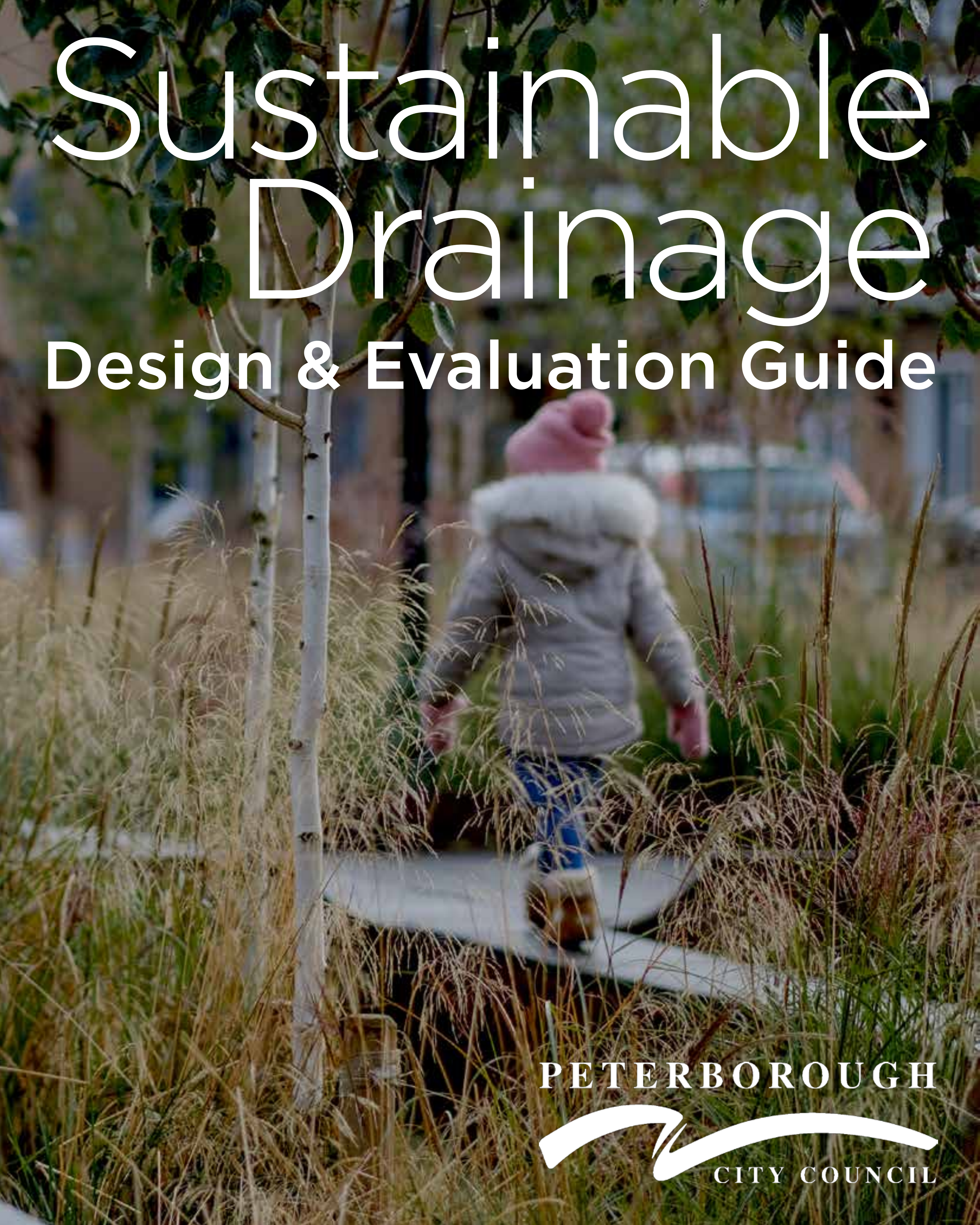

Sustainable Drainage

Design & Evaluation Guide

PETERBOROUGH
CITY COUNCIL

Preface

Why this guide is needed

Our understanding of the negative impacts of conventional drainage are now well understood.

Pipe drainage collects and conveys water away from where it rains, as quickly as possible, contributing to increased risk of flooding, likelihood of contaminated water and the loss of our relationship with water and the benefits it can bring to us all.

Sustainable Drainage, or SuDS, is a way of managing rainfall that mimics the drainage processes found in nature and addresses the issues with conventional drainage.

Who this guide is intended for

In 2010 the Flood and Water Management Act proposed that SuDS should be used on most development and this was confirmed in a ministerial statement on 23 March 2015 introducing the 'non statutory technical standards' for SuDS.

The responsibility for ensuring that SuDS are designed and implemented to a satisfactory standard lies with the Local Planning Authority (LPA).

SuDS Designers will need to meet these required standards when submitting proposals to the LPA.

What the guide provides

This guide links the design of SuDS with the evaluation requirements of planning in a sequence that mirrors the SuDS design process.

This guide promotes the idea of integrating SuDS into the fabric of development using the available landscape spaces as well as the construction profile of buildings. This approach provides more interesting surroundings, cost benefits, and simplified future maintenance.

This guide begins by giving a background context for SuDS design. Next, the three accepted design stages are described: Concept Design, Outline Design and Detail Design. Subsequent chapters offer supporting information.

It is intended that this guide will facilitate consultation, in order to achieve the best possible SuDS designs.

Contents

Anthony McCloy *Director McCloy Consulting*

Anthony McCloy is a Chartered Engineer working exclusively in the water sector since 1998. Since 2003 he has focused on SuDS design, hydraulic modelling for SuDS and flood risk. He has co-authored SuDS Guidance documents for Planning Authorities and is a key tutor for the (CIRIA) National SuDS training workshops since 2006.

Bob Bray *Director Robert Bray Associates*

Robert Bray has been a pioneer of UK SuDS since 1996. He has been at the forefront of demonstrating how SuDS can be fully integrated with the surrounding landscape. Bob has been a key tutor for the (CIRIA) National SuDS training workshops since 2003.

Kevin Barton *Director Robert Bray Associates*

Kevin Barton has been working as a Landscape Architect for over 20 years and designing SuDS landscapes exclusively since 2011. In addition to project work, Kevin has also contributed to SuDS Guidance documents for Planning Authorities and presented on SuDS topics at Conferences, CIRIA 'Susdrain' events and to Planning Authorities.

Acknowledgements

Kevin Tidy - LLFA (retired)

Ruth Newton - Planner

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Project Partners

- Lewisham Council
- Lincolnshire County Council
- London Borough of Bexley
- London Borough of Enfield
- London Borough of Hackney
- London Borough of Hammersmith and Fulham
- London Borough of Haringey
- London Borough of Hillingdon
- London Borough of Merton
- Luton Borough Council
- Oxford City Council
- Oxfordshire County Council
- Peterborough City Council
- Royal Borough of Kensington and Chelsea
- Worcestershire County Council
- North Worcestershire Water Management Districts:

  Wyre Forest District Council

  Bromsgrove District Council

  Redditch Borough Council

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9.0 Design and Evaluation Stage 3 – Detailed Design

The SuDS strategy will be reasonably fixed by Detailed Design stage. The management train, selection of SuDS features and general means of storing runoff will have been evaluated and defined at earlier design stages.

The development and refinement of Concept and Outline designs at Detailed Design stage will demonstrate that the project objectives can be delivered upon and will be presented with either the detailed planning application or to discharge planning conditions, or reverved matters, depending upon the requirements of the LPA.

Competent design details ensure that runoff is collected, conveyed, cleaned, stored, controlled and discharged from site in an effective manner that provides wider benefits.

Failure of individual elements of the design can:

- invalidate expected storage volumes and flow rates
- prevent adequate treatment
- negatively impact or miss opportunities to contribute to amenity use
- create hazards to wildlife or miss opportunities to support biodiversity
- cause local ponding, flooding and inconvenience to the public
- increase maintenance difficulty and cost.

Grey to Green project, Sheffield City Council. Groundbreaking project integrating SuDS into the heart of Sheffield, replacing redundant roadway with exciting planting, to a sequence of landscape cells leading to the River Don.

9.1 Objectives of Detailed Design

Detailed Design should develop and refine the agreed SuDS strategy from the Concept and Outline design stages. Outputs from the detailed design should:

- provide sufficient information to give the LPA and LLFA a full understanding of how the scheme will appear and operate
- meet the requirements for NPPF and NSTS along with Local SuDS Standards and SuDS related planning policies
- confirm how the SuDS scheme maximises opportunities for amenity and biodiversity
- deliver schemes which are legible and function passively.

9.2 What Detailed Design should demonstrate

The SuDS Detailed Design considers in detail all the influencing factors on the scheme with over-arching requirements as follows:

- the use of Source Control techniques provides a controlled flow of clean water through the site
- demonstrate that the modified flow route(s) provides for extreme flows and where possible connectivity corridors for biodiversity through the site
- carefully consider all site levels to ensure that the system will function as intended in 'day to day' and also extreme conditions
- demonstrate that individual SuDS components meet respective design criteria
- proportionate analysis to confirm attenuation volumes with allowances for climate change and urban creep, and controlled flow rates for each sub-catchment and final site discharge rates
- materials and plant varieties specified accord with local landscape character
- demonstrate safe design for contractors, operatives and general users of the site
- that SuDS which are being offered for adoption meet the relevant standards of the adopting body.

Design Note :

Schemes invariably evolve and change from concept stage. The designer should therefore confirm no material changes to drainage strategy from that agreed with LPA at the Concept or Outline design stages. Any materials changes should be discussed and agreed with the LPA prior to detailed design submission.

9.3 Typical Detailed Design package

The Detailed Design package should be proportionate to the scale of the development and will generally encompass a design statement with accompanying drawings. Supporting information including calculations, maintenance plan and risk assessment will also be required.

9.3.1 SuDS Design Statement

The SuDS Design Statement should cover SuDS provisions on quantity, quality, amenity and biodiversity and how opportunities provided by the site have been maximised along with addressing the following:

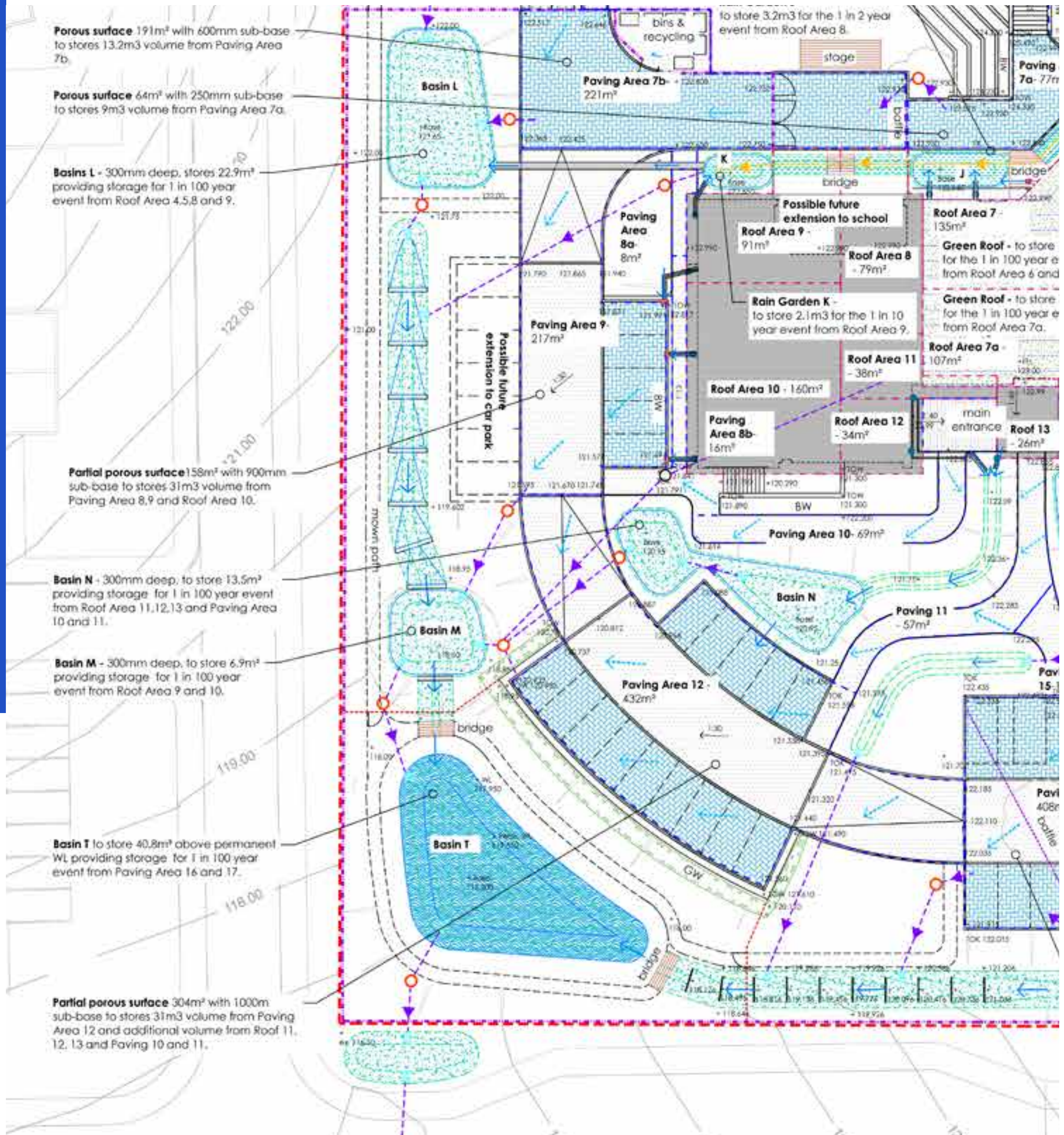
- confirm drainage design criteria agreed with LPA. For example, rainfall return periods, discharge allowance, traffic loading requirements etc
- summarise the findings of the FRA and highlight any other significant site constraints
- outline how requirements of NPPF, NSTS, local SuDS policies, requirements for multi-functional use of SuDS space and local objectives for sustainability including climate resilience are dealt with
- explain how SuDS will function passively in terms of treatment and management
- outline details of any offsite works required, together with any necessary consents.

9.3.2 Drawing package

The SuDS drawing package should include the following:

Design information drawings	Topographical survey of the site Coordinated constraints map identifying all potential design constraints including areas of flood risk (fluvial, pluvial and ground water), contaminated land, archaeological significance, poor ground conditions, unexploded ordnance (UXO), presence of invasive species, protected habitats, tree Protection Orders (TPO) and root protection zones (RPZ). [note : list is not exhaustive] Existing utility services drawing. Details of existing site surface water drainage infrastructure and ownership established Plan of site detailing flow routes including exceedance flow routes, subcatchment boundaries, flow control locations, storage locations, contributing impermeable area, and phasing where appropriate; Drawing of site drainage catchment areas showing permeable and impermeable areas within defined subcatchments.
Design drawings	Detailed site layout at an identified scale (1:200 or 1:500 or as appropriate or any other scale agreed) including a North direction arrow. Long sections and cross sections for the proposed drainage system, including surrounding site level and proposed finished floor levels (where appropriate) Construction Details – inlets, outlets, flow controls, storage, edge details, connection details to receiving watercourse / sewers / public surface water sewers / highway drains; Planting arrangement and surface treatment / materials drawings where detailed not included on other drawings. Critical design levels should be identified on all relevant drawings.

