3.0 SuDS Components
3.1 What is appropriate for London?

Sustainable drainage systems are a combination of components on-and off-site that make the most of all-round benefits as described in chapter 1. This section explains the SuDS components that may be appropriate for use in London. Introducing and integrating hard and soft engineering requires a holistic design approach.

SuDS use a variety of components to manage water quality and volume and to deliver amenity and biodiversity. An understanding of topography and local surface water discharge options are critical in identifying the most suitable combination of components, with particular attention to:

- Where the rainwater lands and how it is collected (source)
- Identifying conveyance options (pathway)
- Determining the most appropriate discharge points (receptor)

SuDS should maximise potential by ‘thinking upstream’ that is, they should take advantage of specific upstream source control measures.

A number of case studies illustrating the application of various components from a variety of sources and locations are incorporated within this chapter.
SuDS components in the street could include one or a number of the following depending on the context, opportunity and site constraints:

- Permeable pavements with robust surfaces which allow rainwater to pass through them. Attenuated in granular subbase material or below ground structures, this can replenish groundwater or discharge at a controlled rate into a sewer.
- Tree planting to intercept rainfall within the tree canopy, beneath which the ground surface may be impermeable. Trees naturally manage rainwater through transpiration, increasing soil permeability and enabling water to infiltrate into the subsurface.
- Tree trenches connecting below ground rooting zones. This maximises the accessible water and soil volume to rooting systems and is beneficial to the long-term sustainability of trees and planting.
- Bioretention systems or bioretention rain gardens, including a filtration layer that provides required treatment and detention before the rainwater is discharged at a controlled rate to a watercourse or sewer.
- Filter drains to collect water and treat pollution, particularly effective in combination with grass filter strips that trap silt before water reaches the filter drain.
- Detention basins to attenuate in shallow, grassy depressions. These are mostly dry but can store and treat water at shallow depths with vegetation when it rains.
- Hard ‘basins’ or lowered areas of hard landscape. These provide attenuation and temporary storage of runoff before slow release to the next component in the SuDS management train. This may be particularly appropriate in combined sewer areas where water treatment is less important.
- Swales provide linear attenuation that are particularly versatile for highways and the rail network. They can be designed as a ‘storage swale’ and/or for water conveyance.
- Pools, ponds, canals, rills and runnels can be integrated into formal or informal urban landscapes, depending on design, and used to store and treat water.
- Surface water drainage soakaways and infiltration systems depend on the stability of ground conditions, proximity to foundations, below ground structures and infrastructure, and protection of ground water quality and geology. They provide groundwater recharge with minimal land take and are easy to build, operate and retrofit.
Opportunities for integration of other SuDS components in the management train may be appropriate, depending on the disposition of assets and through constructive partnerships. For example and with reference to TfL, these might include:

- building roofs (depot and station office etc.)
- car parks (station, schools and office etc.)
- ancillary structures (platform canopies, substations and bus stops etc.)
- platforms
- embankments

These assets may be viable for designing in, or retrofitting:

- ‘living roofs’ (green, brown or blue roofs) to provide source control
- water butts and tanks to intercept and harvest rainfall by disconnecting and diverting downpipes
- rain gardens to create temporary localised ponding for roof runoff, allowing plants and trees to benefit from that ponding
- rainwater planters to attenuate in above ground planters, with integral storage and slow release
- integrated water management strategies that can be delivered as part of re-development or transport improvement schemes
- de-paving, bioretention and street tree planting, retrofitted as part of already planned annual highways maintenance, repair and improvement programmes
- permeable pavement construction
- re-purposing linear green infrastructure, such as verges and embankments along roads, railways and waterways
- retrofitting for cycleways and greening to address the cycling and healthy streets agenda
- decompacting existing parkland soils
- repurposing existing greenspace for swales, rain gardens and bioretention components
- bioremediation of contaminated site
- rainwater harvesting, by installing water butts and storage tanks
- bespoke solutions to meet specific situations, management regimes, project drivers and community aspiration and campaigns (such as Love the Lea and SuDS for Schools)
- retrofitting green infrastructure, in particular, living roofs, green walls and street tree planting
- protecting existing assets that are effectively operating as a SuDS components, including London’s urban forest (including street trees), parks and gardens, verges and infrastructure corridors

The SuDS components are described in more detail in the order found in CIRIA C753 The SuDS Manual.
Retrofit cycleway and SuDS in Lyon: Linear green infrastructure with asymmetric kerb design for surface water runoff to planting
3.2 Structures

Some of the TfL structures within London’s streets include stations (although many are over station developments), walls, bus stops, offices and transport related infrastructure. All provide an opportunity to install living roofs and green wall systems that intercept and retain rainwater runoff at source depending on operation constraints and requirements.

Living roofs are an effective way to integrate green infrastructure no matter how intense the development. The term living roofs include ‘green’ (planted), ‘blue’ (water attenuation) and ‘brown’ (recycled substrate) roofs. They all effectively integrate significant areas of source control SuDS, without taking up space on the ground. Typically the three types of living roofs can be characterised by:

- Extensive roofs: these have varying substrate depths and vegetation that generally includes grasses and wildflowers, creating minimal loading on structures.
- Intensive roofs: these typically have deeper substrates supporting a range of vegetation. This puts larger loadings on the structure.
- Blue roofs which attenuate through vegetated substrate specification and drainage design

‘Green walls’ are vegetated walls that are supported on cables, cellular systems or can be self-clinging and unsupported. They can be proprietary systems with irrigation, or formed over time by planting climbing plants into the ground that are more self-sufficient.

Benefits
Living roofs and green walls provide multiple benefits and are an important component of the green infrastructure vision for London. They reduce rainwater runoff rates and the urban heat island effect, and filter air pollution. Benefits include:

Amenity: living roofs enhance outlook over the roofscape while providing amenity where there may be little space on the ground. Rooftop parks and gardens act as an educational and urban farming resource. Green walls soften the hard city environment, reducing air temperatures, while being space efficient.

Biodiversity: living roofs safeguard, enhance, restore and create habitat with no additional land take. They provide important habitat stepping stones and connectivity within the built environment and contribute to London’s natural capital. In particular, they provide refuge for rare invertebrate populations. Green walls provide vertical habitats for nesting and food for pollinators.

