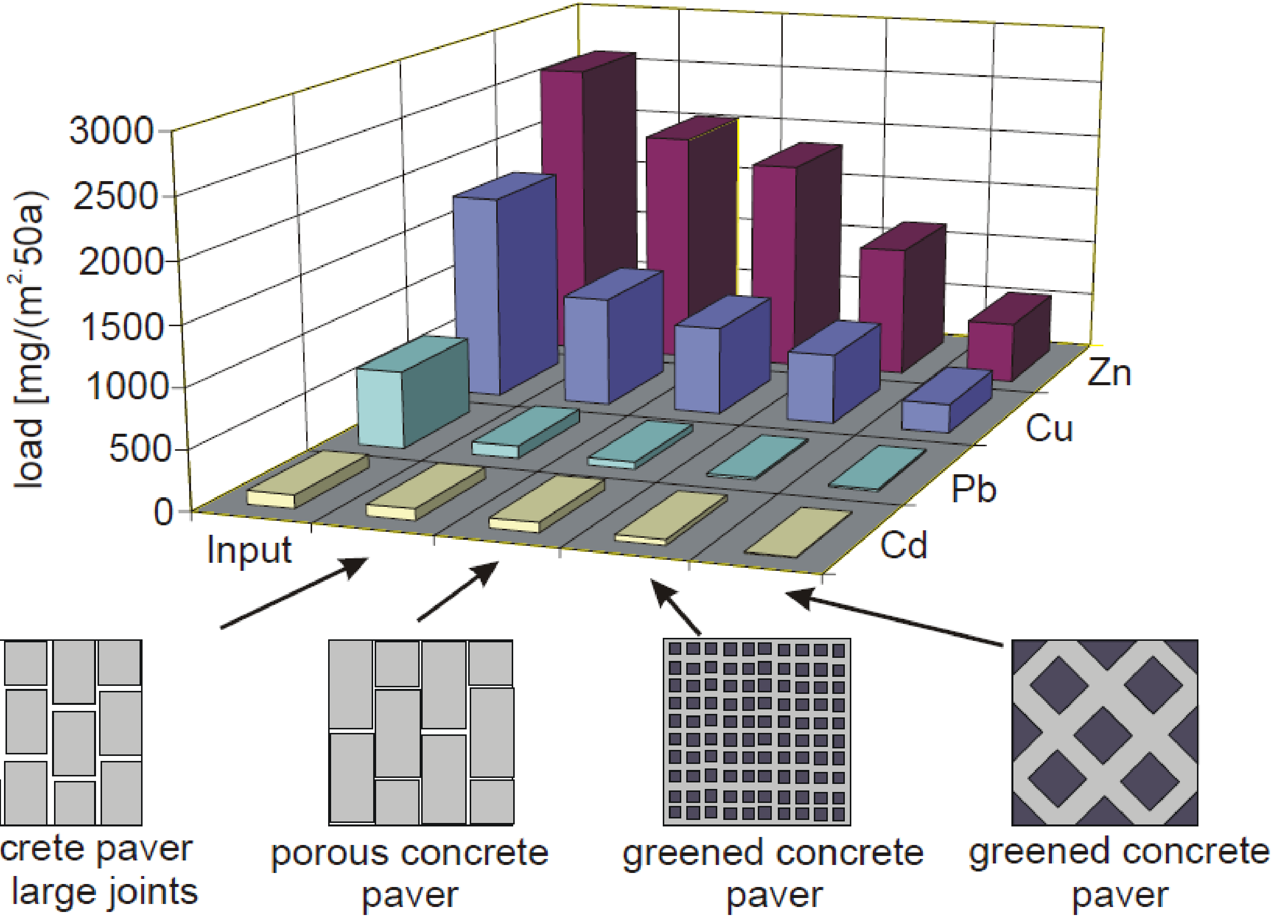
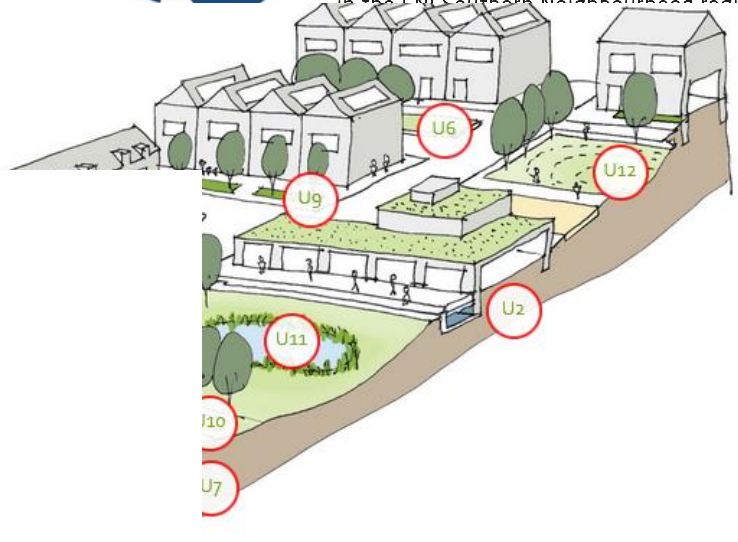
Natural Water Retention Measures (NWRMs)