Facing:
Rectory Gardens Rainpark, Hornsey.
A small public park that collects polluted road runoff through silt forebays and underdrained infiltration basins that discharge clean water slowly to the River Moselle.



Plan excerpt: proposed new Holyoaks Primary School, Redditch. The detail design stage confirms the layout, character and function of the SuDS, Including detailed levels, volumes, flow controls and component design.

9.3.3 Supporting information

Depending on the nature of the scheme various investigations, tests and calculations may need to be performed along with obtaining necessary consents:

- Ground investigation, including infiltration test results, soil testing and groundwater monitoring as appropriate.
- Design calculations which demonstrate compliance with the design criteria for the site including all hydraulic and structural calculations for permeable pavements and underground storage structures as appropriate.
- Completion of standard design information forms as may be provided by the LPA.
- Details of any offsite works required, together with any necessary consents in place (or can be obtained).
- Confirmation that discharge consents are in place (or can be obtained): Environmental Permit (Environment Agency) - an Environmental Permit may be required for works in, under, over or near a main river (including where the river is in a culvert), works on or near a flood defence or for works in the flood plain of a main river; Ordinary Watercourse Consent (LLFA) for any structure with the potential to affect flows in an ordinary watercourse; highway drain (Highways Authority); or with Sewerage Undertaker for any connections to the public sewer. Discussions should be held with EA for Infiltration within Source Protection Zone areas or higher risk sites; Local Authority and Inland Drainage Board byelaws, comments and constraints.
- Proposed maintenance schedule and confirmed management arrangements for all non adopted drainage. Identify any proposed split of the SuDS between private (curtilage) and public (open space or highway) land.
- Designers hazard and risk assessment- to consider construction, maintenance and operation by personnel and day to day site use by public.
- Details of any informative signage proposed for SuDS.

9.3.4 Detailed Design Evaluation Checklist

The following table provides a list of key considerations for design and evaluation.

The CIRIA SuDS Manual Table B.3 provides other aspects for checking which may be incorporated on a case by case basis.

Deliverable	Key design points	Key evaluation points	Responsibility to check
Design standards	Designers should confirm how all standards have been achieved for quantity, quality, amenity and biodiversity.	Confirm allowable attenuation rates. Confirm amenity and biodiversity requirements.	LPA
Confirm method & locations of discharge	Where positive discharge is made to a watercourse / sewer, consider likelihood of surcharge on storage from the receiving sewer / watercourse. Infiltration – outline how ground will be protected from compaction during construction.	Review the level at which water is stored relative to receiving flood plain levels/sewer invert. Infiltration – review how groundwater table level has been confirmed and how ground will be protected from compaction during construction. Review risk of infiltrating close to buildings. Review how infiltration on brownfield sites has been assessed.	LLFA
Hydraulic calculations	Detailed checklist is contained Section 9.5.10.	The level of analysis required should reflect the risk of failure, scale of development and complexity of drainage.	LLFA
Detailed consideration of site and drainage design levels	Levels are crucial – check that there are no locations where low points might compromise design. Designer to present drawing showing detailed levels across the site	Sensibilty check to be performed for each subcatchment, comparing top level of storage, and lowest level of contributing areas.	LLFA
Drainage details	Minimise risk of blockage by designing protected outlets and flow controls	Review of inlets, outlets, flow controls, storage, edge details, connection details to receiving watercourse / sewers	LLFA
hydraulic calulations & drawing volumes match	Drawings should confirm volumes provided and refer back to hydraulic analysis requirements. Drawings references / annotations should clearly relate to calculations.	Sensibility check to be performed to ensure that sufficient storage is provided to meet hydraulic calculations.	LLFA
Designers hazard & risk assessment.	To consider construction, maintenance / operation by personnel and day to day site use by public.	Demonstrate safe design for users and operatives of the scheme.	LPA & LLFA
Long sections and cross sections	Cross sections should not use exaggerated vertical scales to allow proper understanding of how scheme will actually look	Review in general, side slopes and depths shown.	LPA & LLFA
Planting design & schedule	Outline any SuDS specific planting requirements.	Ensure plants from accredited source to minimise risk of invasive species.	LPA & LLFA
Landscape design drawings	Integrate SuDS within the wider landscape design	Check that the SuDS network is accessible, multifunctional and contributes to the overall landscape quality.	LPA & LLFA
Consents & permits	Vary and can include: discharge consents; offsite works & 3rd party access consent. The list of required consents may be initially defined at pre-app discussion.	Check that relevant consents are in place or can be obtained in principle.	LPA & LLFA & EA & IDB & WASC
Maintenance	Key plan (1 side of A4) detailing the maintenance regime and identifying key maintenance locations such as outlets and flow control locations.	Maintenance type & cost is appropriate & proportionate and features are easily accessible. Design achieves passive maintenance where possible.	LPA & LLFA
Adoption arrangements	Confirmation of commitment to adopt aspects of the scheme being offered for adoption. Confirmation of ownership and maintenance responsibilities for all parts of the SuDS scheme which are not being adopted.	Review that sufficient safeguards are in place for the long term maintenance and operation of the drainage. Consider the potential impact of replacement of propriety products.	LPA, LLFA, WaSC & Highways & IDB & WASC

9.4 Critical levels

Levels are important in any drainage system and especially so for surface based SuDS. The proposed surface levels should align with the modified flow route analysis in providing a flow path across the site and storage volumes can be significantly affected by inaccurate levels.

The following levels should be evaluated when developing or reviewing a design:

- The flow control invert level relative to storage - the flow control should not be situated above the base level of the storage component unless there is a requirement for permanent or semi-permanent water.
- The overflow level should demonstrate that the required volume of storage is contained between the flow control invert level and the overflow level.
- Areas contributing to a storage component should not be situated below the top level of storage as they may flood prior to the storage being filled.
- For storage components that are sloping, such as permeable pavements or linear basins, the 'effective' storage should be determined rather than the entire volume of the structure.
- A review of site levels should not identify any obvious obstructions along exceedance flow paths.

Note :
The LLFA will carry out a high-level review of levels only - Liability for design is retained by the designer in all cases.

Facing: Accurate levels were critical at Bewdley School Science Block.

Grey to Green project, Sheffield. The 3 flow control criteria: low flow, overflow and exceedance are demonstrated elegantly here.

9.5 Designing for hydraulic requirements

Development causes an increase in runoff which increases the risk of flooding on site and elsewhere. Where runoff is temporarily stored it allows for a controlled release either into the ground or into a watercourse or sewer.

The storage volume required can be estimated using information such as the local rainfall characteristics and the rate at which flow is controlled to leaving the site.

Expressing calculation outputs in an understandable format allows for easy application within the design process as well as transparency for evaluation.

9.5.1 Objectives of hydraulic calculations

Hydraulic calculations can:

- inform and validate the SuDS design
- provide confidence that there is sufficient capacity to cater for the additional runoff generated by the development to desired design standards
- make allowance for unknown factors such as potential for runoff from off-site
- provide confidence that SuDS will function hydraulically and will not be prone to erosion.

9.5.2 What calculations should demonstrate

Designers should demonstrate through the calculation process:

- how the rates and volumes of runoff generated from development will not pose a flood risk within site boundary or elsewhere
- that future impacts to runoff such as climate change and urban creep are accounted for
- that the correct calculation inputs and processes have been used
- where exceptional flows are experienced, such as; design exceedance, instances of blockage, or flows from offsite, they can be managed within flow routes without causing unreasonable risk to humans or development.

9.5.3 Calculation processes

Calculations used in SuDS design should always be viewed as estimates of what is experienced in reality. Calculation outputs will vary depending upon how inputs are selected and the calculation process used.

The calculations for SuDS design are used to assess:

- appropriate discharge rates via infiltration or controlled discharge rates to a watercourse or sewer
- the volume of runoff that requires storage to allow infiltration or attenuation to controlled discharge rates (see 9.6)
- the long-term storage volume that needs to be managed (see 8.4.7)
- flow velocities.

There are a number of methods that can be used to carry out the calculations including manual calculations, spreadsheets, online tools and a variety of hydraulic modelling software packages.

Calculation processes are summarised in the following table:

Calculation process	Purpose of calculation	Main calculation inputs
Runoff rates from greenfield and brownfield sites estimate	Used to define flow control rate	Local rainfall data; site area; soil characteristics.
Attenuation storage or infiltration storage estimate.	The runoff generated by the site is balanced against the controlled rate of outflow.	Local rainfall data; site area; proposed site impermeable area; climate and creep adjustments; infiltration rates; soil characteristics; discharge rate(s).
Long term storage estimate	Determining the difference in the volume of runoff between pre-development and post development scenarios	Local rainfall data; site area; existing site impermeable area; proposed site impermeable area; infiltration rates; soil characteristics; rain harvest volume, losses provide by SuDS, proposed discharge rate(s).
Flow velocity check	Flow velocity calculated to ensure: Conveyance along vegetated channels do not cause erosion; Low flow velocities for 1 in 1 year rainfall to allow settlement of silt.	Component sectional geometry; component gradient; component surface type (roughness); proposed flow rates.

9.5.4 Calculation inputs

9.5.4.1 Rainfall data selection

Rainfall depths and intensities for a range of return periods and storm durations is one of the key calculation inputs.

The choice of rainfall data can have a significant effect on the volume of storage calculated.

FEH 2013 rainfall data is considered the most up-to-date data availabale and therefore recommended for use.

Where FSR rainfall values are used the designer must demonstrate that rainfall values are consistent with FEH 2013 data.

FEH 2013 rainfall data can be sourced online at fehweb.ceh.ac.uk

9.5.4.2 Defining runoff coefficients (Cv)

In extreme rainfall conditions the losses anticipated from hard development surfaces such as roofs or paved areas are anticipated to be minimal.

The designer must evaluate the runoff coefficient (Cv) for the types of surfaces contributing runoff to the storage location. Sewers for adoption (Section C5.1) recommends assuming 100% runoff from impermeable areas which equates to a Cv of 1.0.

Runoff coefficients of 0.95 for roofs and 0.9 for paved areas would be considered acceptable by the LLFA where drainage is not being adopted by a Water and Sewerage Company (WaSC).

Some modelling software packages contain 'Default' Cv values (0.75 Summer, 0.84 Winter) which assume that there will be 25% summer and 16% winter losses from hard surfaces.

These default values should not be used for storage estimation calculations.

The designer must justify where a Cv of less than 0.9 is used for calculations.

Where a reasonable amount of permeable surface contribution to SuDS storage, then this should be considered within calculations. The 'UKSuDS' website was recently updated to allow input for permeable surface runoff contribution within attenuation calculations.

9.5.4.3 Making allowances for interception losses

As a rule of thumb, where the total wetted area of SuDS components equates to at least 25% of the development area (all buildings and hard surfaces) then it is acceptable to make an allowance for interception losses.

This loss can be applied within storage calculations by reducing the rainfall depths by 5mm.

For more detailed analysis methods see SuDS Manual Section 24.8

9.5.4.4 Defining infiltration rates

The specified infiltration test methodology should be representative of the proposed design.

The depth of water and depth of test trench below ground level should seek to replicate the attributes of the proposed infiltration system.

For example, tests should not be undertaken 1.5m below ground level when shallow infiltration is proposed from permeable pavement, rain gardens or basins which will be located close to ground surface.

Bromsgrove Civic Centre re-development. Permeable block and slab paving with a central grass detention basin provide a fully integrated infiltrating SuDS scheme.

Detailed Design

9.5.4.5 Defining attenuation flow control rates

LPAs require that SuDS attenuate runoff from all sites (Greenfield and Brownfield) to equivalent greenfield runoff rates. There are 2 primary methods for controlling rates as follows (see Section 6.4.3.5):

- **Approach 1** - where the volume of runoff is controlled, the rate of outflow is controlled to the 1 in 1 year and 1 in 100 year greenfield runoff rate.
- **Approach 2** - where the volume of runoff is not controlled the rate of outflow for all rainfall events is controlled to Qbar/Qmed.

NSTS S2,S3 and S6

Qmed / Qbar rates are anticipated to be in the region of 2-7 litres per second per hectare (l/s/ha) depending on local rainfall and soil characteristics.

FEH methods are now preferred for estimating Greenfield runoff rates. Care must be taken when selecting the catchment to define descriptors to ensure that a small localised catchment is selected.

The IoH124 method has been superseded by the FEH methods.

In most cases the value derived from IoH124 method is similar to FEH methods and due to its common usage IoH124 values will be accepted by the LLFA until FEH methods become more commonplace.

Further notes on the application of the different methods are listed below:

- **FEH ReFHv2** – analysis should ensure that there is no urbanised component within the runoff estimate. The flow rate for any return period can be derived using the ReFHv2 software. The peak rate of catchment runoff is factored back to the site size to establish the greenfield runoff for the site.
- **FEH statistical** method requires the designer to establish Qmed (SuDS Manual EQ.24.2) using FEH catchment descriptors and then undertake a pooling analysis to derive flow rates if 1 and 100 year flow rates are required.
- Establishing Qbar using **IoH124** (SuDS Manual EQ.24.3) is based on 50ha area input and then factored down to the size of the site. Where Approach 1 is used, the 1 in 1 and 1 in 100 year Greenfield runoff rates should be calculated by factoring the Qbar rate using growth curve factors. (SuDS Manual Table 24.2)

Design Note:
Regional maps may not be representative of site soil conditions and calculation inputs may have to be adjusted accordingly.

Detailed Design

9.5.4.6 Accounting for Climate Change

Future predictions suggest that more extreme rainfall events will occur with greater regularity.

To make allowance for this within SuDS calculations the current industry approach is to factor up rainfall intensities for **Climate Change Allowance**.

Flows in excess of the storage capacity of SuDS components should be directed along modified flow routes. When the sensitivity test indicates potential for flows across the surface, the designer should evaluate likely flood volumes, depths and velocities to ensure there is no significant risk to development or people. Generally, depths less than 0.25m will not present a risk, but steep parts of sites may generate high velocities which may be unsuitable.

Table 2 from the DEFRA Guidance on climate change is replicated below with additional advisory notes on how the upper end and central projections should be applied:

	Design life 2015-2039	Design life 2040-2069	Design life 2070-2115
Upper End Projection Carry out sensitivity test. Where unacceptable flood risk to site or adjacent sites is identified Upper End Projection allowances must be incorporated into design (i.e significant flood depths on site during this event could present a danger to people)	10%	20%	40%
Central Projection These represent the Minimum climate change allowances that can be adopted where sensitivity tests demonstrate that no unacceptable flood risks are introduced by not allowing for Upper End Projections.	5%	10%	20%

Design Note:
Climate Change should be considered for both attenuation storage and conveyance calculations.