Interception: living roofs act as source control and intercept rainwater where flora and fauna benefit. Green walls integrate recycled water systems for irrigation, if not planted in the ground.

Attenuation: living roofs attenuate surface water by providing storage, water reduction through evaporation and transpiration, enabling a reduced discharge rate.

Filtration: living roofs treat water through a variety of physical, biological and chemical treatment processes, within the soil and root uptake zones. They regulate surface water runoff temperature that could adversely affect ecology of local water bodies.

Design considerations
Living roofs can be retrofitted or designed as an integral part of re-development. If retrofitted, they provide significant SuDS performance in terms of achieving greenfield runoff rates or betterment targets. Access, safety and edge protection needs to be considered at an early design stage.
Exceedance: roof drainage design should counter the risks associated with exceedance. Interception to recycle rainwater for irrigation should be integrated where possible.

Structural resilience: living roofs add additional loading to a roof structure, depending on the material used, in the form of a dead load. This is typically around 0.7 to 5.0 kN/m, with imposed loads up to 10 kN/m.

Fire resistance: fire risks can be managed through the use of appropriate materials and design. Ensure vegetation is kept at a minimum distance away from vulnerable areas such as openings and vents.

Substrate: soils and growing media can be formed of recycled material, which support different potential for flora and fauna. Varying depths of substrate, together with integration of dead wood and aggregates within a single roof landscape, create different microclimates and the potential for habitat diversity.

Vegetation: living roofs support a variety of plants for amenity, biodiversity and food growing. The species selection, whether seeded, self-seeded, pre-grown or planted should be adapted to microclimate and substrate specification. Roof conditions
are often hostile, with high winds, extreme temperatures, periodic rain and drought. Diverse dry meadow mixes, that are naturally self-sustaining in exposed environments, can be used. Natural windblown or bird-borne self-seeding is a viable and economic alternative, naturally adapted, rather than off-the-shelf, imported monocultures.

Outlets: living roofs should be easily accessible for inspection.

**Maintenance**
Living roofs require periodic maintenance, including for possible irrigation, inspection of outlets and removal of invasive plants. Frequency depends on the type of system. Green walls formed by climbing plants may need to be periodically attached to supports. Proprietary products require routine maintenance of plants and irrigation systems and may require occasional replanting.

**Useful design guidance**
CIRIA C753 The SuDS Manual, Chapter 12

Structures - Case study 1

Location  
Takparken  
Malmo, Sweden

Date  
2010

SuDS Components
Living Roof

Objectives
To provide a destination space and method of source control for rainwater.

Outcome
The Takparken green space is on the roof of a Malmö shopping mall. It spans over 27,000m² and is considered one of the largest green roofs in the world. It is dominated by sedum planted stylised hills with elements of undulating perennial plantings with some larger shrubs. The roof is accessible to the public and provides an outdoor amphitheatre, seating and botanical interpretation. The roof intercepts rainfall at source as well as providing an important biodiverse habitat.

Takparken: Sedums and perennials

Takparken: Roof plan
Chapter 3

Structures - Case study 2

Location
Goods Way
London Borough of Camden

Date
2012

SuDS Components
Green Wall

Objectives
This new neighbourhood is being built around a green framework, 40% of the 67 acre development is given to open space. Over 400 new trees are being planted and walls and roofs are being greened.

Outcome
The green wall contributes to a biodiversity network of green spaces that deliver a whole range of economic and health benefits, encourage wildlife and help reduce the risk of flooding. 200 linear metres of green walls have been planted since 2012. As part of a Living Landscape strategy, these green walls together with the living roofs minimise the urban heat island effect by increasing air-plant exchange and contribute to the SuDS strategy for the area by intercepting rainwater.
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<td><strong>Objectives</strong></td>
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<td><strong>Outcome</strong></td>
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Images courtesy of J & L Gibbons
3.3 Infiltration systems

London’s parks, gardens and greenspace provide large scale SuDS infiltration in the open soil, coupled with the interception that parkland trees provide. Intense pedestrian use can affect soil capacity for infiltration through compaction. Decompaction is therefore important to boost the existing green infrastructure’s ability to intercept rainfall.

Designed infiltration systems include the following sustainable drainage components:

- Soakaways: pits that temporarily provide storage before infiltration
- Trenches: linear soakaways and strips of grass that are predominantly dry, but in heavy rainfall, fill up and store water for a period of time before infiltration
- Infiltration basins: depression performing the same function as trenches
- Blankets: open, flat areas of grass, allowing infiltration over a wider area than a trench or basin. This might be below a car park where the storage layer is part of the pavement construction, or below playgrounds or sports pitches

These components are designed to promote infiltration where capacity and permeability of soils permits and where the depth to groundwater allows.

Benefits

Infiltration components allow groundwater to be replenished. They can incorporate marginal and wetland habitat. Planting introduced to improve ecology slows the flow rate by retaining the drainage properties of the soil, creating a more effective SuDS component. They can be used to manage overflows from rainwater collection systems, such as water butts and runoff from small areas, such as drives and roofs.

Design considerations

Infiltration components can be retrofitted, designed as a series of small linked elements, or as a single larger one.

Runoff flow to be directed to a SuDS infiltration component can be collected laterally along the edge of an impermeable surface. Kerb openings and roadside lateral inlets help to direct, control and reduce flow velocities.

A minimum of one metre from the base of the infiltration component to maximum groundwater level is required. Upstream pre-treatment should be integrated where possible to remove sediment and silt.

Performance of the components may be compromised if surface soils become compacted, therefore they should be designed to withstand high intensity pedestrian use. Performance depends on the capacity of the soils surrounding the component. When rainfall rate exceeds the design capacity, a flow route or temporary storage should be provided.

Soil infiltration can be enhanced by:

- Managing construction traffic to prevent compaction during construction
- Mixing sand with soil to retain its drainage properties
- Ensuring tight construction tolerances are adhered to
- Reusing existing topsoil that allows the inherent seed bank in the soil to regenerate quickly, reducing erosion, enhancing the potential for infiltration
- Soil decompaction

Maintenance

This can usually form part of the wider routine landscape maintenance. Control structures require periodic inspection. Existing parkland, particularly in critical drainage zones that are subject to intensity of use should be periodically decompacted.