Water and Environment Support

3. Permeable Surfaces





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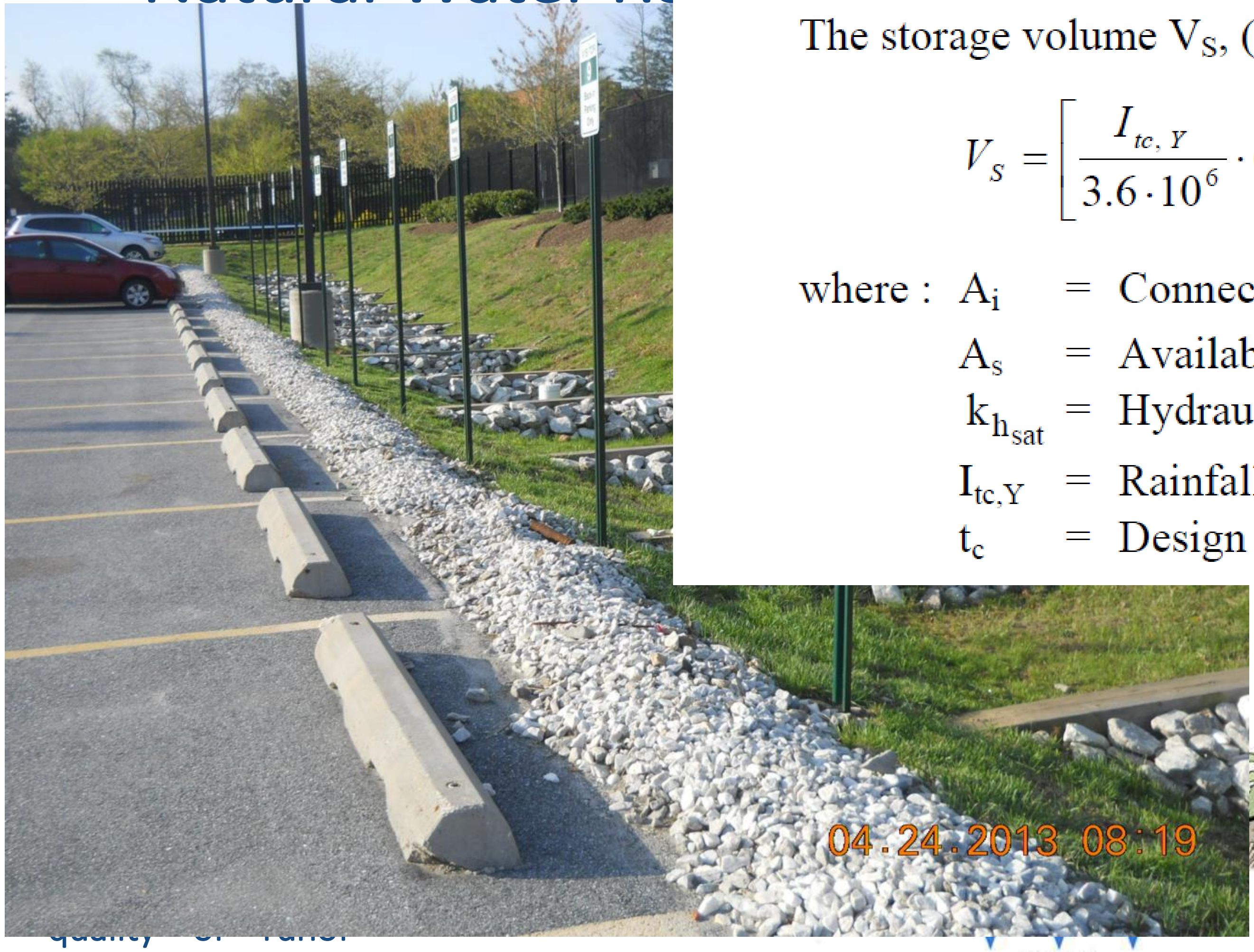
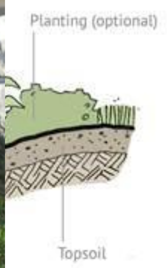
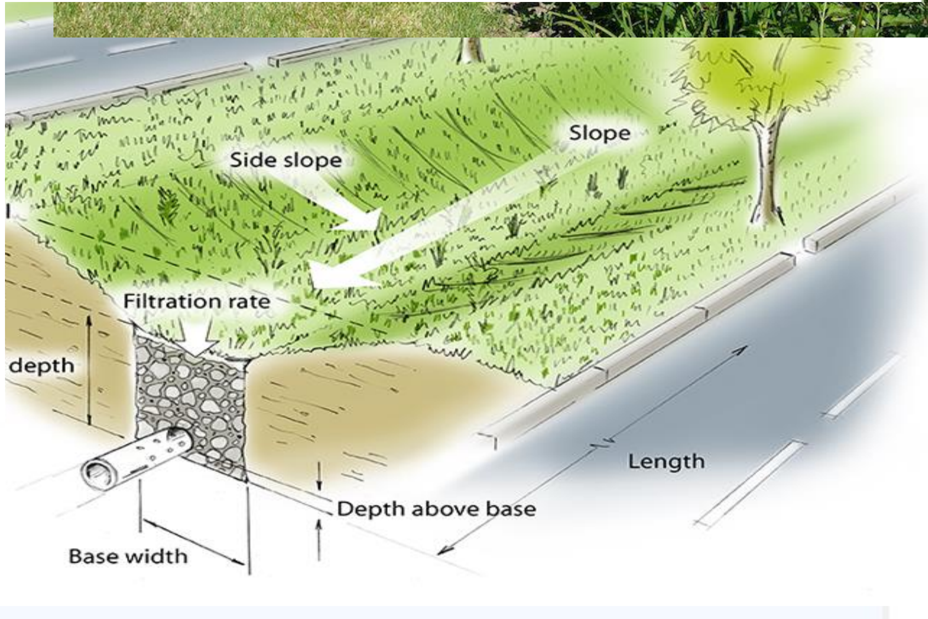


The storage volume V_S, (m^3) of a swale is calculated using the following formula:

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

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)





particulate pollutar

Infiltration

U06	Filter Strips
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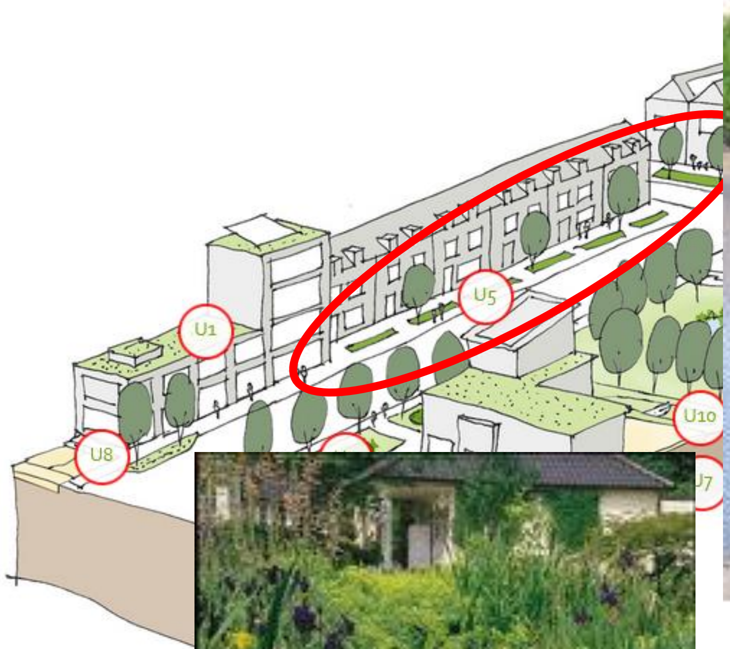
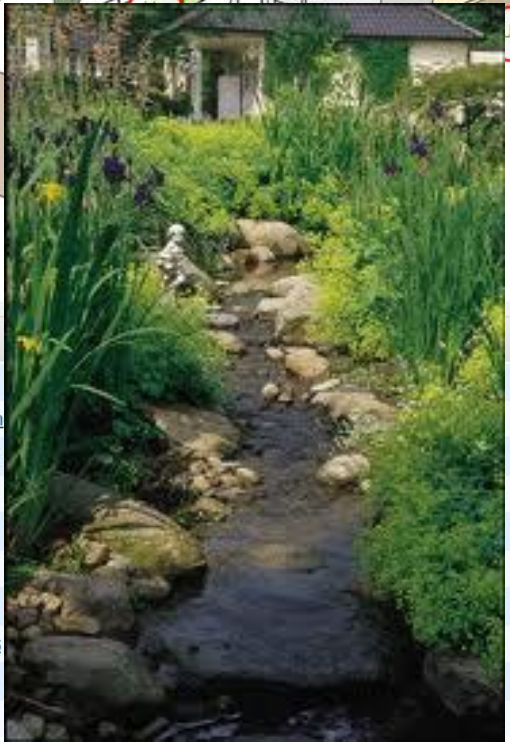
Natural Water Retention Measures (NWRMs)

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).





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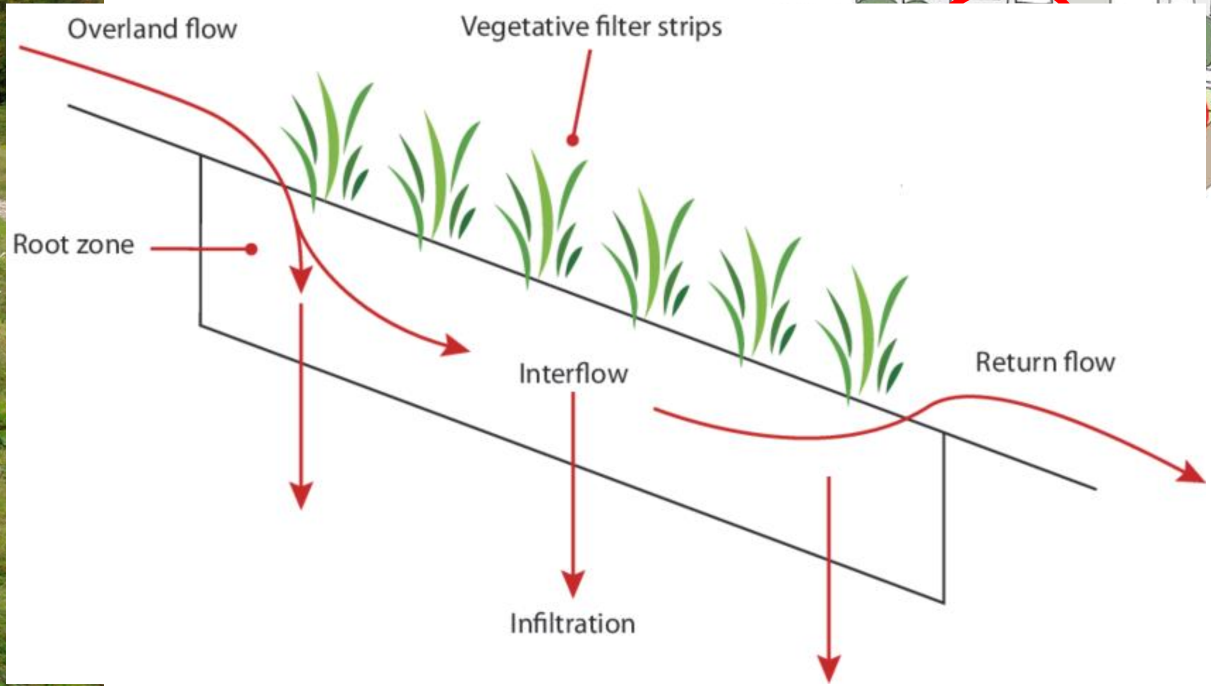
ures (NWRMs)