9.5.4.7 Accounting for Urban Creep

Urban Creep considers the potential impact on the drainage system from permitted development such as paving over front gardens to create driveways. Permitted development rights generally applies to residential development but can also apply to commercial development and schools.

The following table is taken from LASOO Guidance document and defines the anticipated percentage increase to impermeable area:

Paving over front gardens with impervious surfaces is increasingly common. This example could easily have been permeable block paved.

	Residential development density (dwellings per hectare)					
	≤ 25	30	35	45	≥ 50	flats & apartments
Percentage area increase applied as percentage of proposed impermeable area within curtilage of private lands.	10%	8%	6%	4%	2%	0%

For housing developments designers should calculate the number of properties per hectare and apply the percentage increase to non-adopted impermeable areas, for example roofs, pathways and driveways.

Urban creep allowance for commercial developments and schools should be agreed with the LLFA at pre-application stage.

9.5.5 Calculating storage requirements

Runoff rates and volumes can be managed by either infiltration or controlled discharge.

Infiltrating runoff through the soil into underlying geology is the first preference. Where soil, geology or ground conditions do not enable infiltration, then attenuating flows and volumes to controlled discharge rates would be appropriate.

Both infiltration and attenuation require storage within the development to hold water long enough to be discharged either into the ground or through flow-controlled discharge to a watercourse or sewer.

Sections 6.4.3.1 and 6.4.3.5 cover the basics of infiltration and attenuation storage calculation and should be referred to prior to progressing with this section where calculation inputs are considered in more detail.

9.5.5.1 Infiltration

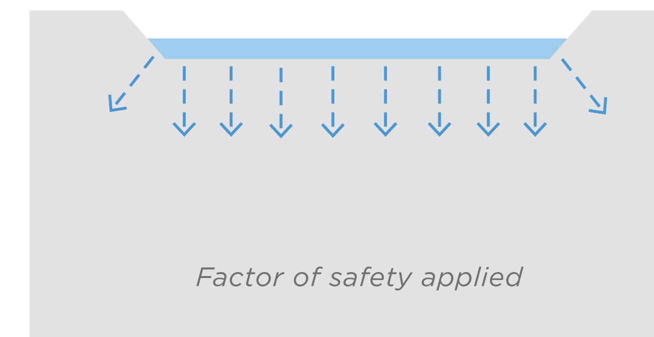
There are two methods for calculating temporary storage for infiltration.

The CIRIA 156 method assumes that there will be infiltration through the base and sides of the structure on an ongoing basis. Factors of safety ranging between 1.5 and 10 depending on the consequence of failure, and the area draining to the infiltration structure (see C753 Table 25.2), are allocated to account for potentially reduced infiltration over time.

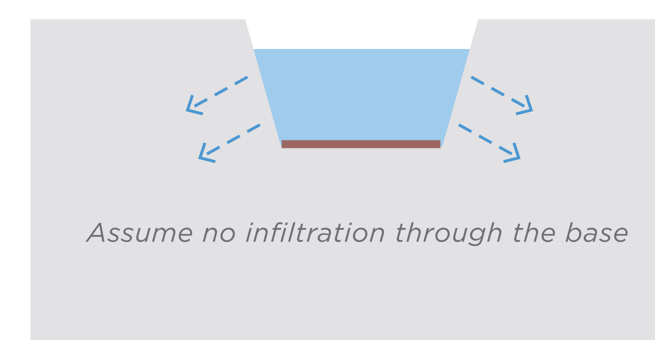
The BRE 365 method assumes that the base of the system, such as traditional soakaway, will silt up and therefore infiltration is only calculated through the vertical sides. The assumption of no infiltration through the base is the equivalent of the factor of safety.

It is noted that various systems such as permeable pavement are resilient to siltation. However, infiltration schemes are not straight-forward and sites which are free draining can quickly become compacted during the construction phase.

CIRIA 156 method



BRE 365 method



9.5.5.2 Attenuation and long term storage

Approach 1

For Approach 1, some runoff must be retained on site for a longer period after attenuation storage has emptied to mitigate for the increased runoff volume generated by the development. (NSTS S4)

There are a number of ways to reduce and manage the volume of runoff generated by development as follows:

- **Rain harvesting** - Where it can be demonstrated that the harvesting system will be in use for the majority of time and demand exceeds supply, 50% of the rain harvesting volume can be offset against the long-term storage volume requirements. (BS 8515:2009)
- **Natural Losses** – For SuDS components which provide natural losses a 5mm reduction can be applied to rainfall depths to account for interception losses. To demonstrate potential for sufficient interception losses, a ratio of 'SuDS space' to 'developed area' of 1:4 would be considered acceptable by LPAs. Where SuDS components are unlined, some infiltration may occur even if rates are very low. These additional losses can be offset against the long-term storage volume requirements.
- **Separate area of storage** - A separate area of storage can be provided. There are no set procedures on how frequently long term storage is utilised.

It is prudent for areas which serve other purposes such as carparks or playing fields not to be inundated on a regular basis.

The 1 in 30 year event is suggested as the point at which these areas would be first utilised for storage.

In other locations such as raingardens and long term storage basins within pond complexes the frequency of fill may be much more regular - i.e. they will be inundated for rainfall events less than 1 in 30 year.

Outflow from Long Term storage area should be via infiltration or a controlled discharge rate of 2 l/s/ha.

Design Note:
Infiltration tests where low rates of infiltration are anticipated may have to be specified over a period greater than 24 hours

Approach 2

Where volumes cannot be managed to predevelopment status, then outflow rate should be controlled to a maximum of Qbar rate (which is equivalent to a 1 in 2 year or Qmed which is used by FEH methods) for all rainfall return periods up to the 1 in 100 year rainfall event plus climate change allowance.

This is the approach most commonly utilised by industry at present due to simplicity of analysis, but can result in a greater storage requirement due to more restricted outflow rates. (NSTS S6)

Riverside Court, Stamford.
Permeable pavement delivers a controlled flow of clean water to landscape canal and rill features and to the River Welland.

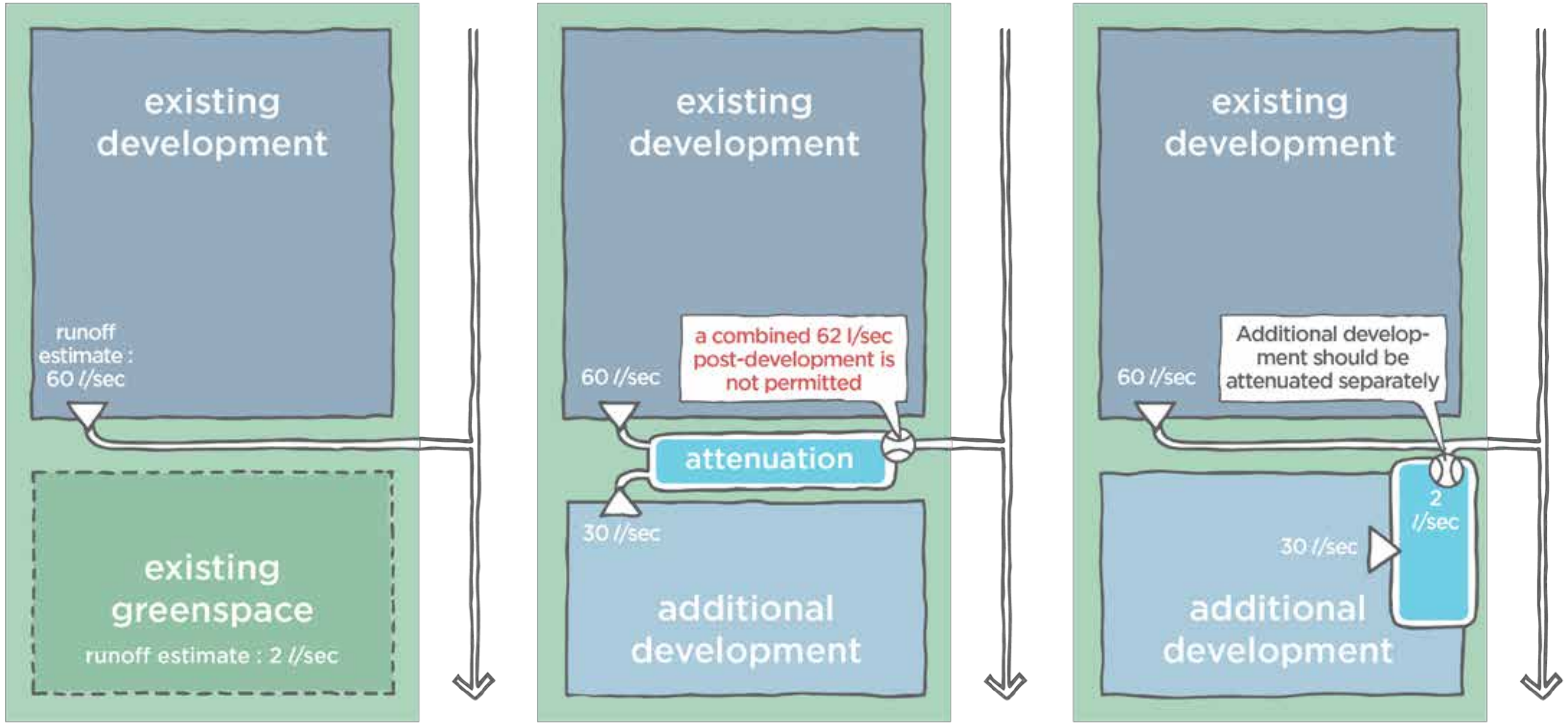
9.5.6 Managing runoff rates from Brownfield sites

On Brownfield sites (also known as Previously Developed Land or PDL), if infiltration of the 1 in 100 year rainfall event is not possible, the rate of discharge should be reduced to greenfield runoff rates. Where greenfield rates cannot be achieved, the designer must demonstrate why reduction in rate is not achievable. The designer will be required to demonstrate that they have explored all options for storage including the use of storage on roofs (e.g. blue-green roofs), permeable pavements, and the use of appropriately designed underground storage. (NSTS S3 and S6.)

Not all planning applications comprise a complete redevelopment of the site, and only a small parcel of the overall site may be planned for re-development. On such occasions LLFA will not expect the entire development to be returned to greenfield runoff status.

In these circumstances LLFA will not accept the combining of the greenfield runoff rate for the development parcel with the existing impermeable runoff rate from the remainder of the site when the designer is undertaking storage calculations.

The existing development remaining intact and the parcel of land proposed for development should be treated separately in terms of calculations and drainage strategy.



Facing: The Islington, Ashby Grove Raingarden. A raingarden for a single property with control tube and overflow that can manage the 1 in 100 year return period rainfall event.

Designers should provide the following:

- the net increase in impermeable area
- greenfield runoff rates are calculated based on the area of the redevelopment parcel and not the wider development
- storage requirements for additional impermeable area based on outflow controlled to greenfield rates for the development parcel.

9.5.7 Designing for exceedance

The designer must demonstrate that extreme flows, beyond design parameters, can be managed in a safe and predictable manner. Site levels should be designed to allow exceedance flows to flow from one storage location to the next along a defined management train/conveyance route.

9.5.8 Managing off-site flows

Many sites are at risk of significant surface runoff from offsite with indicative flow routes identified by Surface Water flood maps.

SuDS design should demonstrate how offsite flows are intercepted and managed through the site without causing flood risk to the site or increasing flood risk elsewhere. Unless specifically required by LPA / LLFA developers are not required to attenuate flows which are generated from off site. This advice may be revised in exceptional circumstances which will be determined on a case-by-case basis.

EA Flood maps - www.flood-warning-information.service.gov.uk/long-term-flood-risk/

9.5.9 Flow velocities

Peak flows should be retained to less than 1m/s velocity to avoid risk of erosion of vegetated surfaces such as swale channels.

Where velocities are less than 0.3m/s this will encourage silts to drop out of flow along the Management Train.

The Manning's Equation (SuDS Manual EQ.24.12) is used to estimate open channel flow velocities. The depth of flow will affect how much 'roughness' is applied by the channel. The SuDS Manual Figure 17.7 details the manning's roughness values which should be adopted for SuDS calculations.

Lamb Drove, Cambourne, Cambridgeshire.
Levels of pathways and roads can be adapted to allow for a simple cascade of flow from one SuDS component to the next in the event of exceedance or inlet blockage.

Facing: At this development flow rates have not been managed within the conveyance system, requiring rock reinforcement of the swale to reduce erosion.

Below: The amenity plan basin and low flow channel have a flow control before water continues along a conveyance swale.

9.5.10 Calculation checklist

Key calculation inputs and outputs should be presented in the 'Flows and Volumes checklist' (see appendix). The following checklist identifies useful calculation checks:

Parameter	Guidance on design/calculation input	Information for technical assessment
Rainfall data.	FEH 2013 rainfall data preferred. Where FSR rainfall data is used, conversion factors should be applied to bring in line with FEH rainfall data.	Confirm the rainfall source and any conversions applied to data.
Areas generating runoff	All area of contributing runoff should be represented within the storage calculation. The designer must justify where a Cv of less than 0.9 for impermeable area is used for calculations.	Provide a drawing clearly identifying the areas of surface runoff contribution within each subcatchment. Designer to state Cvs used and justify use of Cv less than 0.9.
Maximum flow control rate	Statutory authorities e.g. LLFA, sewerage undertaker, IDB or EA, might place restrictions on the outfall flow rates based on the available capacity of receiving infrastructure.	The flow control rate should be identified along with the method for defining the rate.
Climate change allowance	CCA has been applied within calculations based on design life of development and any applied sensitivity assessment.	Designer to justify selection of CCA based on development type and design life.
Urban creep	Urban creep allowance applied to non-adoptable impermeable areas on developments where permitted development is likely to occur.	Designer to justify selection of Urban Creep percentage
Initial interception losses	As a rule of thumb, where the area of development is no greater than 4 times the SuDS wetted area, a 5mm allowance may be made for interception losses for each m^2 of development.	Designer to confirm whether 5mm interception losses have been applied in calculation.
Critical duration	A range of rainfall durations must be considered when calculating attenuation storage.	Designer to demonstrate that sufficient rainfall durations have been considered to achieve worst case scenario.
Control of runoff volume	Where the designer demonstrates that water can be 'lost' or stored separately Approach 1 can be applied for the control of flow being discharge from the site.	Designer to confirm how volume of runoff has been controlled.