Useful design guidance
CIRIA C753 The SuDS Manual, Chapter 13
Hyde Park: London’s parks naturally provide existing large scale SuDS
Infiltration systems - Case study 4

**Location**
Streatham Common South
London Borough of Lambeth

**Date**
2013

**SuDS components**
- De-paving
- Tree planting
- Kerb inlets

**Objectives**
Streatham Common South falls within the Streatham Critical Drainage Area (CDA). The project included implementation of a raingarden to alleviate flood risk and was completed within a standard highway maintenance scheme.

**Outcome**
Pavement SuDS, where inserted with verges, replaced concrete dished channels. These slow surface water drainage into the sewer system. Modeling undertaken has shown that the grass verge can theoretically remove 6m³ of surface water runoff in a 1 in 100 year 6 hour storm event.

*Images courtesy of Owen Davies*
Infiltration systems - Case study 5

Location 50 & 60 Reedworth Street
           LB Lambeth
Date 2012

SuDS Components
Permeable paving

Objectives
To increase the permeability of front gardens.

Outcome
The paving over of front gardens in London is a major issue and contributes to the risk of surface water flooding. This project highlighted how hard standing can be removed without affecting parking. Residents were supported in changing materials including by the provision of tools, technical advice and practical assistance. The initiative has increased the permeability of the front gardens and improved streetscape aesthetics.

Images courtesy of Owen Davies

De-paving of private front gardens

After with gravel and planting
Filter strips are uniformly graded, gently sloping areas of grass that allow water to flow as a sheet towards a swale, bioretention system or filter drain. They provide a simple form of source control through pre-treatment of water, to protect swales or filter drains from clogging up with silt.

Filter strips are effective at intercepting rainwater where the soil is sufficiently permeable. The grass and vegetation slows the water, allowing it to soak into the ground. The plants help evaporate water and filter out pollution.

Benefits
Filter strips create soft open space next to impermeable areas. They can either be seeded with amenity or meadow grass and managed as long or short mown grass to support biodiversity by providing:

- Foraging for birds and invertebrates
- Habitats for invertebrates
- ‘Stepping stone’ habitats, particularly in the urban environment

Design considerations
Filter strips’ efficiency depends on length, width, vegetation cover and soil specification. Considerations include:

- Soil permeability
- Vegetation specification
- Height of vegetation and flow depth
- Peak flow velocity in relation to particulate settlement
- Time of travel of runoff across the filter strip
- Protection of the strip from vehicular run-over and development
- Designed for management by standard landscape maintenance machinery

Maintenance
This can form part of the wider landscape maintenance operations, to ensure the feature meets design performance standards. Measures to prevent soil compaction are particularly important.

Useful design guidance
CIRIA C753 The SuDS Manual, Chapter 15

Filter strips should generally be greater than 2.5 metres wide, laid ideally to a one per cent slope. Small filter strips that are 1-2 metres long create effective connections between broken kerb lines and the side slope of a swale. Lengths of greater than five metres help improve water quality performance. Filter strips should be shielded with a kerb or low-level barrier when they are next to a road or car parking.
Filter strip: Parkway retrofit
3.5 Filter drains

Filter drains are usually linear components along the roadside, which drain the roadway. They are deep, narrow, gravel-filled trenches that collect and move water. They often include a perforated pipe at the base to help drainage. Water flow through the gravel removes some pollutants.

Benefits
Filter drains provide:

- Long and short term water storage during a storm between the aggregate particles
- Silt removal, by eliminating suspended sediment in the water
- A material that enhances biodiversity by hosting micro-organisms and providing a breeding ground for insects and amphibians

Design considerations
Filter drains must be able to accommodate high return periods (ie, one in 100 year events) without suffering damage.

A geotextile (not a geomembrane) below the surface of the aggregate traps silt to prevent it clogging up the drain, while allowing permeability.

Filter drains can be protected from silt by an adjacent filter strip (see 3.4) or flow spreader.

Filter drains are usually 1-2 metres deep, with a minimum depth of filter medium beneath any inflow and outfall (0.5 metres) to ensure reasonable levels of pollution removal.

These components can be located at the bottom of embankments to intercept surface water runoff or with filter strips on the highway. Equally, they can be integrated as an architectural feature in the public realm.

Maintenance
Filter drains require routine maintenance to ensure vegetation or debris is removed from the surface.

Useful design guidance
CIRIA C753 The SuDS Manual, Chapter 9 and 16
3.6 Wet swales and dry swales

Swales are linear components that provide slow water conveyance. They provide filtration, attenuation and storage of surface water runoff from relatively small catchment areas. They can be designed to accommodate a range of rainfall events.

Generally, swales are sloping sided, flat bottomed, vegetated open channels, constructed at a gentle gradient. Steeper gradients can be accommodated through the use of check dams. Swale design is limited by available space and is only effective when close to catchment areas. Swales can be dry or wet.

Dry swales allow surface water to infiltrate and are designed to include a filter bed with an underdrain to prevent waterlogging. They can be lined or unlined depending on groundwater levels. Where there is ground contamination on brownfield sites, the design should incorporate a liner, unless leaching can be managed to an acceptable level. The liner level should rest above the level of seasonal high groundwater level.

Wet swale: Upton, Northants
Wet swales retain water, behaving like a linear wetland. They are best located where sites are level and soils are poorly drained. Here they can deliver amenity and biodiversity through specific wetland planting. Storm water is retained in the swale before it is conveyed to a downstream outlet.

**Benefits**

Conveyance: swales are a simple and effective means of collecting and distributing runoff, or as a means of conveying runoff on the surface, while enhancing open space or the roadside environment.

Filtration: engineered soils can help neutralise contaminants and sedimentation caused by runoff. Designs can include submerged anaerobic zones to promote nutrient renewal.

Attenuation: swales are typically designed to capture a one in 10 year storm event by storing water within and on top of the filtration media where the water can disperse over time.