Water and
Environment Support



ways, roof downspouts,

	reen Roofs
U02	Rainwater Harvesting
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Natural Water Retention Measures (NWRMs)

7. Rain gardens

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U10 Detention Basins

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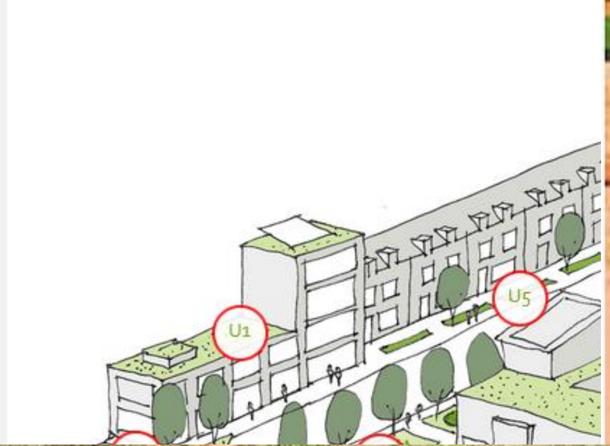
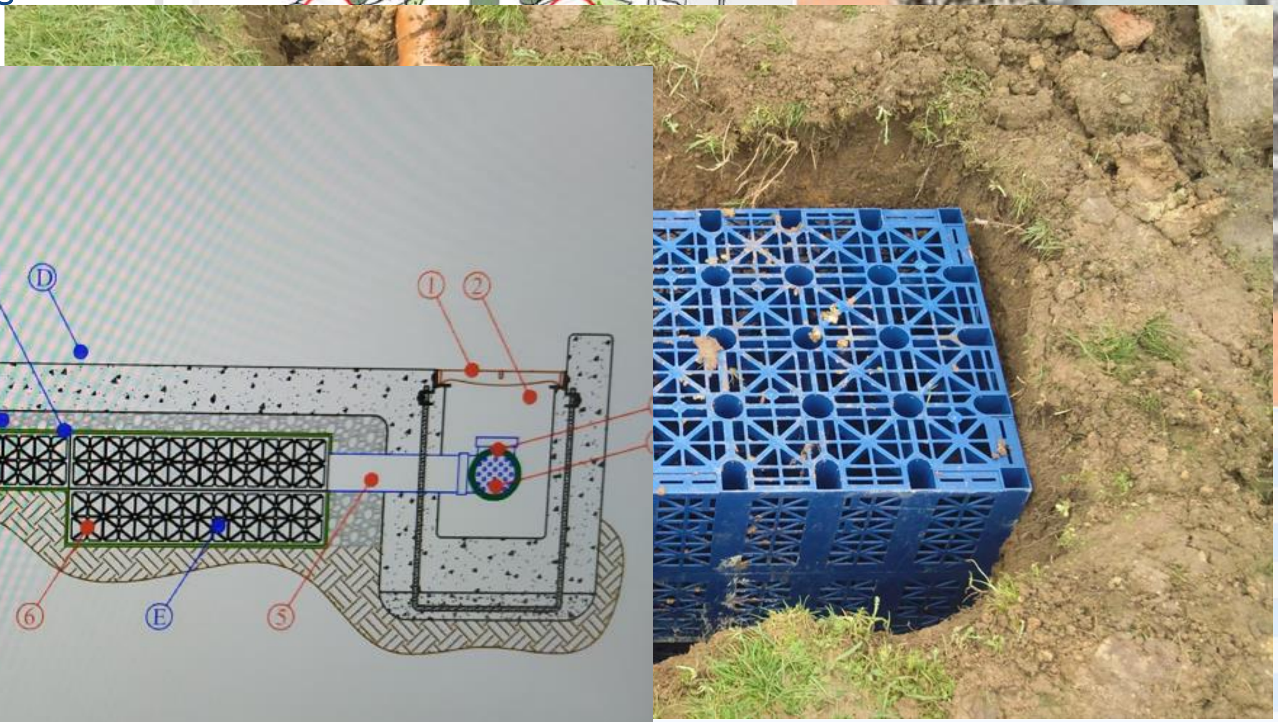
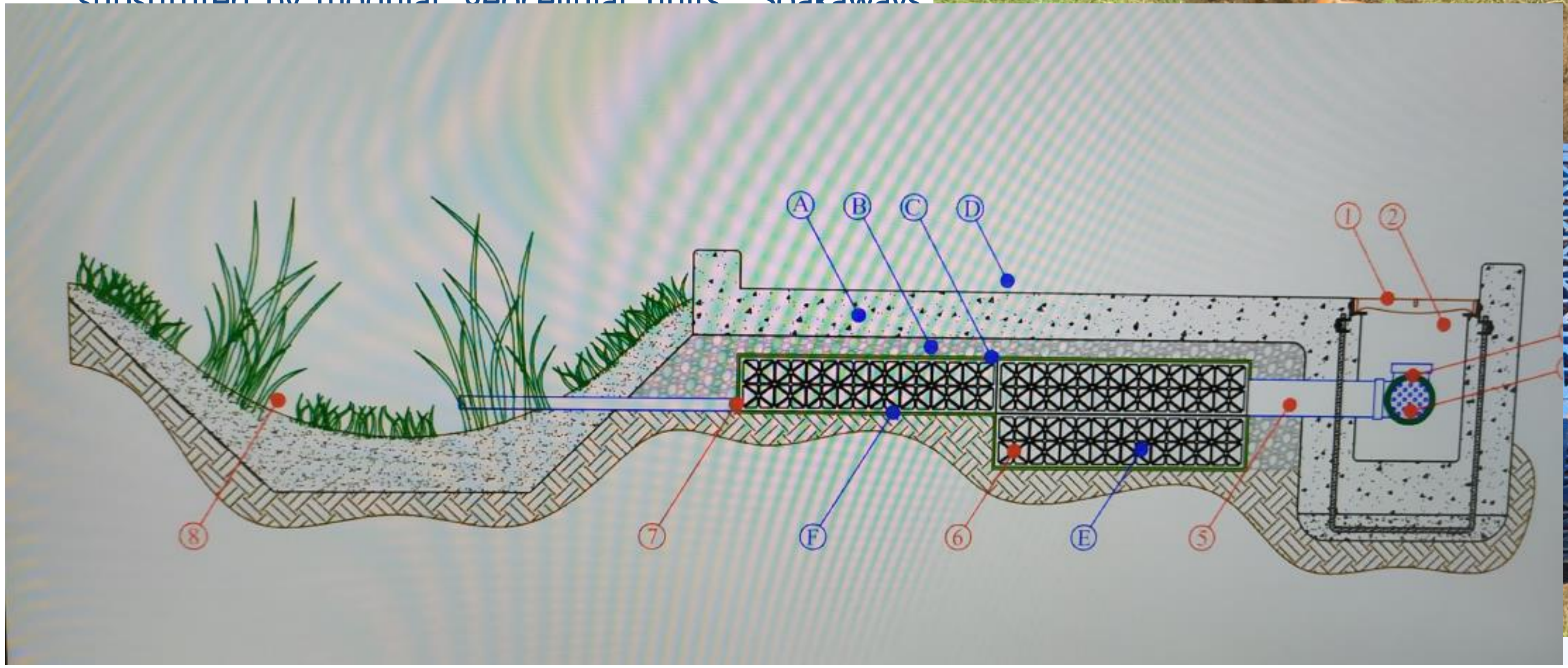
Natural Water Retention Measures (NWRMs)