Parameter	Guidance on design/calculation input	Information for technical assessment
Modelling of the SuDS layout.	It is not anticipated that SuDS design will require modelling of extensive piped systems. In some instances where the scheme is relatively small and not hydraulically complex standard calculations will be accepted in lieu of a hydraulic model. Layout drawings should be clearly labelled with the numbering convention used by models.	The designer is to justify where no hydraulic modelling is undertaken. Calculations/model outputs should be provided to support the Flows and Volumes proforma
Outfall design	Outfalls into receiving sewers or watercourses can be at risk of surcharge and lack of free discharge due to elevated water levels. This can result in additional storage being required. Free discharge should not be assumed. The risk of surcharge should be assessed and accounted for within calculations as appropriate.	Designer is to indicate whether SuDS storage calculation is likely to be influenced by high water levels at the point of discharge.
Long section	Long sections will allow detailed consideration of levels across the site.	Long section showing peak water levels.
Erosion check	Flows along swales (or other vegetated surfaces) are at risk from erosion. Peak flow velocities should be less than 1 - 2 l/s. Concentrated inlet points are also prone to erosion.	Designer to demonstrate that they have considered risk of erosion and taken measures to safeguard scheme. Peak flow velocity calculations to be provided as appropriate.
Designing for exceedance	The design should incorporate overflows at each SuDS component. Hydraulic calculations should demonstrate that overflows have sufficient capacity to deal with anticipated flow rates. SuDS layout drawing should identify the anticipated flow route for exceedance events.	Locations of overflows should be identified on the layout drawing along with proposed exceedance flow route.
Managing flows from off site.	The FRA should identify the potential for flows from offsite. These flows can be unpredictable and difficult to quantify. Management of flows through the site should not increase flood risk elsewhere. Detailed modelling to establish the rates of flow anticipated would not be considered compulsory (but may be required on a case by case basis).	The designer should demonstrate how anticipated flows from off site will be managed through the site using the layout drawing and design statement.
Consistency of calculations and design.	Detailed design of SuDS components should reflect hydraulic calculations / hydraulic models, taking into account slopes and low lying levels. The LLFA will consider design drawings to ensure that flow control sizing and storage provision is as per calculations.	Drawings should clearly identify site levels, storage locations and flow controls with cross sections and long sections. The design statement should confirm that drawings deliver calculated volumes.

9.6 Controlling flows

Where a single storage volume is presented, it is the intuitive response of most designers to try and accommodate all flow at a single storage location. However, the opportunities for storage across the site are diverse and flexible.

Appearance, functionality and character of a space can be influenced by how flows are stored and controlled within each SuDS component.

Plastic spacers are used to form open joints between standard slabs at Abbey Park Campus Leicester College, where all hard landscape areas, including the pedestrian entrance plaza to the building, are used for storage.

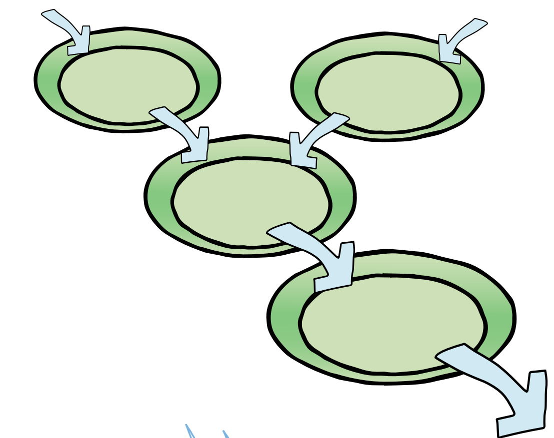
Raingarden and rill exploiting small pockets of green space for creative water management at Bewdley School Science Block. These features visibly fill whenever it rains.

9.6.1 Design flexibility

A framework of three approaches which deliver variable outflow rates (Approach 1) are explored by this guide. These approaches are intended to inspire the designer to think about the possibilities that exist for integrating storage as part of the development rather than defaulting to an underground storage structure prior to discharge from the site. They can be summarised as follows:

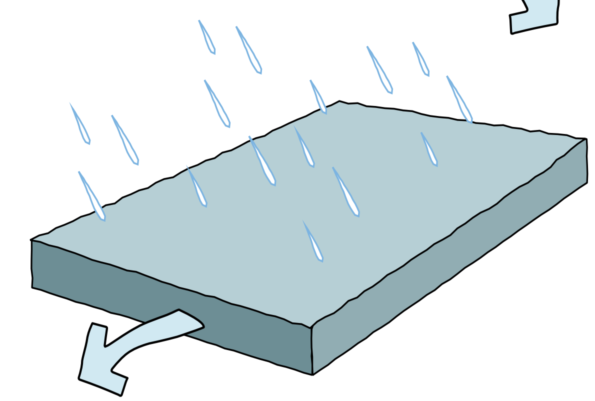
Distributed storage components

- distributed storage volumes into discreet storage components such as raingardens, swales, basins and permeable pavement with the potential for different rainfall depths being stored at each location.



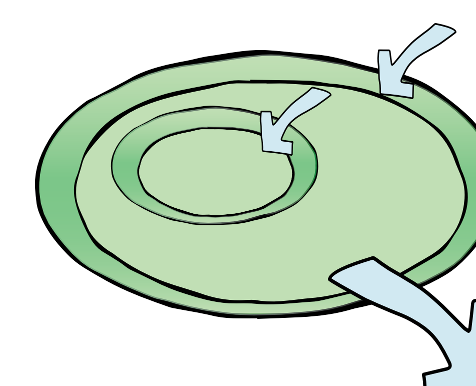
Single, uniform storage components

- store up to the 1 in 100 year rainfall in a single storage component, such as a permeable pavement or blue-green roof, with openings sized to achieve the variable outflow rates.



Single, tiered storage components

- store up to the 1 in 100 year rainfall in a single, tiered storage component, such as a smaller basin used on a regular basis within a more extensive basin for more extreme rainfall events and openings sized to achieve the variable outflow rates.



9.6.2 Distributed storage components

This approach is useful for exploiting small parcels of available space within the development and results in features, such as rain gardens and small basins which can be located close to buildings. These small features are usually sized for between the 1 in 1 year and 1 in 10 year rainfall, with excess rainfall volumes conveyed along the management train to site control.

This approach keeps subsequent storage components from regular wetting as around 95% of rainfall events would be managed by the first component.

This can protect the functionality of downstream components as amenity spaces. The flow control opening for each component can be easily calculated and outflows from one storage component will passively move through subsequent storage components without the requirement for further storage.

Raingardens, such as this wildflower raingarden at St Paters School, Gloucestershire, are an excellent example of the opportunities presented by distributing storage throughout a development.

9.6.3 Single, uniform storage components

Permeable pavements and blue-green roofs which have relatively flat formations can store all rainfall events up to the 1 in 100 year within their footprint. In this scenario the flow control would be designed to ensure that the depth of stored flow discharged at the respective 1 in 1 and 1 in 100 year greenfield runoff rates.

Permeable forming a plaza outside Bewdley School Science Block.

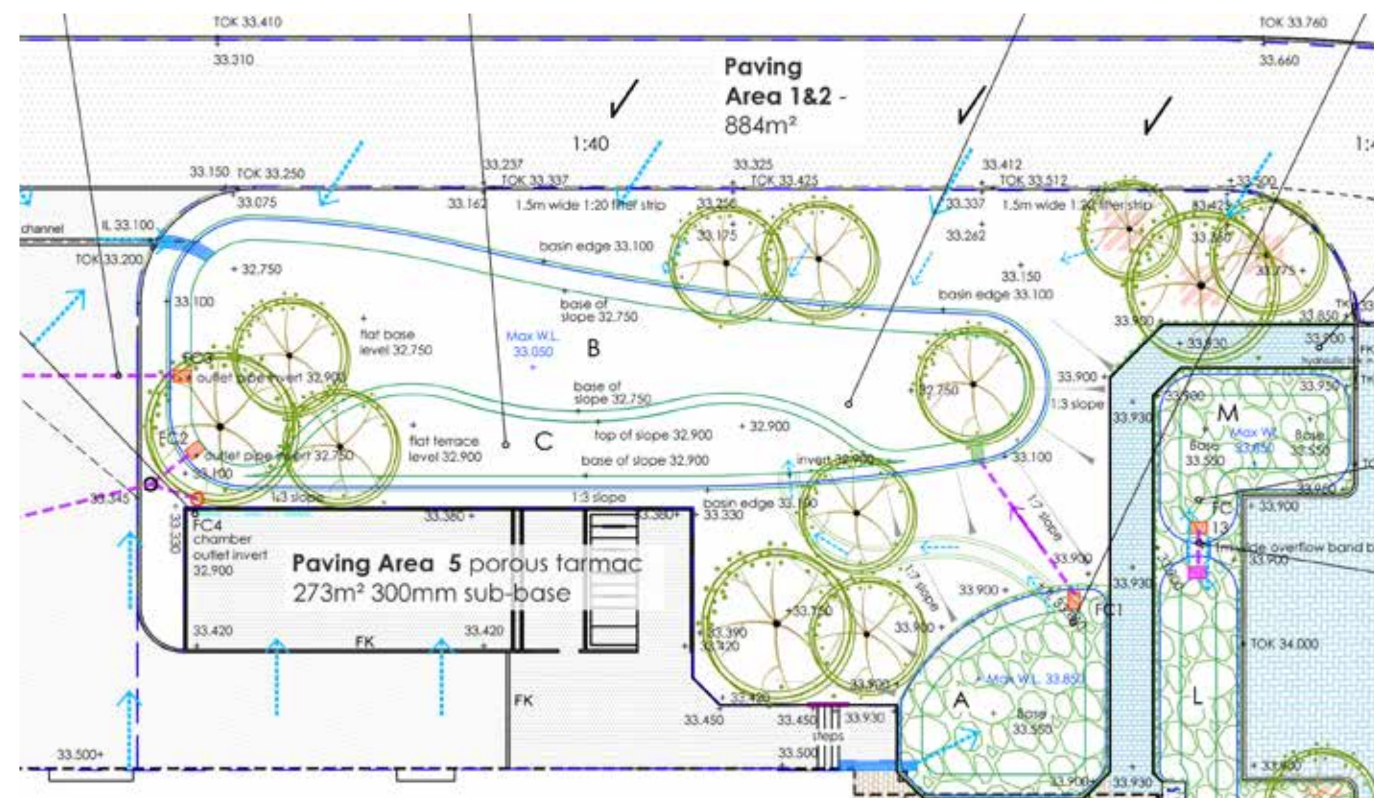
9.6.4 Single, tiered storage components

Source control should be in place where flows are taken to an amenity play basin. In this scenario, a tiered approach to storage is useful in order to maximize the usability of features for general amenity, play or sports. Biodiversity can be introduced in the smaller basin by creating wetland or any other desired habitat.

More frequent rainfall events which produced less runoff such as the 1 in 1 event, are prevented from covering the whole storage component by accommodating them in a smaller basin located within a more expansive basin which can accommodate further volumes of runoff up to the 1 in 100 event. As with other approaches the flow control can be designed to manage the desired variable outflows at various depths of storage.

This wetland basin at Fort Royal School can store day-to-day rainfall whilst the much larger basin in which it sits - defined by the berm on the left of the photo - can store up to the 1 in 100 volume.

Below: Excerpt of a detailed plan showing a tiered basin with two levels (B & C) at a new warehouse in Evesham. This example also demonstrates the principle of distributed storage components with a planted raingarden (A) accommodating up to the 1 in 10 rainfall event.



9.6.5 Flow controls for SuDS

Attenuation storage within sub-catchments and along the management train can require several flow controls. Flow controls come in many forms including orifice plates, slot or V-notch weirs and vortex controls. Any type of flow controls can be prone to blockage unless the opening is protected.

The rate of flow of water through SuDS components is slow as it is restricted to 'greenfield rates' of runoff through each flow control. There should always be an overflow arrangement to deal with blockage or exceedance of the design storm.

Silt is trapped at source in SuDS components and settles out along the management train. Where slow movement of flow is maintained throughout, floating debris that easily blocks outlets is not driven against openings; as is the case with conventional drainage. Simple design features such as sloping headwalls can direct floating debris past the outlet as the storage structure fills.

Orifice flow control chambers such as this one by Controflow are simple, reliable, cost-effective and easy to maintain.

Flow controls in the landscape can make interesting features and help tell the story of how the system works. Although more prone to blockage, features such as this slot weir at Hollington School are very easy to unblock.

9.6.6 The importance of protected openings

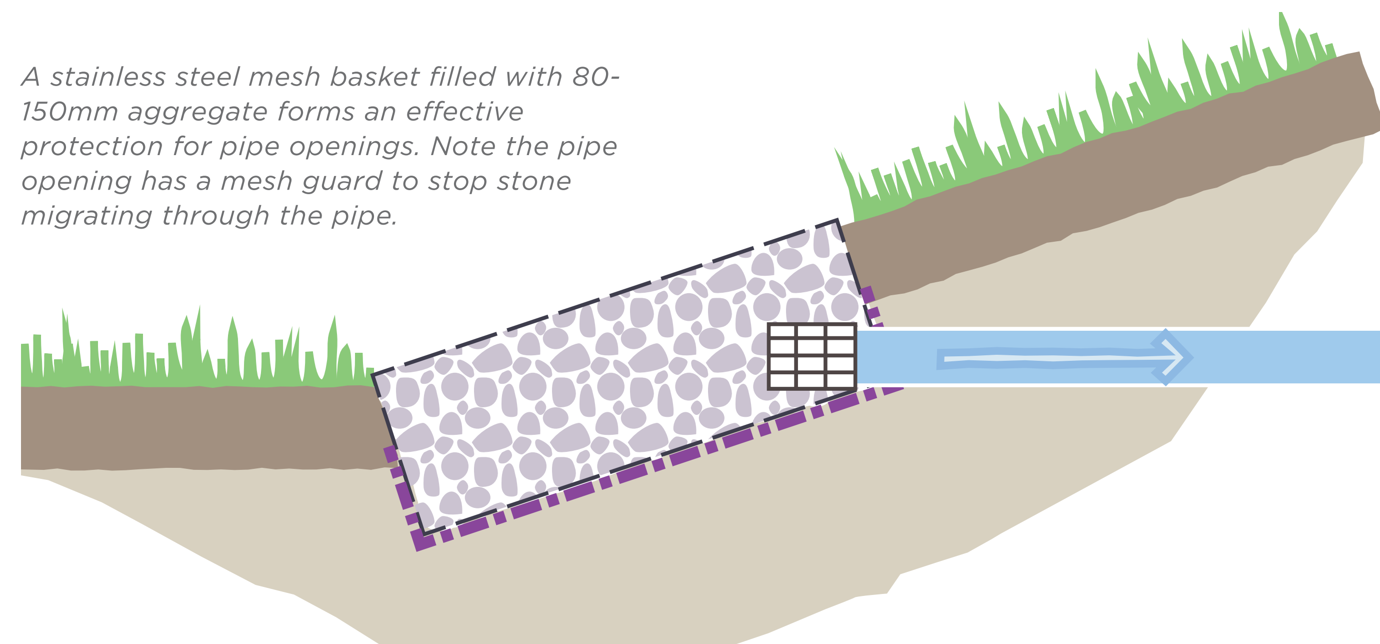
There are no minimum thresholds for attenuated flow rates in SuDS design. Previously the drainage industry has applied a minimum flow rate of 5 l/s but this does not take into account the need in SuDS for low flow rate controls and the design of **protected openings**.

Small sites and sub-catchments of larger sites may need to meet minimal outflow flow rates. Flows can be controlled down to 0.5 – 2 l/s using small openings (15-20mm diameter) with shallow depth of storage.