Amenity: swales provide shallow linear planted features in the landscape that are space-efficient and adaptable to location. They integrate well alongside highways, cycleways or pathways. They allow bridging structures to

Native marginal planting: Iris pseudacorus, yellow flag iris
SuDS In London: A Design Guide

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Design considerations
Swales should be designed to suit the scale and character of the specific location, taking into consideration orientation, aspect and proximity to other landscape or townscape features. The design of soft or hard edges depends on the urban design context.

Mini swales can manage small events with overflow to other SuDS components.

Ground conditions: consideration should be given to existing ground conditions and hydrology to determine the use of either a wet or dry swale. The volume of water to be stored, or infiltration capacity of the soils, allow the designer to establish the basic swale dimensions.

Edge protection: as a component that typically sits below pavement surface levels and can hold standing water, the designer should consider the edge detail.

Exceedance: swales are designed to provide a level of storage that can accommodate a one in 10 year storm event. The storage capacity of a swale depends on its size, which depends on the available space. A swale can overtop during severe storms, so designers should build in contingency flow paths and/or provide outfalls.

Health and safety: swales are shallow surface features and should not present a danger to the general public. Risks can be mitigated through design to address edge conditions or provide shallow side slopes and shallow flow depths.

Vegetation: planting in the swale stabilises slopes, reduces erosion and slows water flow. Swales provide an ideal location for a variety of planting that can provide amenity, habitat and foraging. The selection of vegetation should be from native species that provide appropriate habitat for indigenous biodiversity.

Biodiversity: swales can be designed with a variety of marginal planting and wildlife meadow that contribute to habitat creation and connectivity.

Erosion: swales are intended to convey and/or retain flowing surface water and therefore soft landscape is likely to erode. Reducing the velocity of water flow limits erosion through the use of measures such as weirs, check dams, erosion control matting and planting.

Vegetation: planting in the swale stabilises slopes, reduces erosion and slows water flow. Swales provide an ideal location for a variety of planting that can provide amenity, habitat and foraging. The selection of vegetation should be from native species that provide appropriate habitat for indigenous biodiversity.

Native grasses: Luzula sylvatica, woodrush
species. Where over-the-edge drainage is required, the grass level should be 25mm below the edge of the hard standing to be drained, to ensure effective surface water flow.

Trees: swales can accommodate trees within their design, provided conditions needed for growth and the hydrological effects are considered. Swales should respect the presence of existing trees and ensure root systems are not compromised. Proposals should accord with BS 5837:2015 and take account of tree preservation orders and conservation area designations.

**Maintenance**
Swales require routine maintenance to ensure efficient operation. Different swale construction and operation affect maintenance prescriptions.

**Useful design guidance**
CIRIA C753 The SuDS Manual, Chapter 9.8 and 17
HD 33/06 Surface and Sub-Surface Drainage Systems For Highways

Image courtesy Robert Bray Associates

Dry swale
Swale - Case study 6

Location  
Mill Pond Road  
London Borough of Wandsworth

Date  
2016

SuDS Components
Bioretention swales  
Kerb inlets  
Tree trench planting

Objectives
Mill Pond Road is a new road within a development at Nine Elms. It is constructed with a central planting bed acting as a swale to attenuate surface water.

Outcome
The surface water run off is be collected along bespoke broken kerb units and fed into the central planting zone where it filters through to an underground collection and holding tank before being released slowly into the mains sewer system. It is anticipated that there will not be standing water for more than one or two days following extreme rainfall events, the plants have been selected to be tolerant of these conditions.
3.7 Rills, runnels and channel systems

Rills are small, open-surface water channels within paved construction. They collect water directly from hard surfaces and convey water, at a reduced flow rate, to, from or between other SuDS components. They come in a variety of designs to suit the urban landscape and have formed part of the historic streetscape environment.

Rills are used as an alternative to piped drainage, allowing the captured water to remain at shallow inverts. This allows easy discharge into other SuDS elements, compared to buried piped network that may require deep invert levels.

They can be simple channels, runnels or ribbed paving, delivering roof water via downpipes to another feature or a roadside gutter. Rills can be planted, with rainwater bringing them to life.

Benefits
Rills are an effective way to provide SuDS, including water treatment if planted, where space is at a premium.

Amenity: planted rills, interacting with rainwater, enhance the urban environment.

Conveyance: rills are effective at collecting and distributing storm water runoff, while enhancing and demarcating open space. They can be used in place of pipework and traditional outfalls.

Filtration: flow-reducing elements, such as planting, textured paving and other features provide filtration, treatment and sedimentation from captured surface water.

Attenuation: rills can attenuate surface water by providing storage and reducing discharge rates.

Design considerations
Edge protection: typically sitting below pavement surface level, rills have hard edges and can hold standing water. Consider how pedestrians, cyclists and vehicles will interact with them, especially at crossing points and in relation to pedestrian desire lines and vehicle movement.

Vegetation: rills provide an ideal location for aquatic or sub aquatic planting for habitat creation.

Silting: rills can become impaired by silting. This can be prevented by placing upstream SuDS components to filter sediment out.
Outlets: typically rills outflow into other SuDS features. How the rill outfalls into the next feature dictates the rill’s function. Designers should consider ways of restricting the flow at outfall, through the use of check dams, weirs and orifices.

**Maintenance**
Channel systems require routine maintenance of inlets and outfalls, debris and management of plant material.

**Useful design Guidance:**
HD 33/06 Surface And Sub-Surface Drainage Systems For Highways

CIRIA C753 The SuDS Manual

CIRIA publication C698: Site Handbook for the Construction of SuDS

Cambridge City Council, Sustainable Drainage and Adoption Guide 2010
3.8 Bioretention systems

Bioretention systems, which include rain gardens, can be incorporated so they do not need extra land take. They are usually a planted, soft landscaped low-spot, positioned to collect, store, filter and reduce surface runoff from frequent rainfall. As a surface water management component they are versatile and can be integrated into public realm environments through altering street geometry, creative material choices and planting.

Inlets, outlets and control structures are used to control and reduce the water flow rate through the bioretention system.