8. Soakways

Definition:
Soakaways 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. Soakaways





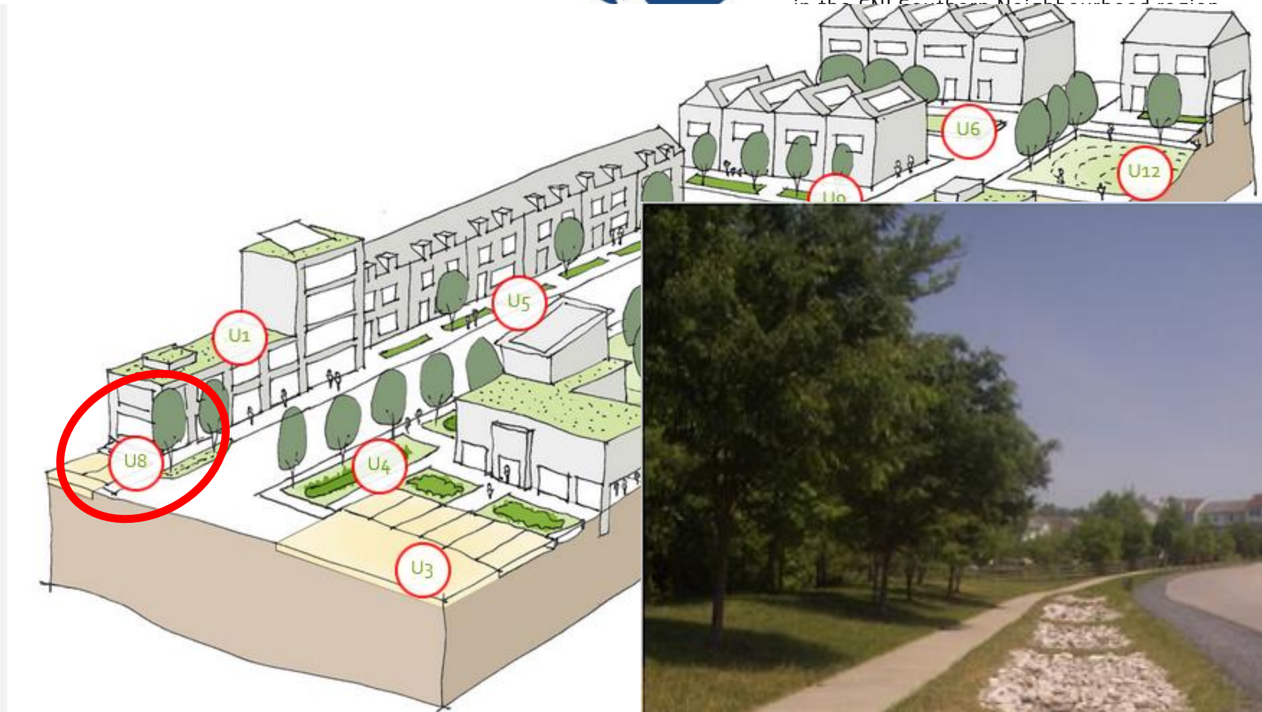


Natural Water Retention Measures (NWRMs)

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.

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Natural Water Retention Measures (NWRMs)

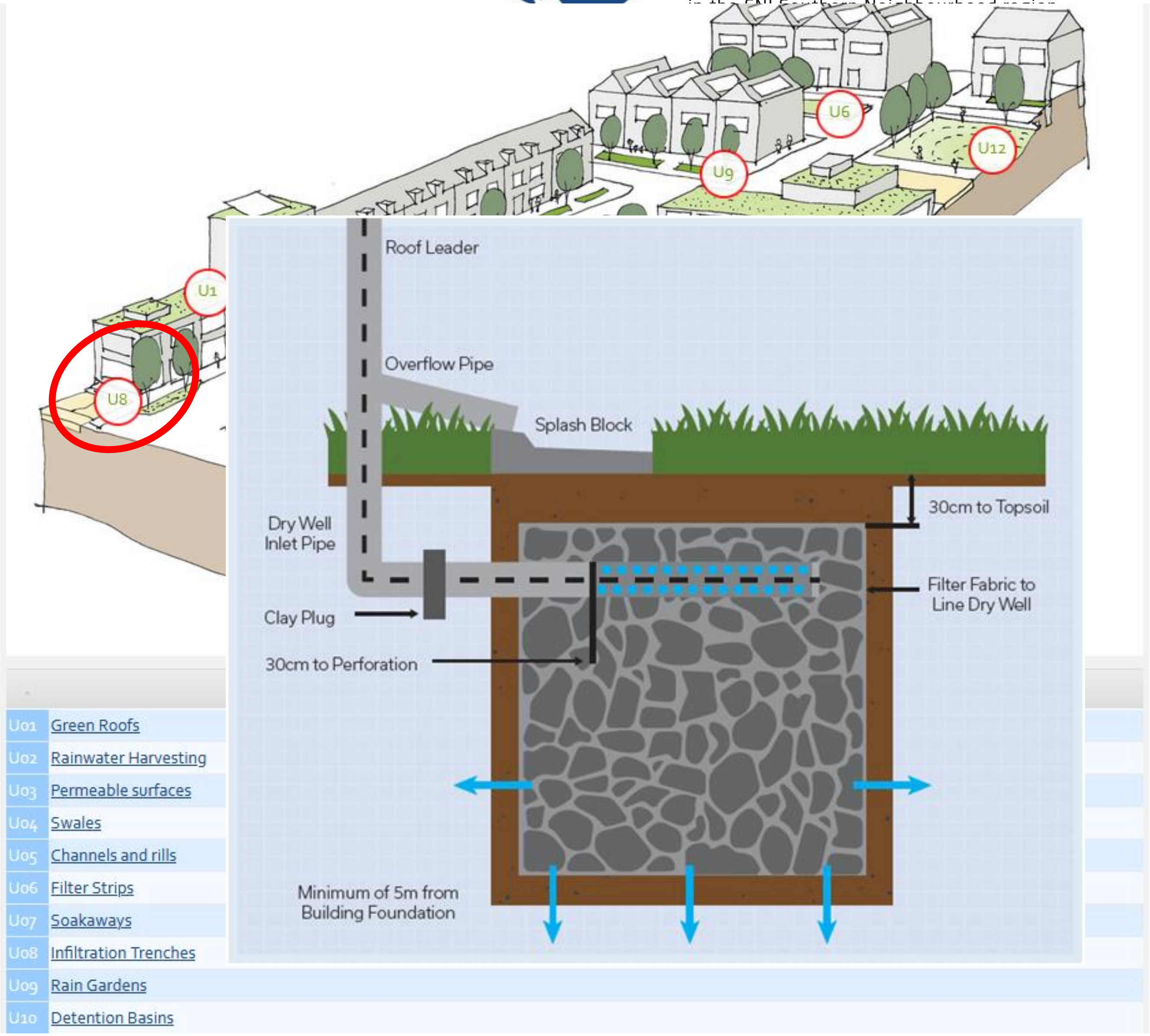
Water and Environment Support

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 1.10^{-6} m/s.