SuDS components such as permeable pavements, bioretention or filter drains are pre-filtered, and assuming collection through perforated pipes or similar, the flow control opening requires little additional protection.

Open SuDS components such as swales, ponds and basins, require additional protection. One way to provide this protection is to use a stainless steel basket filled with 80-150mm stone with the connecting pipe opening set within the stone to prevent floating debris reaching the flow control.

A stainless steel mesh basket filled with 80-150mm aggregate forms an effective protection for pipe openings. Note the pipe opening has a mesh guard to stop stone migrating through the pipe.



Key points to be considered when designing protected openings:

- Protection to the opening should be of a reasonable surface area to allow for accumulation of litter and vegetation across the surface of the protection.
- Outlets in open structures should be located on a slope to encourage debris to pass over the outlet as water rises in the SuDS component.
- Openings in the protective screen should be smaller than the orifice opening size, thus any residual silt passing through protective screen will pass through the orifice opening.

9.6.8 Sizing flow control openings

The following methodologies for sizing flow controls are intended for use by those with knowledge of hydraulic calculations. Careful consideration should always be given to the selection of equations and coefficients. Section 6.4.3.6 outlines two approaches for the control of flow, summarised as follows:

Approach 1 – Variable control

Non Statutory Technical Standard S2 allows for varying the outflow rate for the 1 in 1 year and 1 in 100 year greenfield runoff rates for the respective rainfall events.

Approach 2 - Qbar method

Where the design requirements for volume control (S3) cannot be achieved then all runoff from the site for the 1 in 100 year event including CCA should be discharged at a maximum Qbar rate (or equivalent) for the development. A lower flow control threshold of 2 l/sec/ha is acceptable to enable reasonable drain down times.

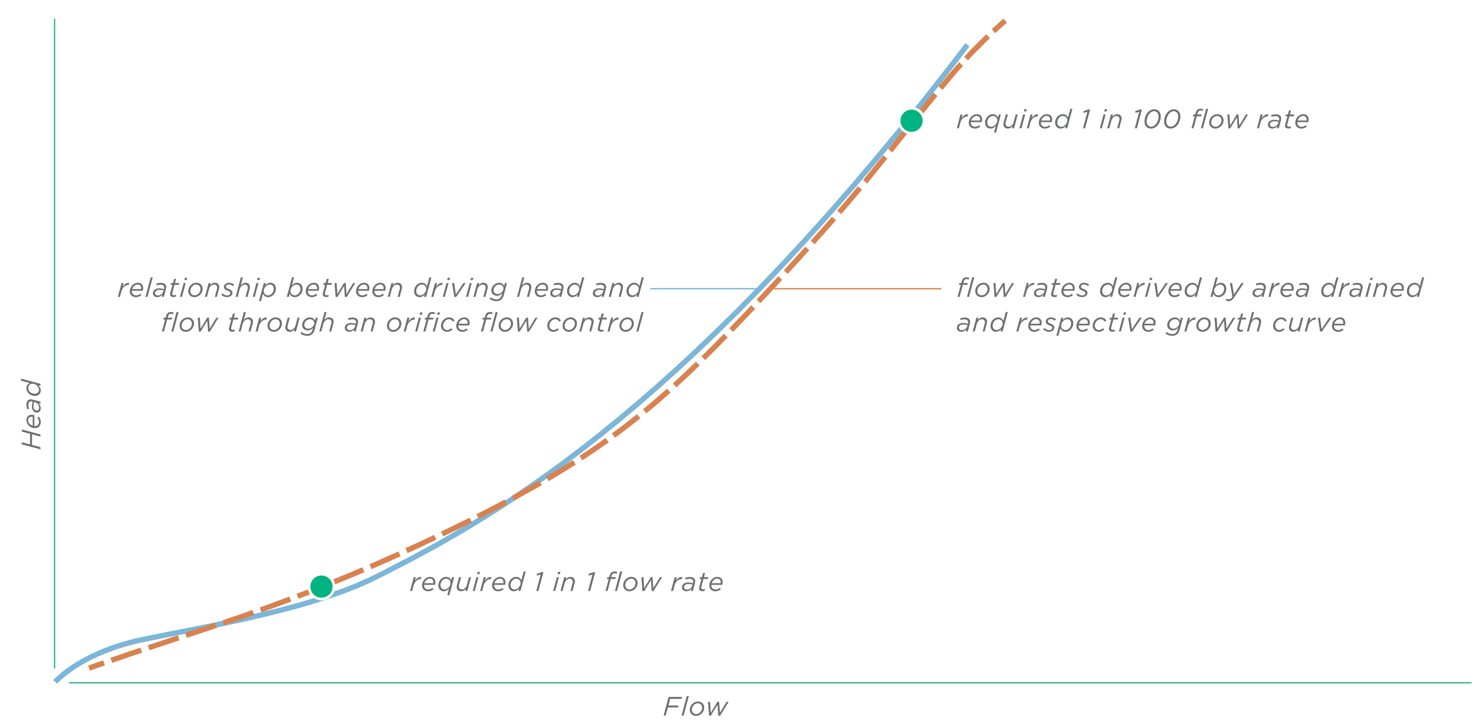
It is noted that the maximum Qbar rate is only reached when the SuDS component is full and the design head reached.

9.6.8.1 Approach 1 methodology

An orifice opening will deliver variable outflow rates as the severity of rainfall increases, producing and storing more runoff. As the depth of stored water increases the gravitational pressure forces more flow through the opening - sometimes referred to as the 'driving head' of water stored.

The following steps outline the process of calculating the opening size of an orifice flow control to meet the requirements of NSTS S2:

1. Establish the controlled outflow (or Greenfield runoff) rates for the 1 in 1 year and 1 in 100 year rainfall event.
2. Define the first, lower orifice invert. A reasonable starting point is to set the invert at the base (or slightly below the base) of storage.
3. Calculate the maximum storage depth for your SuDS component, based on its catchment, for the 1 in 100 year event and the 1 in 100 flow rate - for example this may be 350mm for a permeable pavement or up to 600mm for basins.
4. Make a note of the calculated opening size to achieve the 1 in 100 flow rate at this storage depth.
5. Based on the same storage component design and flow control opening, calculate how a 1 in 1 year rainfall event will behave – make a note of the maximum storage depth and maximum flow rate. Note that the volume and therefore driving head will be significantly smaller for the 1 in 1 year rainfall event and therefore the flow rate through the orifice will be significantly lower.
6. If the calculated maximum flow is less that the 1 in 1 year control rate then the opening does not need changing.
7. If the calculated maximum flow for the 1 in 1 event is larger than the 1 in 1 year control rate then reduce the opening size and recalculate based on the 1 in 1 event being mindful that the 1 in 100 year scenario will have to be reconsidered. Amend the opening size until the 1 in 1 year event is attenuated to the 1 in 1 discharge rate and make a note of the resulting maximum storage depth.
8. Re-run the calculations for the 1 in 100 year event based on the changed opening. The maximum flow rate will now be below the allowable discharge rate resulting in more storage than is necessary. To overcome this, a second opening may be placed above the 1 in 1 storage depth noted in step 7. Add a second opening so that it's lower most point (invert) is at or above the 1 in 1 storage depth and recalculate the storage behavior in a 1 in 100 event. Adjust the opening size and height above the 1 in 100 storage depth until the 1 in 100 flow rate is achieved at the maximum storage depth for the 1 in 100 event.



Graph comparing required flow rates and the variable flow rate through a simple orifice as head increases.

Design Notes:

Both the 1 in 1 and 1 in 100 discharge rates can be achieved by any combination of the following:

- Adjusting the depth of each defined storage tier by adjusting the area and therefore volume of each tier
- Incorporating one or more additional openings

Other options can be explored where there is difficulty in matching outflow rates for both the 1 in 1 year and 1 in 100 year flows:

- Try different types of openings such as rectangular and v-notch weirs.
- Store for a different return period – it is not necessary to store for the 1 in 100 year return period in every sub-catchment. The final discharge from the site must meet requirements of NSTS.

Approach 1 - worked example

For the purpose of the example the following rates are assumed:

- 1 in 1 year 3.5 l/s
- 1 in 100 year 11.1 l/s

Depths of storage are assumed as 150mm and 600mm for 1 in 1 year and 1 in 100 year return periods respectively.

1 in 1 year

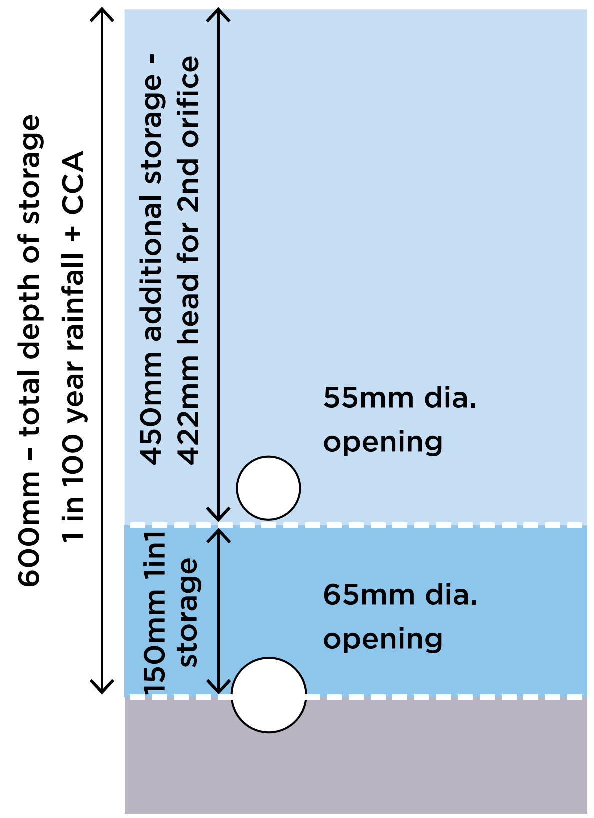
65mm opening with 150mm depth of storage for 1 in 1 year, which provides 3.5 l/s outflow .

1 in 100 year

65mm opening for 600mm depth of storage provides outflow rate of 6.9 l/s. Allowable discharge is 11.1l/s.

Therefore 11.1 – 6.9 = 4.2 l/s. The additional flow will be provided by an additional opening which will only operate once the 1 in 1 year storage is utilised.

Using an additional 55mm opening with invert 150mm above base invert of storage provides 4.2 l/s outflow



9.6.8.2 Approach 2 methodology

A single opening can also be sized to discharge at Qbar for the 1 in 100 year + CCA rainfall event. This does not meet the requirements of NSTS S2 but can be considered to demonstrate S6 as more flow is held back on site for longer.

The Qbar (or Qmed) flow rate will occur whenever the storage volume is full and the design head is reached. This methodology is simpler to apply than Approach 1 as there is only one target flow to be sized for, however, it may also result in increased storage volumes.

The following steps outline the process of calculating the opening size of an orifice to discharge at Qbar rate.

1. Establish the Qbar rate for the flow control location. The Qbar rate should be proportional to the contributing catchment.
2. Define the maximum storage depth. For example 600mm could be adopted for the 1 in 100 year + CCA rainfall event. Define the maximum storage depth.
3. Define the orifice invert. A reasonable starting point is to set the invert at the base (or slightly below the base) of storage.
4. Using the appropriate orifice equation establish the opening size which will convey the required QBar flow rate at the defined 1 in 100 year head (depth of water above the orifice).

9.7 Water quality

Rainfall picks up pollution from development surfaces. As runoff moves slowly through SuDS components most pollution is removed through sedimentation, filtration and bioremediation. Naturally occurring processes in many SuDS components break down organic pollution, meaning that there is no build up or need for removal of this pollution over time.

The NPPF sets an obligation on proposed development to have no negative impact on the environment and encourages provisioning opportunities for biodiversity and habitat creation, not just in the wider landscape, but within development.

Using **source control** and the **management train**, SuDS delivers the requirements of NPPF by providing a **controlled flow of clean water** through the development.

Open water features should not receive flows directly from development without sufficient treatment.

- Hydrocarbons remain in pond sediments for extended periods.
- Silts which carry heavy metals impact on the aquatic environment and add to maintenance problems due to the build-up of toxic sediments.

The amenity and biodiversity value of ponds and wetlands should be protected with pollutants removed at source and along the management train.

NPPF Paragraphs 109, 117 and 118

9.7.1 The objectives of designing for water quality

- Treat runoff to prevent negative impacts to the development's landscape and biodiversity as well as receiving watercourses and water bodies within the wider landscape.
- Design for interception losses to occur for most small rainfall events so that the most polluted part of runoff is more effectively held and treated on site.
- Manage surface water runoff at or close to source and at or near the surface where possible to begin treatment quickly and maximise treatment through the system.

Where water quantity design adopts a SuDS management train approach, as outlined in this document, water quality objectives are normally achieved by default, due to the number of components already limited in series.

9.7.2 What water quality design should demonstrate

For effective treatment of runoff SuDS should be designed to:

- reduce the frequency of runoff by incorporating interception losses
- maximise travel time along the management train
- trap a range of contaminates
- minimise impacts from accidental spillage.

Effective treatment is provided through provision of **source controls** and a **management train**.

9.7.3 Hazard and mitigation risk assessment

Prior to 2015, SuDS water quality design adopted the 'treatment train' approach. This inferred that treatment was provided by allowing run-off to pass through a series of suitable SuDS components prior to discharge. This method remains robust if applied correctly, but has been refined by the 2015 CIRIA SuDS Manual which adopts a '**Source-Pathway-Receptor**' approach, with the extent of analysis required associated with the level of risk.

The varying levels of assessment are identified as follows:

- On low to medium risk sites where discharge is to surface water – apply 'Hazard and Mitigation' Indices approach to identify the number of SuDS components required (CIRIA SuDS Manual Section 26.7.1).
- For medium risk sites where discharge is via infiltration, undertake risk screening to establish whether infiltration will be permitted and apply the Indices approach to identify the number of SuDS components required prior to infiltration (CIRIA SuDS Manual Section 26.7.2).
- For High Risk sites, there is likely to be a requirement for a discharge licence. The Environment Agency will outline level of assessment required and discharge water quality parameter compliance limits.