Bioretention systems are used to treat and manage storm events by collecting local surface water. Water ponds on the surface, before filtering through vegetation and growing/filtration media. Here it either infiltrates or is collected via pipe work leading to a suitable outfall.

Bioretention tree pits and trenches can be incorporated into pavements using soils that intercept, dissipate and cool rainfall runoff.

Bioretention swales are similar to under drained swales with vegetation tolerant of likely inundation occurrences and pollutants.

Rain gardens are localised, less engineered systems. They usually serve a single roof or small paved area and can create an attractive addition to the public realm.

Benefits
Filtration: engineered soil or growing media mixes and filter media can be designed to enhance bioretention treatment performance.

Attenuation: water can be stored within and on top of the filtration and growing media, allowing rainwater to infiltrate over a period of days.

Conveyance: bioretention features can be gently sloped or terraced to allow water to be conveyed at a reduced flow through the use of check dams, weirs and/or vegetation to a suitable outfall location.

Amenity and biodiversity: bioretention features can be integrated in many ways into the streetscape. Integrating planting has multiple benefits, enhancing the attractiveness, diversity and quality of the urban environment, while meeting local Biodiversity Action Plan targets.

Design considerations
Edge protection: typically, bioretention components are sited below pavement surface
systems can remediate water contaminants with the use of filtration mediums, normally sand-based material with a source of organic matter to provide nutrients for planting.

Sedimentation: slowing surface water flow allows fine particles to be removed. Design should limit excessive sediment accumulation that could reduce storage volume, filtration and infiltration rates.

Exceedance: bioretention systems can deal with only small catchment areas and are likely to be overwhelmed during heavy storms. The design should therefore allow for contingency flow paths and/or provide outfall.

Outfalls: if an outfall is required, consider the location, particularly the relative level of potential discharge locations, as bioretention system outfalls can be deep compared to conventional drainage.

**Maintenance**
Bioretention systems require routine site maintenance operations to ensure efficient operation. Inlets and outfalls require periodic inspection.

**Useful design guidance:**
CIRIA C753 The SuDS Manual, Chapter 18

levels and can hold standing water. It is therefore important that the interface with pedestrian and vehicular movement is carefully considered. Bioretention can be profiled in various ways, with soft edges and gentle side slopes, or hard edges and vertical sides.

Inlets: inlets may be necessary, especially when hard edge protection is required. Take care to ensure bioretention systems are not subject to excessive erosion at inlet points. Erosion can be prevented by reducing the surface water flow velocity via a sediment trap or a reinforced and textured zone. Protection grilles should not be used unless the inlet diameter is greater than 350mm. An outfall provides overflow when heavy rainfall means infiltration into the soil is too slow (see below).

Erosion: bioretention systems aim to catch flowing surface water. Soft landscape may suffer erosion. Therefore, the feature should be designed to control the surface water runoff movement through the use of weirs, check dams, erosion control matting and planting.

Pollution/contamination: pollution and contamination sources affecting surface and ground water may affect planting. Planting specification should therefore be designed to meet the specific conditions. Bioretention raingarden: SuDS for Schools

Image courtesy of WWT
Bioretention - Case study 7

**Location**  
Swan Yard  
London Borough of Islington

**Date**  
2013

**SuDS Components**  
Bioretention planter

**Objectives**  
A small office redevelopment has included SuDS components within a limited space to intercept and attenuate rainwater.

**Outcome**  
Previously, roof rainwater discharged into the street. The most effective way to incorporate SuDS has been by diverting and disconnecting downpipes to feed rainwater into bioretention planters and water butts for irrigation.

The planting adds a small element of self-sustaining biodiversity in an otherwise hard paved yard.

*Images courtesy of J & L Gibbons*
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<td>London Borough of Sutton</td>
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**SuDS Components**
- Bioretention planter
- De-pave
- Tree Planting

**Objectives**
To reduce hard paving on a wide pavement and plant trees and perennials to aid water attenuation.

**Outcome**
Six areas were de-paved and planted with birch trees and a variety of hardy perennials. This has improved the streetscape and reduced the hard paved area contributing to surface water runoff. Each planting area is mulched with gravel and contains an outlet. Originally envisaged as rain gardens, subsequently the design was amended to limit surface water run off into the planting areas by installing a raised edge. The project had Local Implementation Plan (LIP) funding and was delivered by Sutton on TLRN enabled these streetscape enhancements.
Bioretention - Case study 9

Location: Granton Road
London Borough of Lambeth
Date: 2015

SuDS Components
Rain planters

Objectives
Trial project: The local school needed to tackle illegal parking on the yellow zig-zags, traffic congestion and conflict as parents queued in their cars outside the school.

Outcome
A six-month trial saw the installation of timber planters. During term-time the planters were maintained by the school children, although this proved problematic over the longer summer break. Traffic was monitored before, during and after the trial. A permanent solution will now seek to incorporate in-ground SuDS, that will address the seasonal issue and provide a learning facility for the school.

The results: 1 year on
Traffic volumes dropped by 44%*

132 cars

72 cars

Traffic speeds have decreased with more cars travelling at 10-15mph*

What the parents think
86% of parents surveyed agree it is safer now
94% of parents surveyed would like the planters to be made permanent**

*between the hours of 7.30-9am in term time
**we surveyed 53 parents, 11% of the school roll

Images courtesy of Sustrans

Timber planters as a trial solution for SuDS

Results of trial
3.9 Trees

Trees in the hard landscape, parks and gardens and to some extent streets contribute significantly to London’s ‘urban forest’. In terms of SuDS, they perform through attenuation, interception and soil permeability. Trees provide multiple ecosystem services and mitigation from the effects of climate change, including cooling and improving air quality. Trees greatly benefit the urban environment in terms of heritage, amenity, and biodiversity. They help to reinforce a sense of place and also complement traffic calming measures.

Benefits

Attenuation: tree pits provide storage of storm water runoff through the use of structural soils or proprietary crate systems.

Filtration: soils and geotextiles that make up the construction of tree pits remove silts and particulates that may be present in runoff water. Through ‘phytoremediation’, trees absorb trace amounts of harmful chemicals, including metals, hydrocarbons and solvents, where they are transformed into less harmful substances or used as nutrients.