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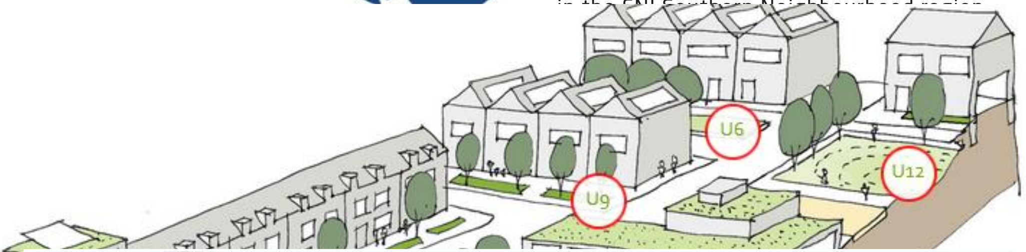
Natural Water Retention Measures (NWRMs)

Water and Environment Support

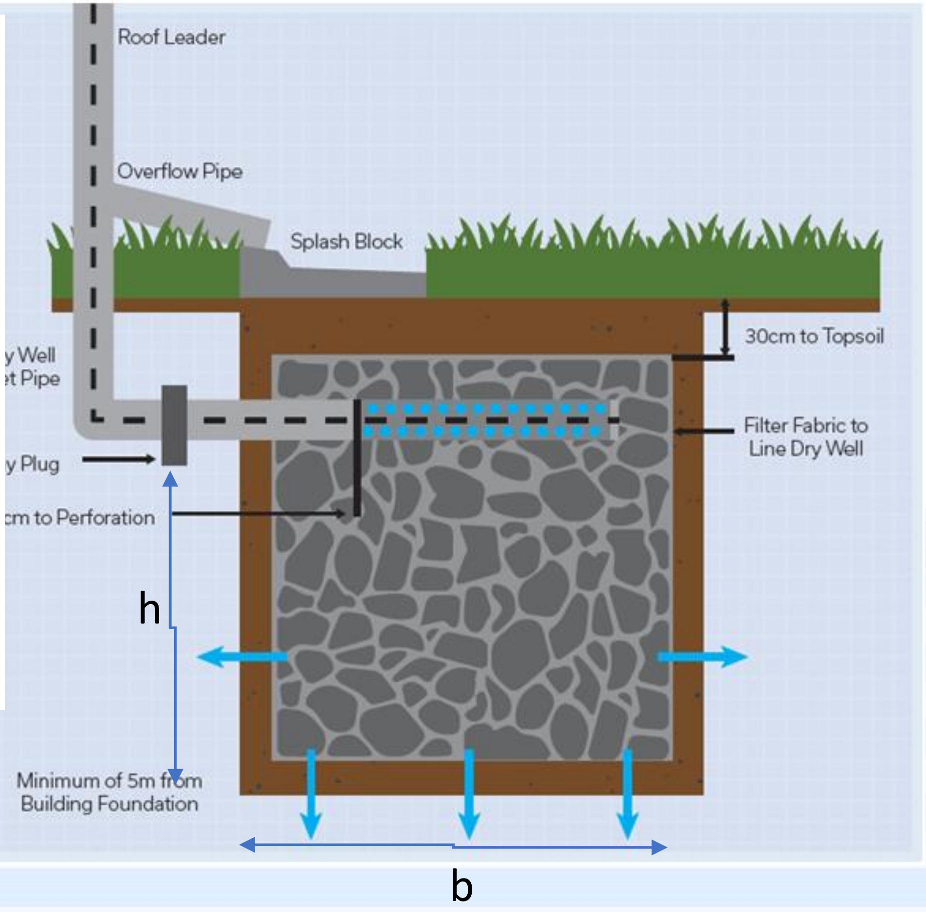
10. Subsoil Infiltration Trenches



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

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)
	=	Hydraulic conductivity of the soil (m/s)
t_c	=	Duration of the design storm (min.)



U05 Channels and rills
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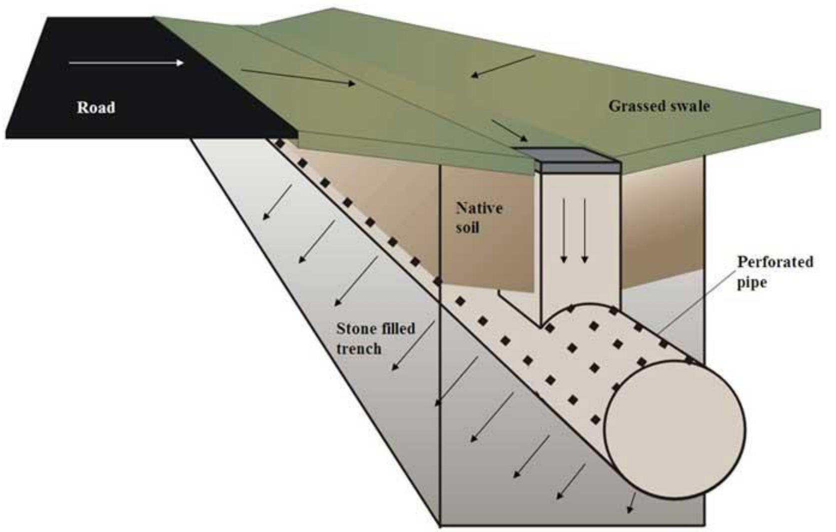
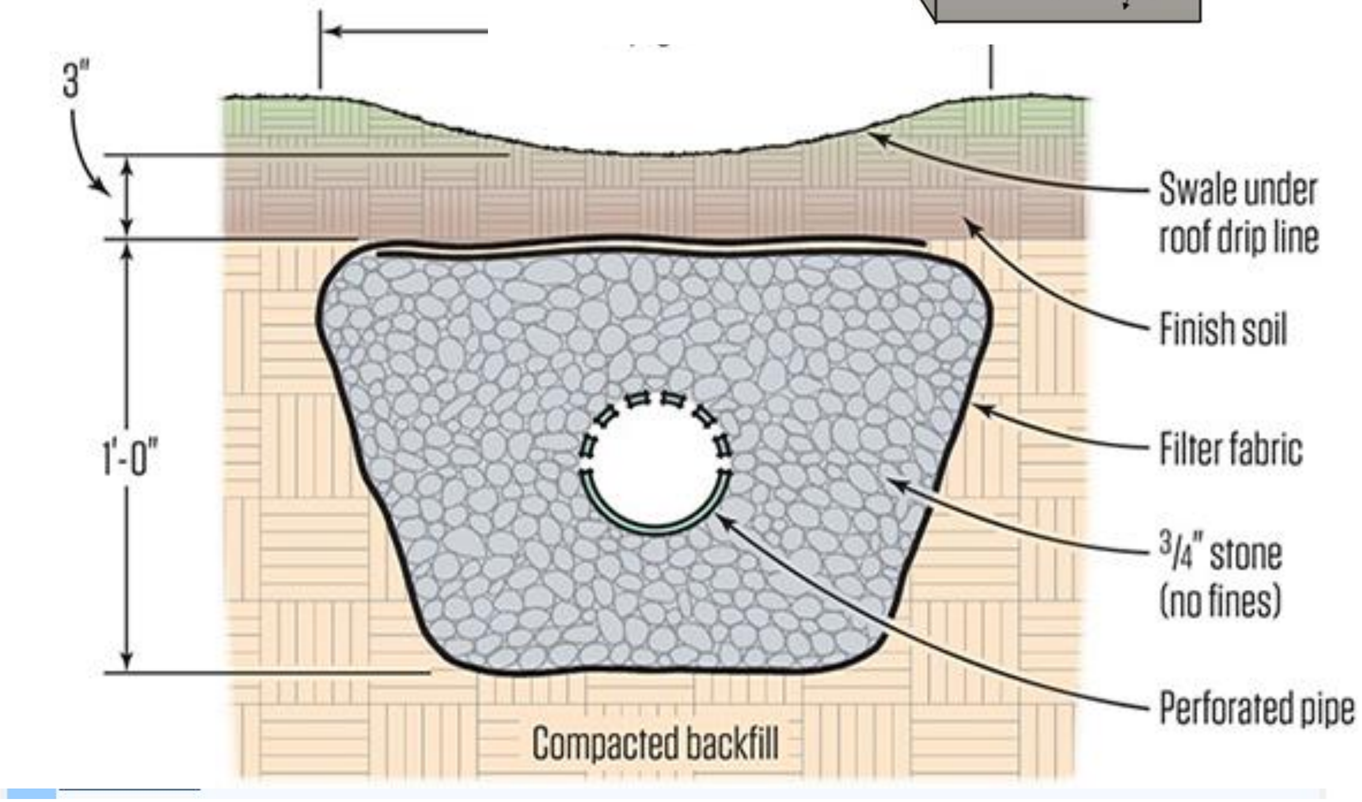
Natural Water Retention Measures (NWRMs

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.