Design Note:

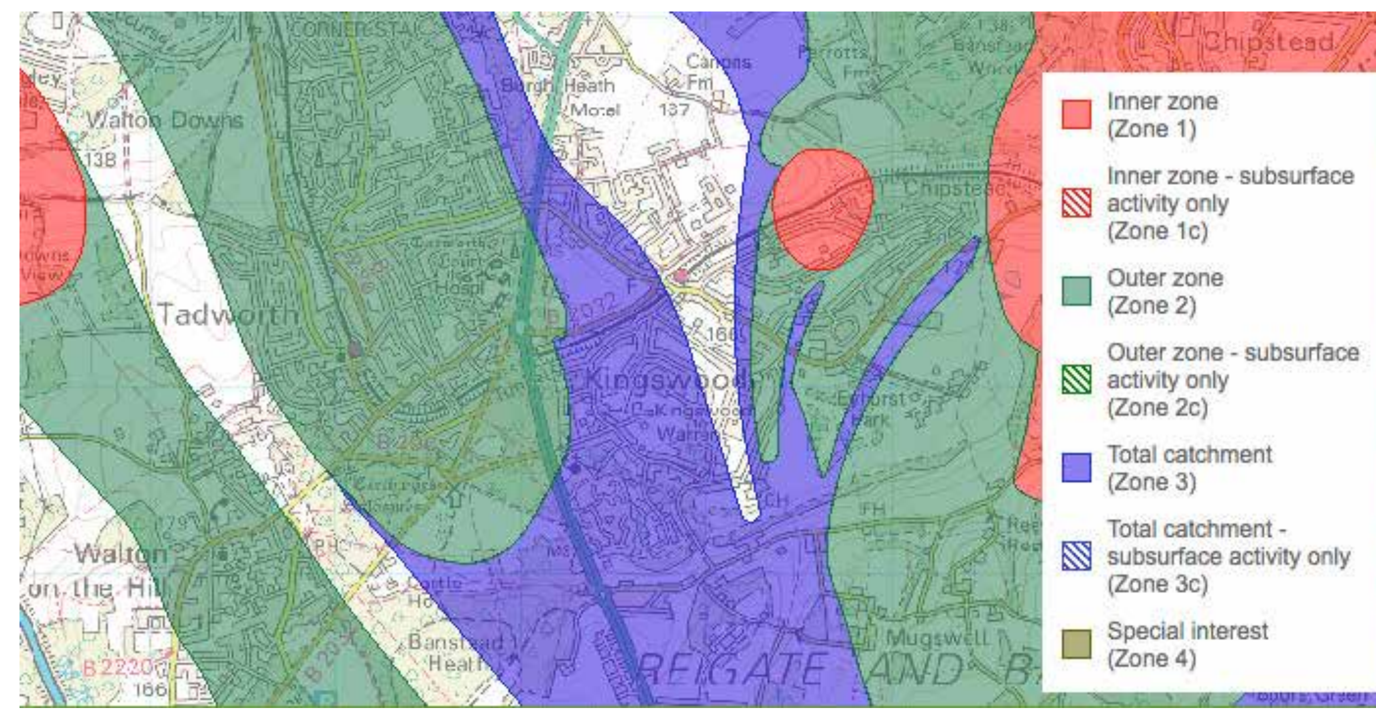
Table 26.15 of the 2015 SuDS Manual denotes that conventional gully and pipe drainage provide **zero treatment**.

For low to medium risk sites, the indices approach for discharge to surface waters is reasonably simplistic to apply.

A level of understanding of the site's soil and underlying geology is required to undertake the infiltration risk screening assessment. The screening assessment will determine whether it will be permissible to infiltrate and the indices approach is applied to define the level of treatment required prior to the point of infiltration.

Discussion will be required with EA where the site overlies Source Protection Zones 1 or 2 or where contamination is identified on brownfield sites.

SPZ areas identified on the EA website: http://apps.environment-agency.gov.uk/wiyby/37833.aspx



Design Notes:

On freely draining sites where insufficient treatment is provided at the first stage of treatment source control, initial SuDS components may require lining to prevent direct infiltration carrying pollutants into underlying geology.

On low to medium risk sites permeable pavement will provide sufficient treatment prior to infiltration into the ground via the pavement subbase.

9.7.4 Dealing with spillage

SuDS components are very effective at dealing with 'day to day' pollution. When a spillage occurs this can overload the treatment processes which occur within SuDS components. Where the spillage is an organic based pollutant a spill kit is used to take up the excess and the residual pollutants left in situ to breakdown naturally.

Designing for spillage should demonstrate:

- spillage is contained at or near the surface so that it is visible and accessible.
- slow travel time through a SuDS management train allows time for reaction and initial clean up to take place
- mechanical mechanisms such as shut off valves should be avoided due to the inherent risk of the essential keys not be locatable at the time of spillage. An awareness of outlet locations which are visible and can be easily sealed off will provide simple and robust containment.

Milk spillages will bypass conventional drainage methods of spill containment
https://naturalresources.wales/about-us/news-and-events/news/nrw-respond-to-milk-spillage-in-llantrisant/?lang=en.

9.7.5 Water quality design checklist

Item	What is being checked	Information presented for assessment
Method of discharge	Sensitivity of receptor and level of treatment required	Design statement to specify method of discharge and sensitivity of receptor.
Treatment	Sufficient treatment in place protecting site biodiversity and amenity assets and the wider environment. Evidence of source control, subcatchments and management train.	Layout drawing clearly indicating SuDS components and management train. Details of Indices approach and infiltration screening assessment (as appropriate).
Infiltration	Presence of SPZ's, contaminated land, depth to seasonal high groundwater table.	Coordinated constraints plan. Evidence of discussion with EA where appropriate
Construction phase	Demonstration of how site runoff could be managed during construction to minimise the risk of pollution to the wider environment due to silty construction runoff.	Section of the drainage design statement outlining a potential approach for construction runoff management. Contractors will be responsible for uptake.
Operation and maintenance plan	Operation and maintenance should be simple to understand and easy to implement. Where available, SuDS design should deploy natural treatment process to breakdown organic pollutants passively. Contingency measures in the event of a minor / major spillage	Concise operation and maintenance plan. Description of tasks and detailing of where personnel are required to visit site to remove hydrocarbon based pollutants (i.e. organic pollutants have not been fully broken down passively as part of SuDS treatment process). Plan indicating potential for containment and positioning of spill kits (as appropriate)

9.8 Amenity

Confirming integrated SuDS design

Amenity is one of the four pillars of SuDS design and perhaps open to the most interpretation and judgement.

Amenity focuses on the usefulness and aesthetic elements of SuDS design associated with features 'at or near the surface', and considers both multi-functionality and visual quality.

The amenity value of SuDS will have been considered at both Concept and Outline design stages but some finer aspects of value will be enhanced by detail design at stage.

An evaluation of the successful integration of amenity uses the design criteria set out in Concept Design.

Informal play, through integrated design.

9.8.1 Legibility

Understanding how the SuDS design functions is important both to everyday users of the SuDS environment and those who look after it.

An exercise in following each management train from source to outfall and imagining how the scheme presents itself to the visitor should highlight any problems with legibility. Considerations will include:

- How is rainfall collected?
- What 'source control' techniques have been used and how they can be accessed and maintained?
- How does runoff travel from where it has been collected onwards through 'source control' components to each part of the site. This is conveyance?
- Where is runoff stored and cleaned along the management train in 'site controls' recognising that these functions may occur within permeable construction?
- Where are flow controls are located?
- Are overflow and exceedance routes clear and understandable?
- Is the outfall obvious, accessible and understandable?

9.8.2 Accessibility

All parts of the SuDS landscape should be accessible to both everyday users and site managers.

Full accessibility requires safety by design for every element of design including:

- open water
- changes of level
- design detailing eg. headwalls, inlets and outlets
- clear visibility of the system
- physical accessibility to all with an understanding of the limitations of level changes and open water.

Hopwood Park MSA M42. Wooden terrace and balastrade with wet bench and planted aquatic bench protection to open water.

9.8.3 Multifunctionality

Many parts of the SuDS landscape can be useful in ways not associated with managing rainfall.

Permeable pavement is an example of full multi-functionality in that the surface is always available for managing rainfall and also allows vehicle access, parking and pedestrian use.

Reasonably level green space can be used for sports and other social activity most of the time but not when inundated. Everyday rainfall (1-2 year return period events) can be designed to be managed elsewhere in the landscape.

Other functionality can include:

- play opportunity throughout the SuDS landscape
- informal leisure like jogging, picnics, dog-walking etc
- community activities such as gardening etc
- wildlife habitat
- education.

Usability of swales and basins can be enhanced by under-draining into filter trenches below the ground to keep grass surfaces dry most of the time. For instance, within housing where grass surfaces are valuable for play.

9.8.4 Visual quality

The overall character of the SuDS landscape and surrounding areas will have been considered during Concept and Outline Design stages.

Design detailing of SuDS components, particularly inlets, outlets, control structures, channels and basins with their edges and profiles remain to be confirmed during Detail Design Stage.

9.8.5 The integration of amenity and SuDS

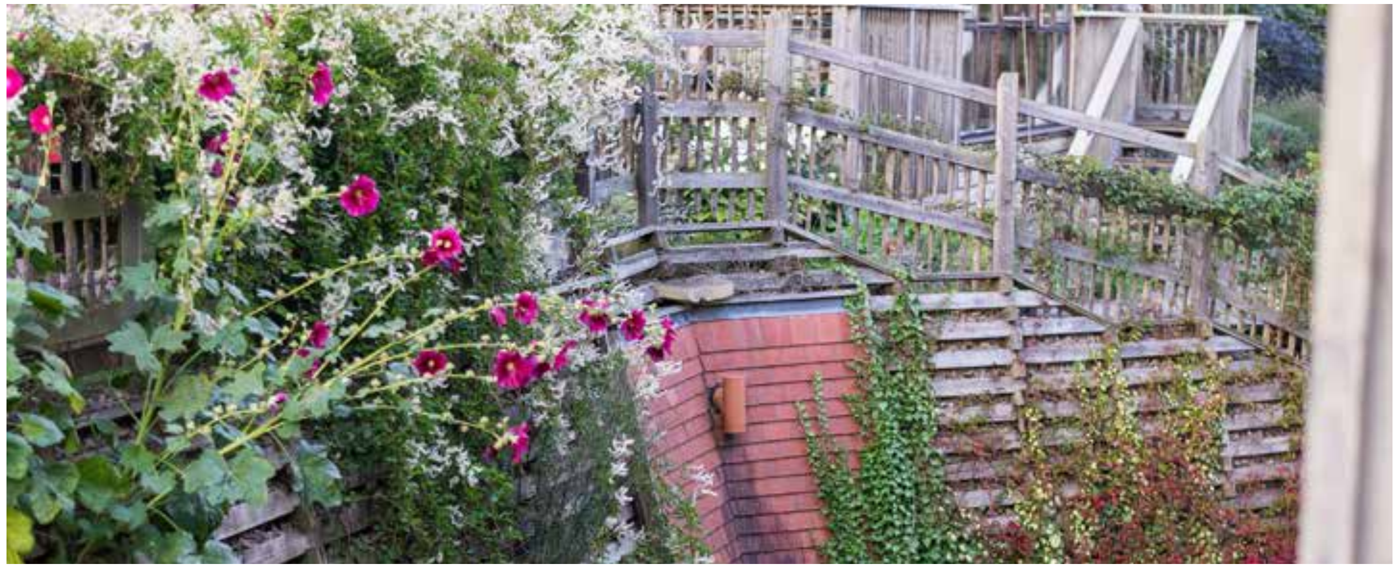
Early SuDS design in Britain tended to create dedicated SuDS corridors with a series of basins, swales and wetlands that were separate from the development they served. In many cases wetland features would be fenced. They were therefore thought to be land hungry, expensive and required additional site maintenance.

In order to maximize the value of SuDS it is important to understand the principle of integrated SuDS design. SuDS design should integrate the requirements of rainfall management with the use of development by people.

Fort Royal Primary School, Worcester. Mini-courtyard with rainchain, rain slide, raised pool and rill.

Firstly the collection and conveyance of runoff can add visual interest to development, spouts, rills surface channels, for instance, should be considered as part of the landscape character of a development.

Springhill Cohousing, Stroud. Tile hung cascade conveys water through terracotta T-piece to lower level.



Secondly it is important to clean runoff as soon as possible so that water that flows through development is as clean as possible for both Amenity and Biodiversity benefits. This requires ‘source control’ at the beginning of the SuDS to remove silt and gross pollution.

Source control components such as permeable surfaces, filter strips, green/blue roofs, bioretention and in some cases swales and basins can all provide early cleaning and flow reduction at the beginning of the management train.

Community use and wildlife interest are both compatible with SuDS design. SuDS should integrate with both designated public open space, where both everyday rainfall and occasional heavy storms can be managed, and public pedestrian routes where conveyance of water and biodiversity can be combined.

The integration of SuDS with Amenity, Biodiversity and site layout provides additional benefits including:

- efficient use of space through multi-functionality
- usability through integrated use of landscape space
- visual and biodiversity interest as part of integrated site design.

Springhill, Stroud - Raised pool and social space.

9.9 Biodiversity

9.9.1 Principles of design for biodiversity

Geology and climate are fundamental influences on the natural character of the landscape and determine the basic habitat types likely to evolve over time.

Local topography, aspect, soils, landscape design and habitat management all affect biodiversity in a developed landscape and can be influenced by SuDS design.

Biodiversity must be considered at the larger catchment scale to create a sympathetic green / blue infrastructure and also at a local scale to provide habitat and connectivity linkages within and around development.

A biodiversity micro-pool set within a meadow raingarden at St Peters School Gloucester,

9.9.2 Biodiversity at development scale

There is usually a **host landscape** that provides an enclosing envelope to the SuDS ‘management train’. This term describes the landscape not directly affected by SuDS features and the impact of rainfall management.

This surrounding ‘host landscape’ may include natural habitat or reflect more ornamental planting, particularly where it is close to buildings.

The wider host landscape should reflect the ecological character of surrounding natural habitat wherever this is possible but careful design can still enhance wildlife value in ornamental planting by following specific guidance.

Where SuDS installations are more isolated, for instance in urban retrofit and re-development, then SuDS spaces can act as biodiverse islands, sometimes likened to ‘service stations’, that act as staging posts and feeding sites for mobile species like birds, insects and other wildlife in an otherwise hostile environment.

9.9.3 Key design criteria for biodiversity in the developed landscape

9.9.3.1 Clean water

Clean water is critical as soon as possible for all open water features in the landscape. Clean water is delivered using initial pollution prevention measures to prevent contaminants reaching water, source control features and further site controls along the management train.

9.9.3.2 Structural diversity

Structural diversity both horizontally and vertically within water features, the landscape and in vegetation generally provides habitat variety for wildlife. Structural diversity is inherent in many SuDS features particularly swales, basins, wetlands and ponds that can easily be enhanced for habitat creation.

Ornamental planting should mimic natural vegetation by developing a complex vertical structure of trees, shrubs and herbaceous cover.

9.9.3.3 Connectivity

Connectivity between wetland habitat areas both within and outside the site encourages colonisation into and throughout the development landscape. These connections are particularly important both for animals on the ground but animals like bats use individual trees and woodland edges to travel from one place to the next and use SuDS wetlands to feed.

Connectivity is inherent in the management train principle but must be considered carefully where one feature links to the next. Surface conveyance and overflow routes, with a minimum use of pipework and inspection chambers, is helpful in retaining wildlife links.

There should be a direct connection between the SuDS landscape and the blue/green infrastructure that receives the ‘controlled flow of clean water’ from the development.

9.9.3.4 Prevent pollution to habitat

Permanent vegetation should cover all soil surfaces to prevent silt runoff and planting should be designed to avoid the use of fertilizer, pesticides and herbicides.