Interception: trees intercept rainfall and store it. This reduces the amount of water reaching the ground, thereby reducing volume of runoff.

Infiltration: soil infiltration rates are improved due to root growth that also enhances soil biodiversity.

Water reduction: through a process called ‘transpiration’, trees draw water from the ground through root systems to their leaves, where it is lost through evaporation. This effects cooling.

Amenity: street trees contribute to the capital, both visually and environmentally, and form an important component of London’s streetscape. London’s climate allows for a wide diversity of native and exotic species. For instance, London’s urban forest removes over 2,000 tons of pollution/ha/year and stores 2.3 million tonnes of carbon per annum. Tree-lined streets make cycling and walking more pleasant, which is directly related to the health and wellbeing of Londoners.

Biodiversity: trees constitute the largest single element of biomass in the city, providing significant biodiversity value. Trees and woodlands provide food, habitat and shelter for birds, invertebrates and other species, some of which are subject to legal protection. For example, a large species tree, such as an oak, can host hundreds of different animals, plants and fungi, with long-term benefit to pollinators and the urban ecology.

Design considerations

Existing trees: existing trees should be retained wherever possible. Proposals should accord with BS5837:2015 and take account of tree preservation orders and conservation area designations.

Available space: tree pits require space below ground to successfully accommodate long-term root growth. Tree pits and trenches (connected pits) should provide adequate soil volume, water and gaseous exchange to the root system. The location of below ground services and drainage should be identified to ensure root zones, utilities and other below ground infrastructure are all coordinated. Protection for both long-term root growth and below ground infrastructure can be provided with root barriers. Guidance on delivering trees in hard landscapes is provided by Trees and Design Action Group (TDAG).
Tree specification: tree species and diversity, provenance, mature size, clear stem height, root preparation and procurement should be carefully considered. For the benefits of large species trees in urban environments see CIRIA C712. Tree specification and soils performance criteria should be developed in parallel as an integral part of SuDS component design and long-term vision.

Catchment: a single tree can intercept the rainfall equivalent to the area draining into a single road gully. However, by combining trees with other SuDS components, the volume of rainwater interception and attenuation in the catchment can be significantly increased. The London iTree eco project, for instance, demonstrated that the combined canopy cover of London produces an avoided runoff of some 3.4 million cubic metres per year.

Soils: where possible, trees should be established within soft landscape areas, rather than confine rooting zones to restricted trenches in hard landscape.

Where tree planting is incorporated into hard landscape, the use of load-bearing tree planting systems may be necessary. New and retrofit SuDS schemes will require these systems, which may categorise the street as a zone of ‘special engineering difficulty’. There are several systems available for planting in hard landscape, including:

- Cell systems
- Urban tree soil
- Raft systems
- Structural growing media

Soil depths: the overall depth of soil should be appropriate for the tree species. Excessive topsoil depth increases the risk of anaerobic conditions (oxygen deficiency). Topsoil should therefore only be used within the upper part of the soil profile, with suitable subsoil in the lower layer. The exact depth permissible will be dependent on soil conditions, the tree specification and the type of load-bearing system (see soils: Chapter 2).

Infiltration rates: the rate of infiltration of a tree pit dictates the size of the tree pit required for water storage means. The construction of the pit can be altered accordingly.

Pollution/contamination: pollution and contamination sources affecting surface and ground water influences tree growth. Certain species are more susceptible than others, and species selection should be specific to each site and SuDS scheme.
Tree lined streets: Multiple ecosystem services
Inlets: surface water can be introduced to a tree in a variety of ways:

- through channels or rills as direct surface water runoff to a tree pit
- via depressions or low points directing runoff from impermeable surfaces towards the tree pit
- via permeable surfaces used to collect and convey surface water to the tree pits

Outlets: tree pits should be well drained as waterlogging during establishment can be one of the key reasons for failure. This is best achieved by infiltration if the ground properties are suitable. Where infiltration is not possible, an outfall to a surface water drainage network can be used, discharge should be deep to prevent waterlogging.

**Maintenance**
Trees require a higher level of management during the first five years after planting because roots need to establish good contact with the growing medium before they can efficiently extract water.

**Useful design guidance**
CIRIA C753 The SuDS Manual, Chapter 19
CIRIA C712 The benefits of large specie trees in urban landscapes 2012
TDAG Trees in Hard Landscapes 2014,
Urban J., Up By Roots Healthy Soils and Trees in the Built Environment 2000
Trees - Case study 10

Location  
Hyllie Plaza  
Malmo, Sweden  

Date  
2010  

SuDS Components  
Tree trench attenuation  
Tree planting  

Objectives  
To establish a ‘forest’ in the plaza using a species of beech typical of the area with fully integrated SuDS. The forest contributes to regional identity whilst intercepting and attenuating rainwater.

Outcome  
The plaza was constructed as a single rooting zone below granite paving. This earthen layer consists of an 80cm thick base course of boulders that form a structural soil, 60 % of which is cavities. Mulch was then watered down into the voids. Twelve parallel slots were cut into the paving and planted with beech trees. The soil in the beds was mixed with pumice, mycorrhiza and charcoal to support effective water and nutrient cycling and was informed by biological research that determined parameters on how to successfully establish the trees.
3.10 Permeable paving

Permeable paving comes in various forms, including block paving, bituminous materials, grass reinforcement, bound and unbound gravels. All promote water infiltration, whether through the porous surface of a paving material or through the joints between the paving units.

Permeable pavements are used as source control as they manage rainfall where it lands. The basic structure of permeable paving is similar to that of a standard pavement. However, the subbase contains a reduced or ‘no fines’ granular fill and geotextiles that prevent sedimentation.

Permeable paving can attenuate and convey water to a suitable outfall. In London, the potential for permeable pavements is significant. Whether grit jointed unit pavers, or interlocking nibbed products, permeable pavements allow water infiltration, while providing robust hard surfacing.

Benefits

Attenuation: increasing the depth of the granular subbase enables storm water to be stored beneath the surface, where it can infiltrate and/or slowly release to a suitable overflow. Geocellular units can be introduced. These are lightweight modular products that provide infiltration and storage. Care is needed in using proprietary systems as high stresses are placed on the units and their performance is difficult to monitor once paving is laid over.