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Natural Water Retention Measures (NWRMs)

Water and
Environment Support

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

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

where :

- b = Base width of trench (m)
- h = Usable trench height (m)
- s_g = Storage coefficient of surrounding gravel, corresponding to the porosity or relative pore volume of the surrounding gravel
- d_i = Inner diameter of the pipe (m)
- d_o = Outer diameter of the pipe (m)

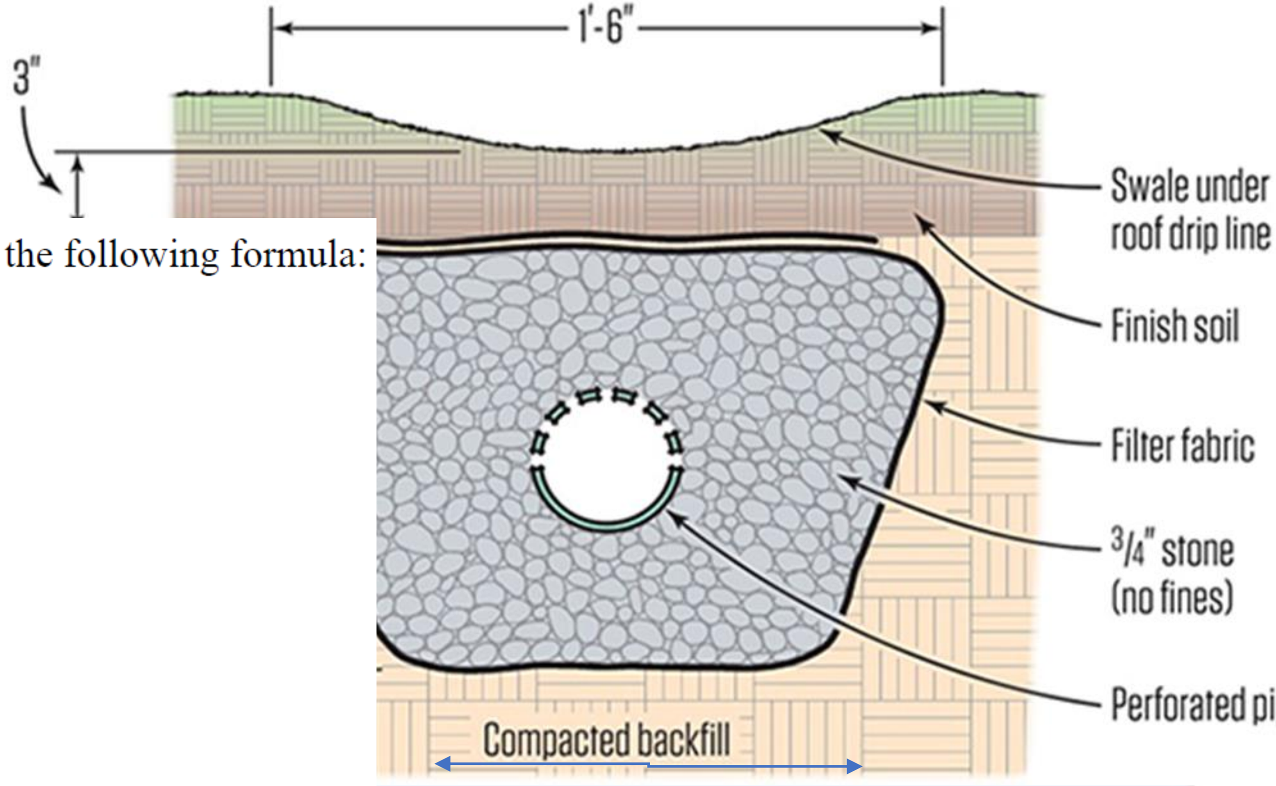
The second step is to calculate the length of percolation pipe L (m) using the following formula:

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

where :

- A_i = Connected impervious area (m^2)
- $I_{tc,Y}$ = Rainfall intensity (mm/hr)
- = Water conductivity of the saturated zone (m/s)
- t_c = Duration of the design storm (min.)

Ground Gutter



U09 Rain Gardens

U10 Detention Basins

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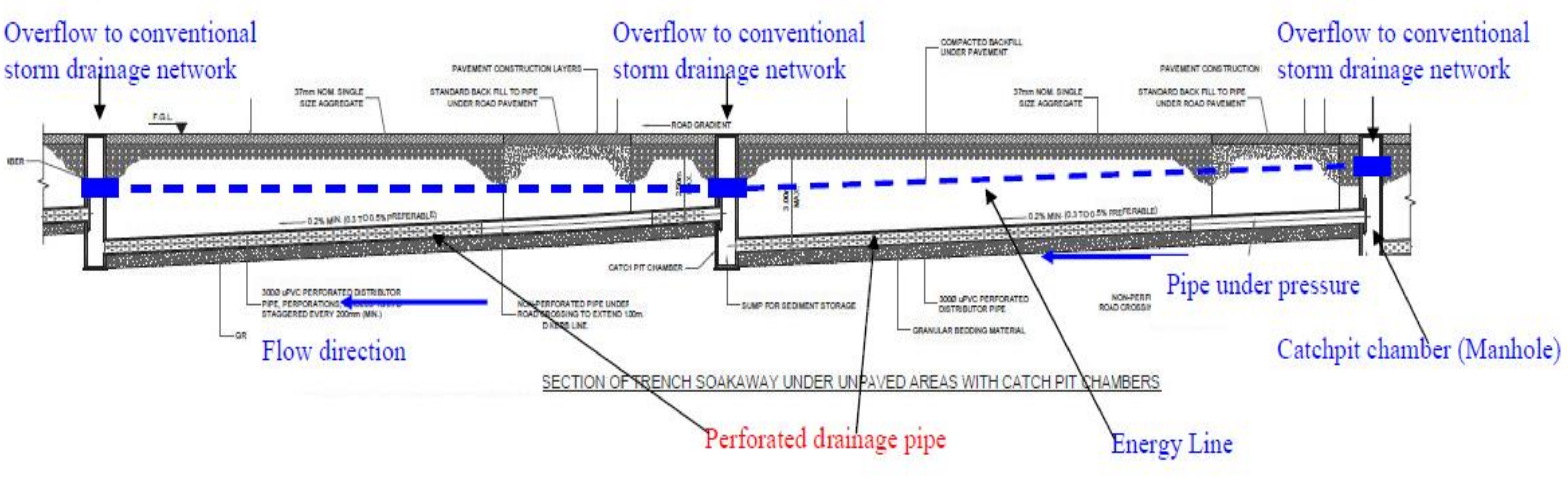
11. Subsoil Infiltration Pipes as Conventional Stormwater Drainage



Natural Water Retentio

12. Detention Basins

Definition:
Detention basin
hold runoff fro
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an outlet cont
Detention basins