9.9.3.5 Maintenance for wildlife

Sympathetic maintenance enhances biodiversity but should be compatible with the aspirations of the local community to ensure acceptance of a more natural landscape character.

9.10 Planting design for SuDS

The choice of vegetation cover and plant species is an important aspect of designing SuDS systems and features. Vegetation is an inherent functional part of any soft-landscape SuDS feature as well as being about aesthetics, usability and wildlife benefits. Vegetation type and species selection can significantly affect hydraulic and pollution control functionality as well as the contribution to amenity and biodiversity.

The SuDS plant palette will often vary from conventional landscape design for reasons of SuDS functionality, different ground conditions and to protect the wider environment from chemical contamination.

Strutts Centre, Belper.
Contemporary 'prarie' planting in raingarden collecting roof runoff and access road runoff.

9.10.1 Objectives of planting design for SuDS

SuDS planting design should satisfy general planting design criteria and relies on an awareness of the landscape maintenance requirements. In addition, planting should fulfill specific SuDS functions, such as:

- preventing soil erosion
- trapping silt and pollution from runoff
- encouraging interception (evaporation, infiltration and transpiration)
- enabling long term infiltration by opening soil profiles through the root growth cycle
- augmenting biodiversity by structure, species richness and careful management (refer to the Biodiversity section 9.9)
- creating attractive surroundings and community amenity
- protection of the environment by avoiding the need for herbicides, pesticides or fertilizer treatment.

9.10.2 The Principles of SuDS planting selection & design

SuDS vegetation choice and design should achieve the following:

- General planting design should connect with the SuDS landscape, ideally with grassland, woodland or ornamental planting creating linkages for visual benefit and biodiversity. The design criteria set out in the Biodiversity section (9.9) should be followed where appropriate.
- Vegetation should permanently cover the ground, both in summer and winter, to prevent erosion of the soil surface.
- The matrix of roots, stems and leaves of vegetation slows the flow of runoff, filtering water and encouraging silt to settle out in components like filter strips, swales and basins.
- A vigorous growth of vegetation, particularly when forming an extensive root mat, encourages natural losses into the ground throughout rainfall events.
- Planting design should avoid fertilizer, pesticides or herbicides wherever possible to avoid leaching of chemicals into the SuDS and groundwater. They should use careful plant selection and a soil conditioner such as 'green waste compost' as an alternative to suppress weed growth and improve soil fertility.

SuDS planting is often naturalistic in character, particularly where SuDS are being applied to a greenfield site. Naturalistic planting is usually the most appropriate, providing maximum biodiversity benefits as well as being cost effective, resilient and most likely to have modest long term maintenance requirements.

In built up areas a more formal and ornamental design style may be required for raingardens, bio-retention features and green / blue roof surfaces. Recent research by the Royal Horticultural Society (RHS) has demonstrated that ornamental plants, close to the wild type, especially from the northern hemisphere can provide similar benefits to wildlife as native planting but the capital cost and management can be more difficult and expensive.

Contract arrangements should always allow for additional or remedial works to ensure the integrity of vegetation surfaces that perform a SuDS function.

Strutts Centre, Belper.
Brick channels collect roofwater for linear raingarden with garden style planting.

9.10.3 SuDS vegetation types

There are a number of vegetation types commonly used in SuDS:

- grass surfaces – a common SuDS ground cover
- herbaceous planting - typically used in raingardens and bioretention
- wetland and pond planting – usually based on native wetland habitats
- trees and shrub planting – used to enhance the landscape and aid interception losses
- green / blue roofs – resilient low planting for shallow growing media on roofs.

These are covered in the following sections.

Rectory Gardens Rainpark, Hornsey. Forebays, swales and underdrained basins use SuDS turf (100-150mm) to filter runoff, with amenity grass for public use.

9.10.3.1 Grass surfaces

Grass is the most cost effective, flexible and familiar surface for vegetated SuDS features like filter strips, swales, basins and the edges of wetlands and ponds. Grass surfaces will often merge seamlessly with the surrounding host landscape.

Grass surfaces are reasonably easy to establish, simple to maintain, meet the most important requirements in managing runoff and can provide biodiversity and amenity benefits.

Grass swards must be vigorous and able to repair themselves if damaged. For this, an appropriate topsoil depth is necessary.

There are 3 general types of grass surfaces used in SuDS landscapes:

- Amenity Grass - for everyday community use and to give a cared for appearance
- SuDS Grass – a longer amenity grass used where water may flow or be contained in temporary storage
- Meadow Grassland - containing a mixture of grasses and flowering plants left long with an annual cut towards the end of the year.

Amenity grass

An everyday grass surface that can be used in SuDS features allowing regular public use.

The great advantage of amenity grass is its availability as purpose grown turf and most of the time it will establish quickly if properly laid on ground that is not too wet. It will grow on the dry shoulders of swales and basins as well as bases of SuDS features that are designed to be dry most of the time. It is useful for providing a 1m wide cosmetic neat edge to longer grass and as amenity green space for the community.

- Amenity turf should be grown on a sandy loam to aid surface drainage.
- Seeding is a cheaper and more flexible option but can fail easily in adverse conditions. Coir or jute matting is a practical way to provide temporary erosion protection.
- A mown edge of amenity grass is often important where SuDS grass and longer meadow grass is used to make it clear that the longer grass is deliberate and to give a maintained appearance.
- Amenity grass is usually mown at 35-50mm as this is the short-mown grass preferred by many Councils and is familiar to the public. This short grass is susceptible to drought and does not provide the flow reduction and filtering required in SuDS.

Parkside, Bromsgrove. Amenity grass shallow detention basin feature, integrated into site design, manages occasional extreme rainfall.

Design Note:

Avoid turf products with plastic mesh (unless they are bio-degradable) as these introduce microplastics to the environment. Photo-degradable is not the same as bio-degradable as the plastic breaks down into microplastics.

SuDS grass

SuDS grass describes the longer amenity grass used wherever water is likely to move or flow, even minimally.

It is ideal for the immediate protection of any flow areas.

Eventually this turf can be colonized by wildflowers adapted to regular cutting but in the first instance an amenity grass mix is often used as seeding or turf to cover the surface of SuDS components before water flows across the surface. Suppliers tend to offer standard species mixes although specific mixes can be purpose grown where there is a lead in time of 10 or more weeks in the growing season.

- The grass is long enough to act as a filter but short enough to prevent 'lodging' (lying flat under flow conditions) and so must be maintained between 75mm and 150mm in height.
- Turf can be laid in spring and autumn or when weather conditions are suitable, for instance in mild spells in winter or wet weather in summer. Pegging the turf may be necessary, with fully biodegradable pegs, to prevent water flow lifting the turves.
- In dry weather a coir or jute mesh covering a seeded surface can be used to establish grass but there may be bare patches to repair in the autumn.

Longer SuDS grass as a filter strip between paved surfaces and a raingarden.

Facing: A seeded meadow in a 'playful raingarden' at Renfrew Close Community Raingardens, Newham.

Design Note:

This is best specified as turf as it is functional as soon as it is laid.

Meadow vegetation

Meadow vegetation has greater resilience to dry conditions with less likelihood of lodging and offers amenity and biodiversity benefits including habitat connectivity and visual interest.

The grass and herb species develop a much greater root and leaf mass that assist both infiltration and evaporation losses. It provides very effective filtering and slowing of the flow of water as it passes through the grass profile.

- The meadow mixture that is most useful where regular or occasional inundation is expected is based on the MG5 grassland community (NVC classification). This mixture is tolerant of both wet conditions in winter and summer drought but as with all meadow grass habitat can require time and care to establish. Other mixtures are available where a drier or wetter grassland might be expected.
- The addition of an annual cornflower mix can give a floral impact in year one.
- Meadow vegetation should comprise native UK provenance seed.
- Usually a single cut, rake off and removal of cuttings towards the end of September or early October is sufficient to keep the sward visually acceptable. Further cuts can be carried out at other times of the year for specific visual or species management.
- Autumn is the best time to seed as some meadow plants need cold weather to break dormancy (cold stratification).

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9.10.3.2 Herbaceous planting

Raingardens and bioretention features, in particular, use herbaceous plants and sometimes low shrubs to create an ornamental appearance or planting that is appropriate to a formal landscape context.

Flowing water can be a constraint to the planting of SuDS features. Raingardens and bioretention are examples of smaller basin structures with less dramatic flows that allow an ornamental planting approach to be taken. This is helped if there are inlet aprons or other erosion controls where water enters the feature.

Plants can be evergreen (e.g. Geranium macrorhizum and Phlomis russeliana) or plants that shrink back to a visible clump (e.g. Alchemilla mollis and Rudbeckia fulgida 'deamii') or with winter-present foliage such as grasses like Miscanthus and Stipa. This planting usually needs a minimum of one strim in February and some weeding during the growing season.

Herbaceous planting, as well as fulfilling the functional and aesthetic criteria of more general soft landscape design, must protect the SuDS network, by means of the following criteria:

- The planting must resist flow, encourage the trapping of silt and pollution as well as collectively be attractive all year.
- Unlike general amenity planting, the planting must be either evergreen or have a presence at ground level year-round.
- Plant selection must take into account that the raingarden will be dry most of the time and although it will be inundated in most rainfall events will usually return to empty within around 24 hours.
- Herbaceous plants should be selected with a fibrous root system to hold the soil together.
- Planting choice should avoid the reliance on herbicides, pesticides and fertilisers to protect receiving watercourses.

Bioretention features are defined by aggregate filtration below specialist highly permeable soils. This can be a testing environment for planting and so further requirements exist:

- Bioretention planting, located in public open space, must be resistant to damage and neglect. Certain evergreen suckering shrubs and ornamental grasses can resist occasional damage and require simple maintenance.
- If tree planting, consider fine leaved species that do not generate heavy leaf fall.
- Select drought tolerant species.
- A regular mulch of coarse organic matter is also important to keep the soil healthy and the surface of the soil open.

Facing: Herbaceous and grass planting used to dramatic effect at Australia Road SuDS Park.

Recent ideas about planting, including 'prairie planting style', have influenced both the choice of plants and the growing mediums used in recent SuDS features.

These new approaches combine a new palette of herbaceous plants and grasses with the free draining soils recommended for bioretention structures and are being trialled on green roofs and modified bio retention features.

Plants chosen to withstand dry conditions of free-draining soil profiles may be from many sources.

In these cases, a deep stone drainage layer overlain by an open graded growing medium based on crushed stone with 15 - 20% organic matter and about 10% of loam added to the mix may be used. This soil layer is then topped by crushed stone.

Road runoff is largely managed by the very large surface area of very free draining soil rather than a dense planting mix.

Attractive and wildlife friendly herbaceous planting by Sheffield City Council in a crushed stone bioretention substrate.

9.10.3.3 Wetland & pond planting

The biology of ponds and wetlands is similar, but not identical. One definition suggests that ponds have around 75% open water and wetlands around 25%.

The planting requirements are very similar.

Wetland habitats are very sensitive to invasive plants and therefore unless the SuDS are part of an enclosed urban situation native wetland plants should be used in planting proposals and should be obtained from an accredited source with confirmation that the aquatic nursery is free from alien and invasive species.

Wetland plants can be divided into 3 categories:

- emergent plants that tend to grow vertically around the edge and into the water depending on its depth
- spreading plants that tend to grow horizontally around the edge and into the water depending on the depth
- water plants that grow in the water column either anchored by roots or free floating.

These plants are usually planted at 5 or 8 plants per square metre or as a linear edge to wetlands. Wetland plants grow vigorously in spring and through the summer with growth slowing as autumn approaches.

Autumn and winter planting of wetland plants often fails to establish well and they tend to be uprooted by water or wind. Plant in spring or early summer wherever possible.

Where wetland plants are being used where people are often present e.g. housing, visually attractive native plants can be selected to enhance acceptability by the community. Flag iris (Iris pseudacorus) and Purple Loosestrife (Lythrum salicaria) are examples of plants that add attractiveness to waterside planting.

Wetland and pond planting design criteria:

- Selection of aquatic plants should normally be native, and a mix of emergent and spreading plants.
- In urban design some ornamental planting may be justified but not where there is a risk of direct links to the natural environment.

Design Note:

Reedmace (also called Bulrush or Typha latifolia) can seed rapidly on exposed mud edges. This colonizing plant should be considered a potentially dominating weed until a diverse plant community is established.

9.10.3.4 A place for trees and shrubs in the SuDS landscape

Trees provide a number of functions specific to the SuDS landscape, as well as providing a great number of other natural benefits.

Design criteria:

- Ensure sufficient space for crown spread and root growth.
- Allow healthy SuDS vegetation below by using a tree with a light foliage and avoid weeping or suckering varieties.
- Give preference to a small or pinnate leaf type that will degrade easily, to avoid smothering the vegetation below and to reduce the risk of blockage to inlets or outlets.

9.10.3.5 Green & blue roof planting

Green roofs are now a familiar technique for managing rainfall. The blue roof is a development of the green roof whereby it is used for collecting and storing rainfall ‘at source’, on the roof.

Drainage layers can exacerbate drought conditions, particularly on a pitched roof.

Shallow soils of 50-80mm depth are also prone to plant failure due to drought conditions. A greater depth of soil permits a stronger plant community and greater absorption of rainfall. Soil depth should ideally be nominally 100mm or deeper to maintain healthy plant growth.

Design criteria:

- Plant choice should be appropriate for the proposed depth of growing medium.
- Plant choice should be appropriate for the proposed use and desired character.
- Plant choice should be drought resistant.
- Plug planting is normally at 20-30 plants per square metre.

Ruskin Mill Horsely, Glos.
Greenroof with gravel edge and rainchain.

Design Notes:

A biodiverse native wildflower mix can be combined with plug planting at between 8-16/m².

A greater depth of soil permits a stronger plant community and greater absorption of rainfall.

9.11 SuDS Components

Competent design and detailing of SuDS components ensures that runoff is collected, conveyed, cleaned, stored, controlled and discharged from site in an effective manner.

The general principles of SuDS component design are considered in the SuDS Manual 2015 Sections 11-23. The purpose of this section is to outline some of the key considerations, experiences and practical detail solutions of commonly used SuDS components garnered over many years by the authors.

The following classifications are not rigid, for example a permeable pavement can be considered as both source control and site control where it provides the required site storage:

Strutts Centre, Belper.
A retrofit downpipe shoe and brick channel into a raingarden.

Source Controls providing storage

Providing storage throughout the site (distributed storage components), means that every opportunity for storage across the site is exploited, greatly reducing the overall volume and size of site controls.

Source controls remove most silt, heavy metals and heavy oils from runoff, allowing basins, wetland and ponds to be designed as site assets.

- green/ blue roofs
- raingardens
- bioretention
- permeable pavements

Source Controls providing collection & conveyance

Water must either be kept at or near the surface to allow runoff to flow into SuDS structures, or it must be collected through permeable surfaces.

The simplest method of collection of runoff from an impermeable surface is to intercept it as sheet flow from a hard surface. Where runoff flows directly from hard surfaces to filter strips or swales then runoff must leave the hard surface effectively without the risk of ponding.