Conveyance: permeable paving can be used to convey storm water within its construction, removing potential overland flow and puddling. Simplicity: conventional below ground drainage features, such as gullies and pipes, are not needed, thus eliminating cost and maintenance requirements.

Filtration: permeable paving provides filtration at either surface level or within the subgrade. This removes or treats sediments, heavy metals, hydrocarbons and some nutrients. Paving filtration capabilities are largely dependent on the construction which can have differing characteristics.

Design considerations

Catchment area: permeable paving provides source control. With careful detailing and design it can manage additional storm water, such as intercepted water from adjacent roof structures.

Silting: permeable paving becomes impaired by silting or mudding. Silting can be prevented using protective upstream SuDS components, eg, filter strips and swales. Intelligent placement and correct construction methods also prevent silting.

Compaction: over-compaction of the subbase and subgrade affects the efficient function of the paving for conveyance and infiltration, so take care when installing.

Ground conditions: consider the existing ground conditions and hydrology to determine the possibility of the subbase of the pavement functioning as a soakaway.

Exceedance: permeable paving can deal with most storm events. However, it could be inundated during big storms (one in 100 year). When this happens, and the capacity of the pavement is reached, the paving conveys water as a traditional pavement. Design should incorporate exceedance flow paths and appropriate outfalls.
Maintenance

Maintenance requirements are no more onerous for permeable paving than for traditional impermeable surfaces. The removal of conventional below-ground drainage features, such as gullies and pipework, eliminates associated maintenance requirements.

Over time, detritus collects in the upper part of the joint material and surfaces pores. This build-up can affect infiltration capability. Even so, studies have shown that long-term infiltration capability generally exceeds UK hydrological requirements.

The maintenance regime of paving is largely dependent on the construction of the surface course. Brushing and joint material renewal is required, the frequency of which is determined by local conditions, and is no more than required of traditional surfacing.

Weeds will need to be removed from joints, unless wildflower establishment is part of the design concept. Maintenance regimes related to design aspiration and SuDS performance need to be clearly established from the outset, with related community interpretation if departing from perceived norms.

Useful design guidance

CIRIA C753 The SuDS Manual, Chapter 20

Interpave, The Precast Concrete Paving and Kerb Association, Information found at: www.paving.org.uk
Permeable paving - Case study 11

Location
Mendora Road
London Borough of
Hammersmith & Fulham

Date
2016 (under construction)

SuDS Components
Permeable paving retrofit

Objectives
This Thames Water Utilities Limited (TWUL) project aims to trial the retrofit of SuDS within the highway with a focus on their flood risk benefits. Three streets were selected for the trial as part of the Counters Creek SuDS Retrofit Pilot Schemes.

Outcome
Mendora Road involves the installation of permeable paving within the parking bays on each side of the road, with underground storage provided by geo-cellular structures on one side and aggregate on the other, with a flow control outlet to the existing sewer.

The scheme is lined to ensure monitoring data carried out by Thames Water gives an accurate representation of the scheme with no infiltration loses.

During construction

After

Images courtesy of Atkins
Permeable paving - Case study 12

Location
Brixton
London Borough of Lambeth

Date
2014

SuDS Components
Permeable paving
Tree planting

Objectives
This project aimed to improve streetscape aesthetics of this ‘back-of-house’ mews in Brixton Market while improving surface water drainage.

Outcome
Five new street trees were planted and an area of concrete pavers replaced with permeable paving. The permeable paving was constructed with large stone aggregate and structural soil, as per the Stockholm method, with areas of permavoid crates for additional surface water attenuation. Water is recycled for watering planters on Brixton Station Road.
Permeable paving - Case study 13

Location  London Borough of Newham
Date      Temporary (2012)

SuDS Components
Temporary permeable paving installation

Objectives
To provide a coach park that would have a minimal impact on the environment so that the site could be returned to its original use as sports fields after the Olympic games.

Outcome
The sub-base was designed to support Marshalls Priora permeable concrete block paving using graded crushed rock aggregate to provide structural strength, integrity and voidage for attenuation. This was placed on a geogrid for additional strength. Creating a void at the joint between the Priora blocks at the surface allowed water to pass through the pavement at source. The joint void was filled with 2-6mm clean stone to provide a permeability rate of 18,750l/s/ha, to cope with any storm event. No additional positive drainage was required.
3.11 Attenuation and storage

Once the rate of rainfall exceeds the rate at which water can leave a surface, street or area, the surface water is attenuated onsite. This may take place at-grade or below ground. It is then discharged, at a reduced runoff rate.

Design considerations
Designers should follow the guidance below:

- Rate of runoff from the site should target greenfield runoff rates where practicable.
- Storm water up to the one in 10 year storm event should be stored within SuDS components.
- Storm water from between the one in 10 year and one in 30 year events should be managed within the SuDS network. No flooding should occur above ground within areas which are not part of the drainage system.
- One in 30 year to one in 100 year storms should be managed within the SuDS network or within the site. This must not result in flooding of property, nor should it impact on the function of the street.

- Where it is not possible to manage storm water from the one in 100 year storm at-grade within the streetscape or SuDS network, consider:
  - below-ground storage in proprietary crates, tanks or pipes
  - allowing an increased discharge rate from the site

Useful design guidance
CIRIA C753 The SuDS Manual, Chapter 21 and 24
3.12 Detention basins

Detention basins are generally dry, low spots within a landscape. They can be designed as multi-functional spaces during dry conditions. During storm events, water is channelled to these basins where it is “detained” before release at a controlled rate.

Basins usually require a lot of space. However, as they can be designed to provide alternative functions, they can be incorporated into relatively dense urban environments as a soft or hard landscape feature.

Benefits
Amenity: as a multi-functional space, detention basins have a variety of uses, such as car parking, play, public open space and habitat.
Attenuation: detention basins provide storage for stormwater before slow release through a restricted outlet and flow control.

Interception: detention basins provide a large surface and depth for holding surface water runoff. If landscaped with soils that are sufficiently permeable, they provide interception by infiltration of small rainfall events.