Detention basins
in periods of hea
(e.g. recreation),
ancillary amenity
fields, recreation
planted with tree
visual appearance

There are no regi
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relatively quickly
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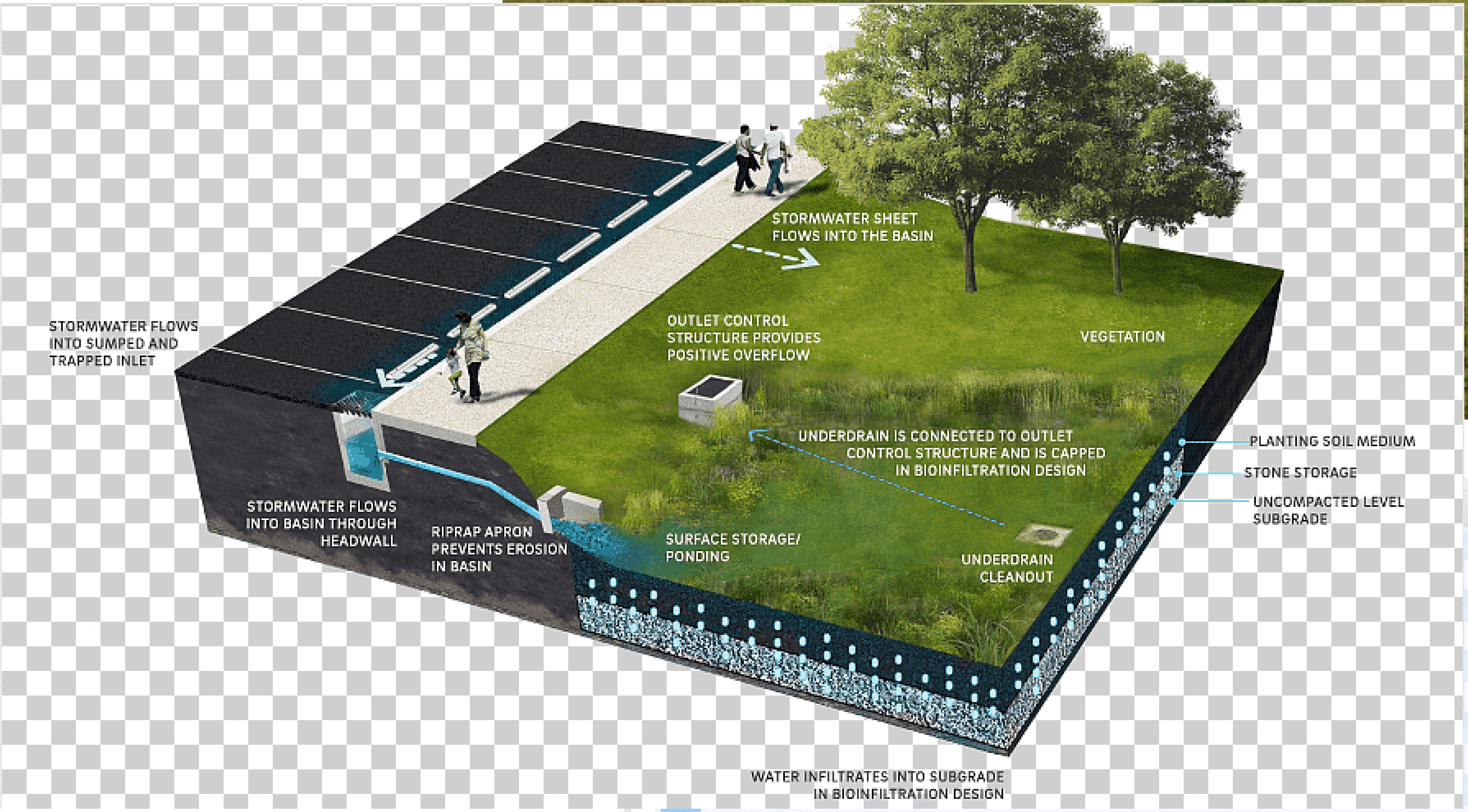

U10 Detention Basins

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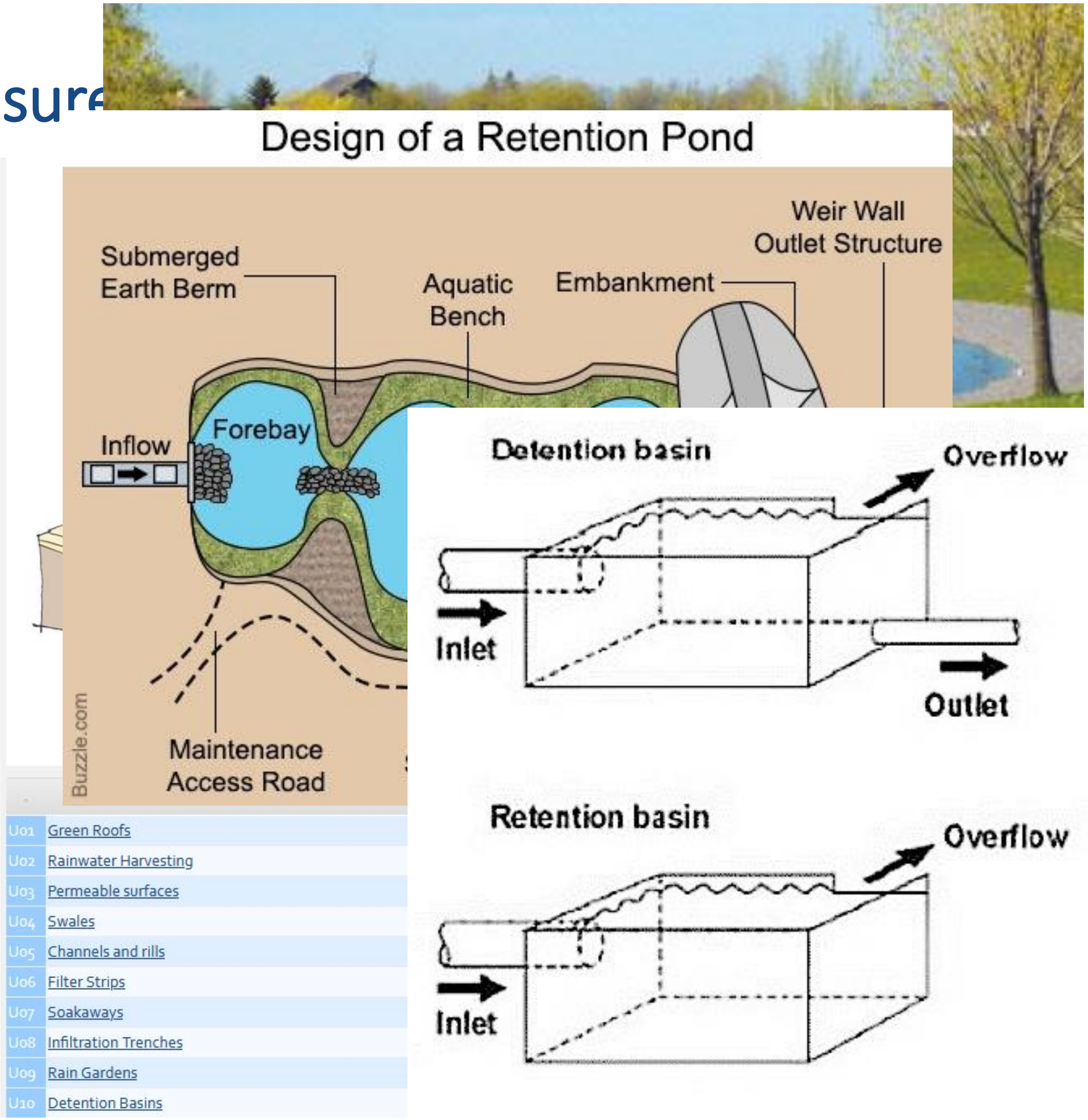
Natural Water Retention Measure

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.