Biodiversity: soft landscaped detention basins can be planted with marginal and wetland vegetation to provide habitat and a source of food for insects and mammals. Planting that enhances the ecological value also increases the drainage properties of the soil to create a more effective component.

Design considerations
The form, depth and profile of the basin depend on topography and existing features, such as trees and vegetation. Detention basins’ scale should fit the landscape and townscape character.

Sedimentation: fine materials can cause sediment accumulation within a detention basin that can affect storage volume, filtration and infiltration rates. Designers should create upstream features or forebays that filter out sediments from storm water before it enters the basin.

Infiltration: consider the existing ground material and hydrology to see if the detention basin can function as a soakaway.

Vegetation: when part of a soft landscape, detention basins allow diversity of planting to providing amenity, habitat, foraging and community growing. Aquatic vegetation can be used to provide stabilisation, prevent scour and re-suspension during heavy storms.

Erosion: detention basins can suffer erosion, especially during heavy storms. Storm water velocities can be reduced using weirs, sectioning or graded stone near the inlet.

Compaction: ensure soils are not over-compacted during construction. The compaction of pond soils can negatively impact infiltration rates and prevent vegetation root penetration.

Inlets: inlets into detention basins come in a variety of design forms. At pipework outfalls, a protection grille should not be used unless the inlet diameter is greater than 350mm.

Filtration: the primary pollutant removal mechanism is settlement. Filtration of nutrients can also occur through biological uptake by surface and submerged vegetation.

Maintenance
Detention basins require routine site maintenance operations to ensure efficient operation.

Useful design guidance
CIRIA C753 The SuDS Manual, Chapter 22
Hard detention basin

Image courtesy of Urbanstein
3.13 Ponds and wetlands

Ponds and wetlands are referred to as ‘catchment’ measures because they are generally used where runoff cannot be managed at source. Such features are viable where there is lots of space available; however, small scale integration is also possible.

Ponds are not usually efficient in terms of collection and conveyance, and therefore are usually located towards the end of the management train, where the demand for storage is greatest, with suitable upstream pre-treatment. They provide high value wildlife and amenity benefits to an area and effectively treat polluted water naturally.

Ponds and wetlands hold a permanent pool of water, even in dry conditions. The depth of water increases during storm events, attenuating and treating surface water runoff before outfall at a controlled rate to a suitable discharge point.

Benefits
Attenuation: ponds and wetlands store a lot of storm water. The more water there is, the more time there is for sedimentation, biodegradation and biological uptake.

Filtration: through the use of engineered soil mixes and additives, filter media can be created to enhance bioretention treatment performance. Designs can include submerged anaerobic zones to promote nutrient renewal. Reedbeds are highly effective at bioremediation.

Amenity: permanent water features, such as ponds and wetlands, offer important aesthetic and amenity benefits to development. Integrating an aquatic bench, to create a shallow zone for wetland planting, increases aesthetic value and the potential for biological filtration and habitat. Ponds can incorporate features such as islands and shallows that allow greater access and interaction.

Biodiversity: design features such as shallow and convoluted edges, uneven surfaces, woodlands, tussock grass areas and dead wood piles increase habitat diversity. These can provide shelter, food, foraging and breeding opportunities for a range of urban wildlife.

Design considerations
Sedimentation: fine materials cause sediment accumulation within ponds and wetlands, reducing storage volume, filtration and infiltration rates. Mitigation measures can be implemented upstream or by installing a sedimentation area within the catchment.

Vegetation: ponds and wetlands are ideal spots for planting, which can provide amenity and habitat. Prioritise native species that are resilient to local conditions. Aquatic vegetation can provide stabilisation, prevent scour and re-suspension during heavy storms.

Edge protection: ponds and wetlands hold standing water so nearby motorists, cyclists and pedestrians need to be considered. Trees, woodland, planting, benches or other physical obstructions can provide natural protection.

Erosion: ponds and wetlands are susceptible to erosion, especially during heavy storms. Storm water velocities can be slowed through planting and low-tech bio-engineering sympathetic to the character of the SuDS component.
Compaction: ensure soils are not compacted during construction. Compaction of the pond soils can reduce infiltration rates, and prevent vegetation root penetration and establishment.

Outlets: a non-clogging, variable flow rate control structure, together with an emergency overflow should be incorporated. This might be a protected orifice, combined with an overflow channel protected with a weir.

Inlets: ensure excessive erosion at inlet points does not occur. Where pipework outfalls a protection grille should not be used unless the inlet diameter is greater than 350mm.

Filtration: ponds and wetlands treat surface water runoff by sedimentation that occurs during the time water remains in the pond. Filtration of nutrients can also occur through biological uptake by surface, submerged and aquatic vegetation, particularly reedbeds.

**Maintenance**
Routine inspection and maintenance is important to ensure the efficient operation of ponds and wetlands. Maintenance regimes over and above routine on-site pond maintenance include water quality monitoring and control of algal bloom.

**Useful design guidance**
CIRIA C753 The SuDS Manual, Chapter 23
Life-cycle management and maintenance are key considerations of SuDS schemes. If well designed, most SuDS components function without additional inspection over and above routine site maintenance of the public realm. Principles of good management and maintenance to ensure SuDS system continues to function long-term are:

1. Design from the outset with long-term management and maintenance in mind. Ensure that site or street management can deal with most SuDS requirements; SuDS components can be managed by operatives without specialist horticultural skill; all SuDS minimise the need for component replacement and ease of inspection.

2. Planting specified should be resilient enough to thrive in drought and flood conditions.

3. Ensure the soil specification and plant species selection meet the specific demands of the SuDS system, site characteristics and geotechnical conditions.

4. The Highway Authority and TfL Street Manager must play a key role in informing design decisions; tailor schemes to suit service level and management/maintenance requirements, to ensure successful SuDS delivery and sustainability.

5. Ensure compliance with TfL Green Estate Management Plan (2013) that guides the management of the TLRN Green Estate, and local authority asset management plans and maintenance procedures and prescriptions.

Operational constraints on management and maintenance vary, principally between schemes on the TLRN and those associated with borough maintained streets. Crucial to successful delivery is close collaboration with the Highways Authority throughout the feasibility and design process.