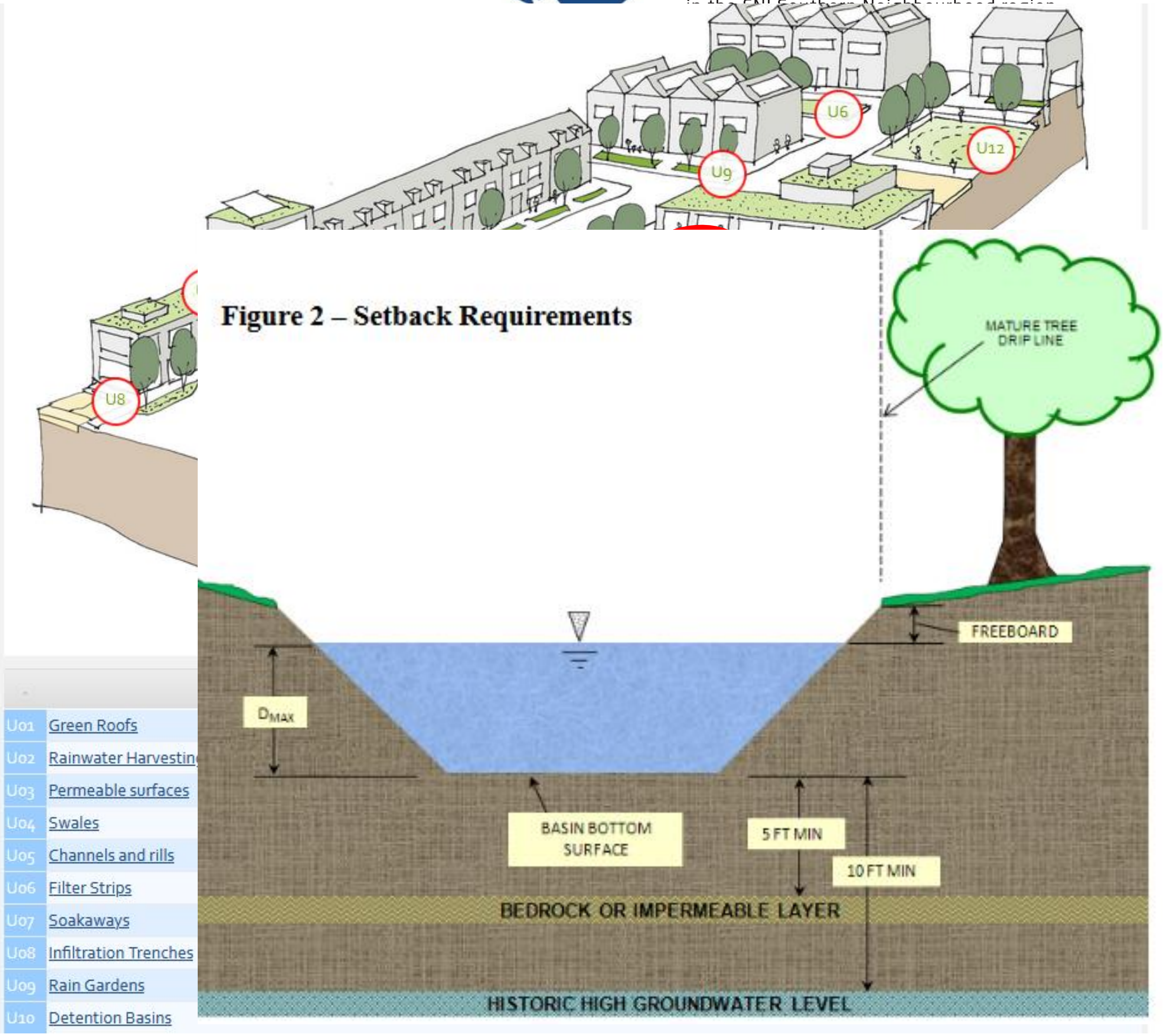
Retention ponds can provide both storm water attenuation and water quality treatment by providing additional storage capacity to retain runoff and release this at a controlled rate. Ponds can be designed to control runoff from all storms by storing surface drainage and releasing it slowly once the risk 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.



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

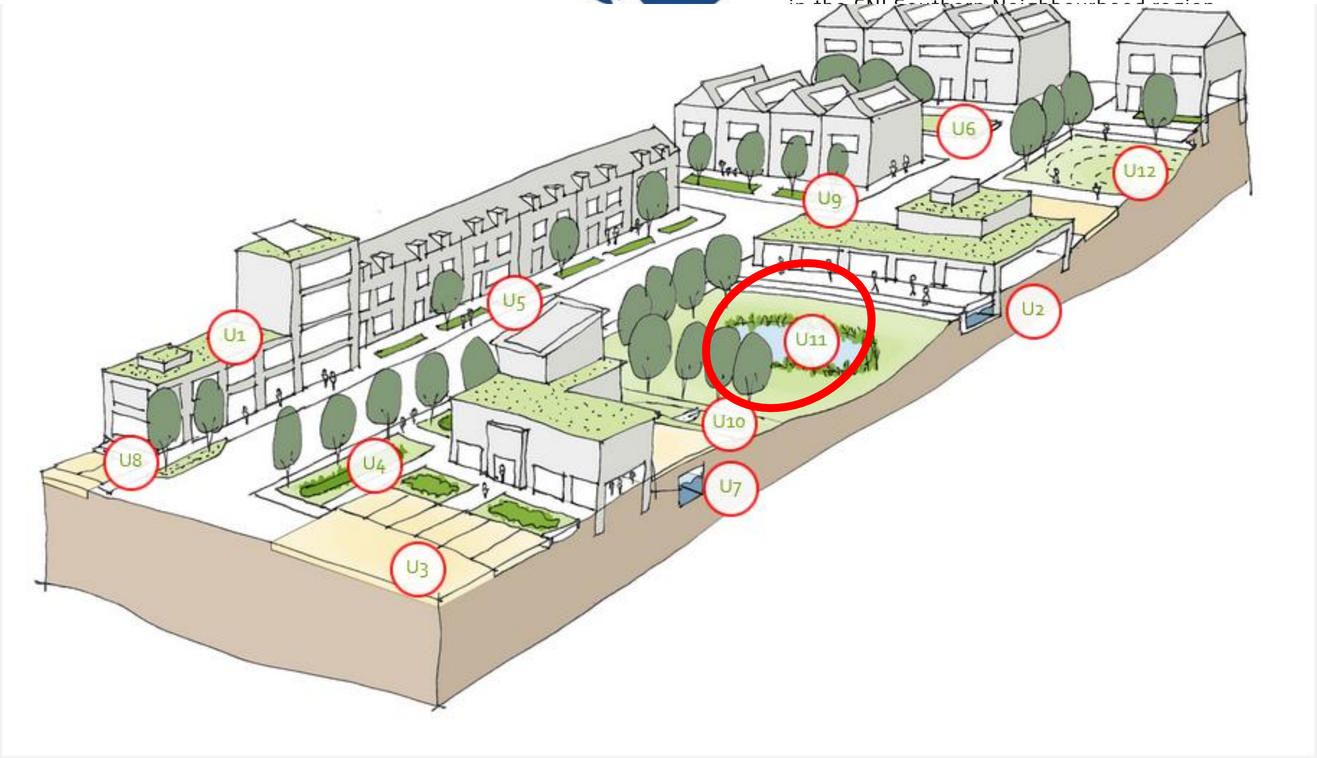
Infiltration ponds are used typically for small drainage areas and are feasible where the soil has adequate permeability and the maximum water table and/or bedrock elevation is sufficiently low.



Natural Water Retention Measures (NWRMs)

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, $d_{max}=f*T_p$, 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	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

Water and Environment Support
in the ENI Southern Neighbourhood region

Thank you for your attention!