- swales
- filter drains

Collection and connection

Where runoff is collected from roofs, conveyance to the SuDS component may be required. Historic urban design shows us a number of surface collection methods including spouts, surface channels and rills.

How runoff is collected and conveyed under crossing points such as footpaths and roads is a primary consideration of any SuDS design. Design details such as road gullies can artificially increase the depth and cost of SuDS.

- channels & rills
- filter strips
- pipe connections

Site Controls

Where runoff is collected at the surface, a depression in the ground, mimicing hollows in the natural landscape, is the easiest and most cost effective way to manage large volumes of water in the landscape.

Where landscape is limited, storage opportunities within pavements and on roofs should be explored.

Careful design can maximize opportunities with different design volumes in different places providing maximum opportunities for multi-functional use and biodiversity.

- basins
- wetlands
- ponds
- storage structures

Detailed Design

Pershore High School, Worcestershire.
Low risk access road with 1.2m wide filter strip source control and conveyance swale.

Pershore High School, Worcestershire.
Swale conveyance into pond site control for final treatment and storage.

Peterborough City Council SuDS D & E Guide
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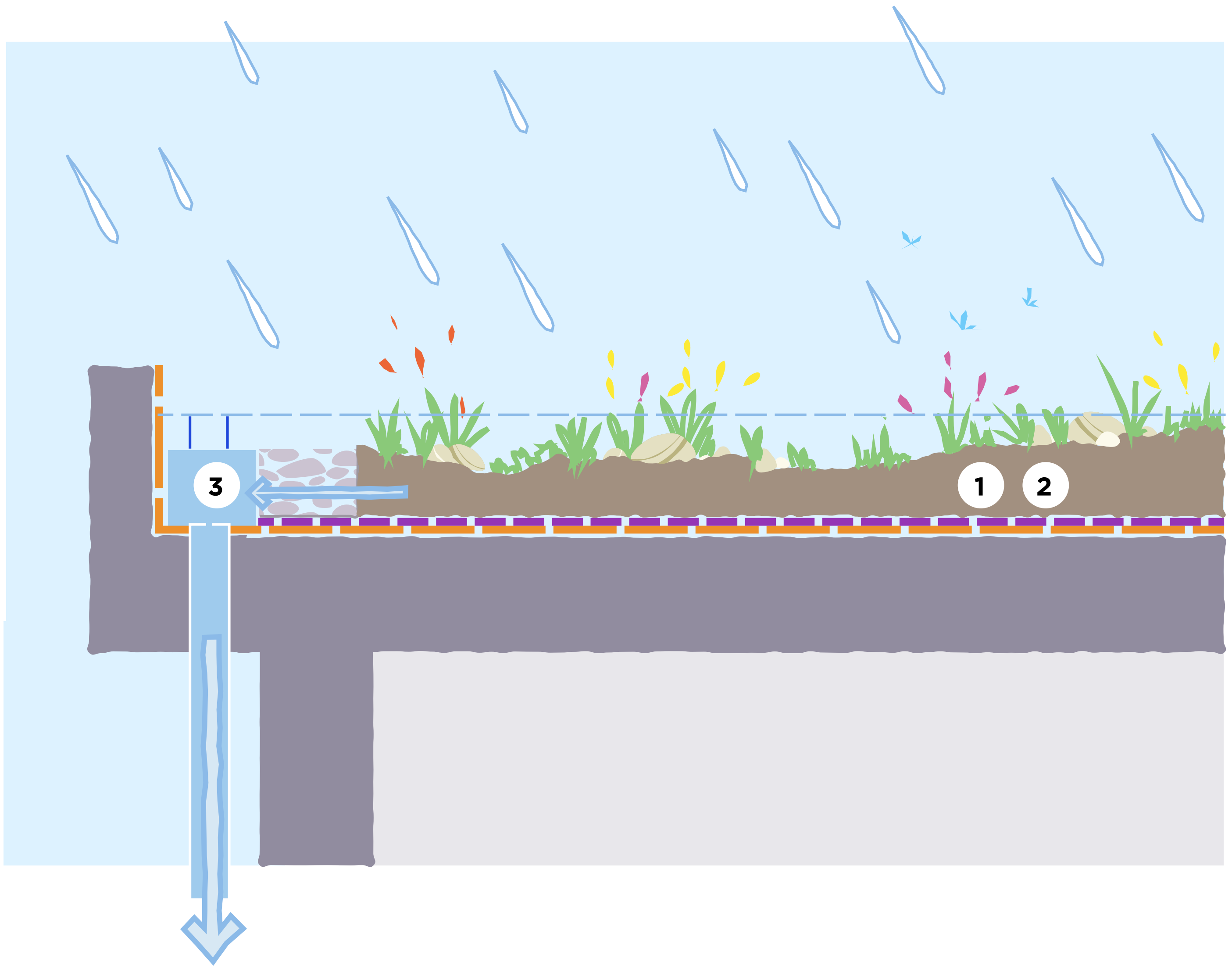
Green & blue roofs

Recent examples in the UK have focused on a shallow depth of growing medium with a Sedum (fleshy leaved, drought tolerant plant) based vegetation. This approach is driven by cost and the idea of minimum maintenance. There are now many examples of failure of planting on this type of green roof due to lack of drought resillience.

1. A minimum 100mm soil depth is recommended for drought resilience and this design is particularly suitable for a natural dry grassland vegetation.
2. Most green and blue roof substrates have a water storage capacity of between 30-40% void ratio.
3. A simple orifice control together with overflow arrangements provides an ideal opportunity to retain water on the roof meaning that it does not have to be stored again at or below ground level.This arrangement is particularly important for urban redevelopment where the building footprint may take up all of the site. This would be referred to as a blue roof.



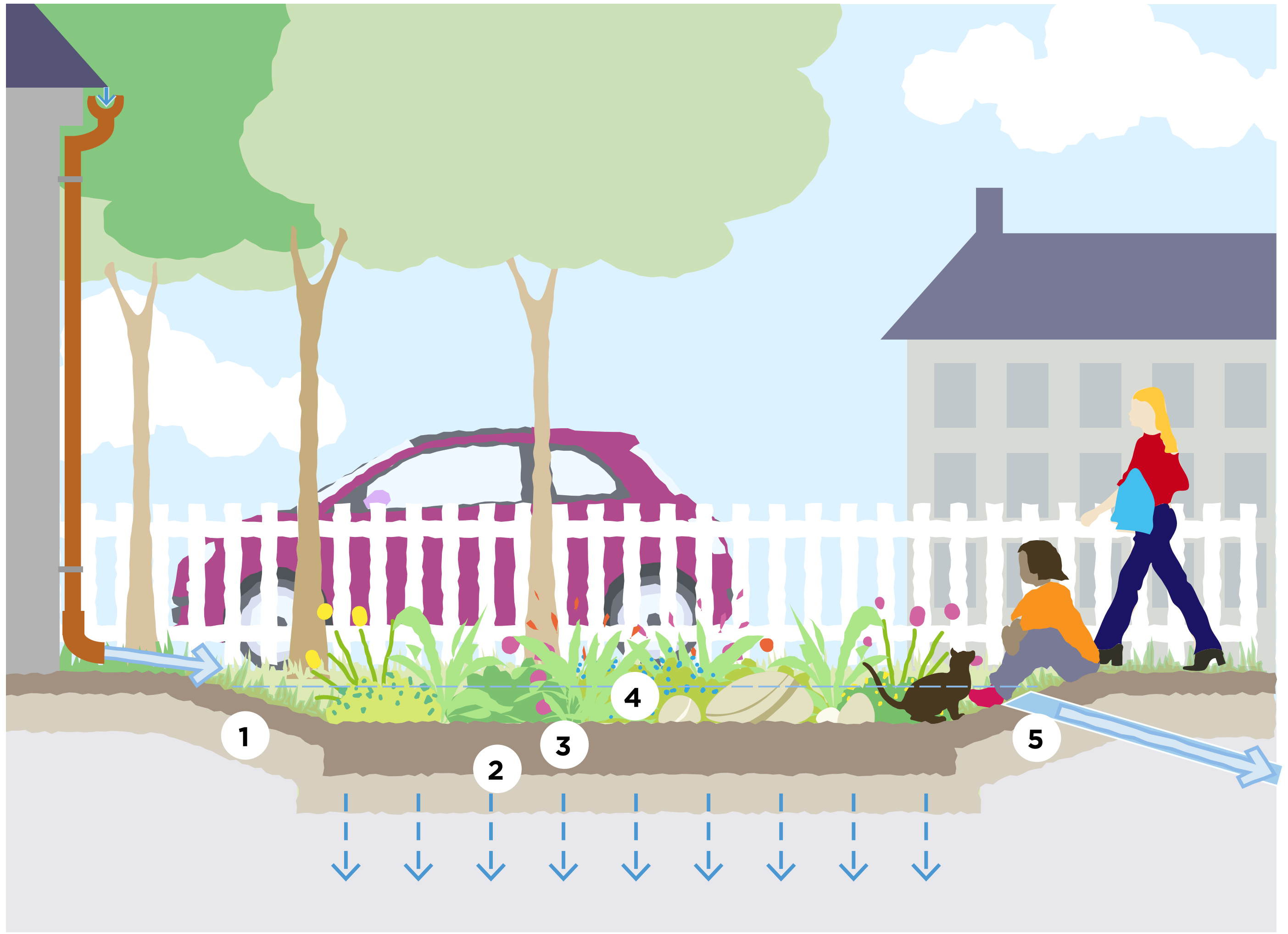
Raingardens

The raingarden concept was pioneered in Prince George's County, Maryland, USA in 1990 when small stormwater basins were proposed for individual houses to replace larger regional stormwater ponds.

Raingardens are designed to collect and manage reasonably clean water from roofs and low risk drives and pathways, has been used where community or private care is available to maintain these potentially attractive site features.

Key aspects of raingarden design include:

1. gentle side slopes with water collected at the surface
2. a free-draining soil, sometimes with an underdrain to avoid permanent wetness
3. a minimum of 450mm improved topsoil with up to 20% course compost
4. garden plants that can tolerate occasional submersion and wet soil – this includes most garden plants other than those particularly adapted to dry conditions
5. an overflow in case of heavy rain or impeded drainage.



Bioretention Raingardens

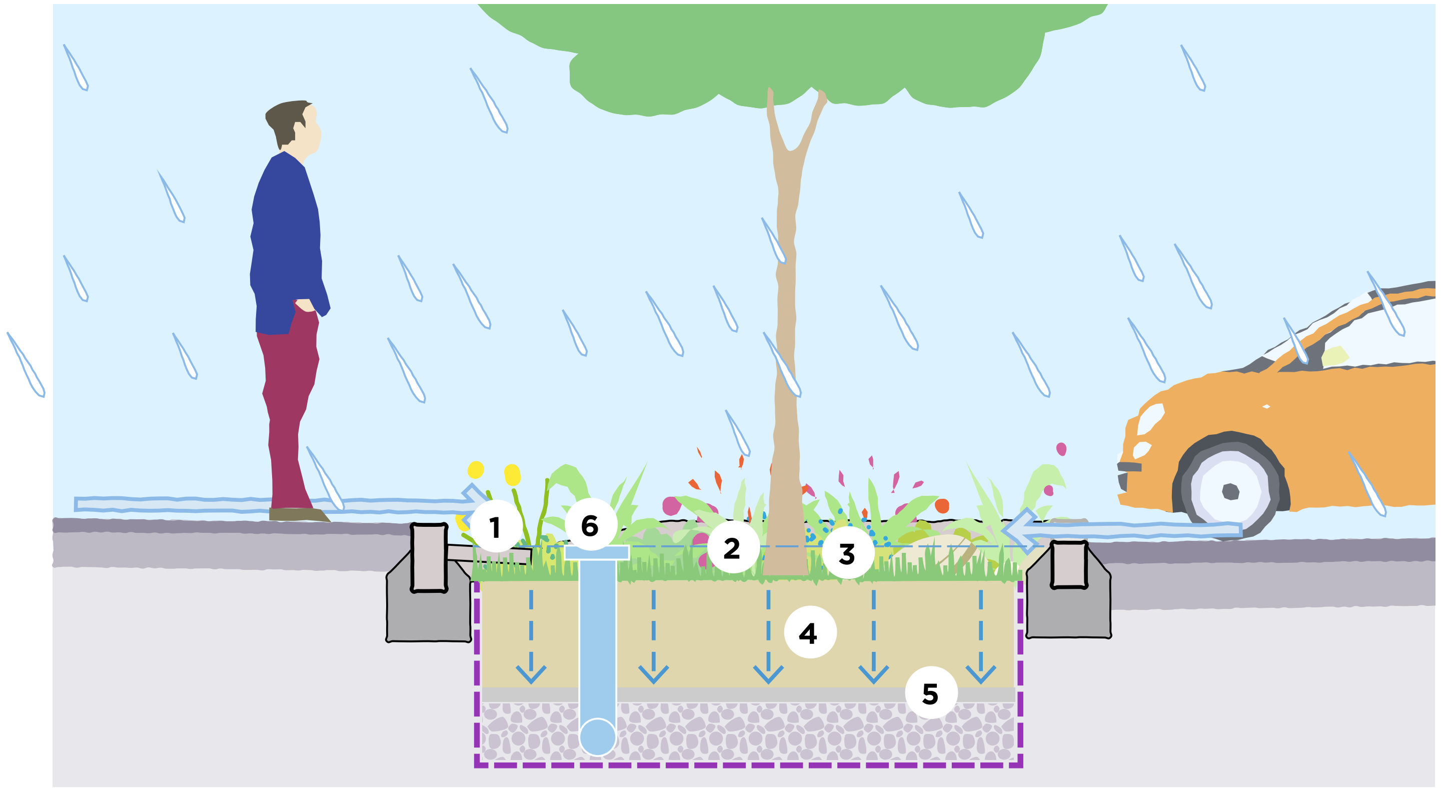
A bioretention structure differs from a raingarden in that it employs an engineered top soil and is used to manage polluted urban runoff in street locations and carparks. These features can contribute significantly to the urban scene so should be designed to meet urban design standards.

The runoff entering bioretention features will normally carry silt and pollution from vehicles and urban street use. Therefore, some maintenance should be expected to remove the build-up of inorganic silt.

The free-draining nature of engineered soils leads to the washing away of nutrients from the soil. The proportion of organic matter should be relatively high and replenished yearly by the application of a mulch layer of well composted greenwaste or shredded plant matter arising from maintenance.

Key design aspects for bioretention raingardens include;

1. silt collection in forebays
2. space above the soil profile for water collection and stilling before infiltration through the engineered soil
3. a surface mulch of organic matter, grit or gravel protects the infiltration capacity of the soil
4. a free draining soil, 450 -600mm deep, with 20-30% organic matter cleans, stores and conveys runoff to a drainage layer
5. a transition layer of grit and/or sand protects the under-drained drainage layer that discharges to an outfall
6. a surface overflow for heavy rain or in the event of blockage.



Permeable surfaces

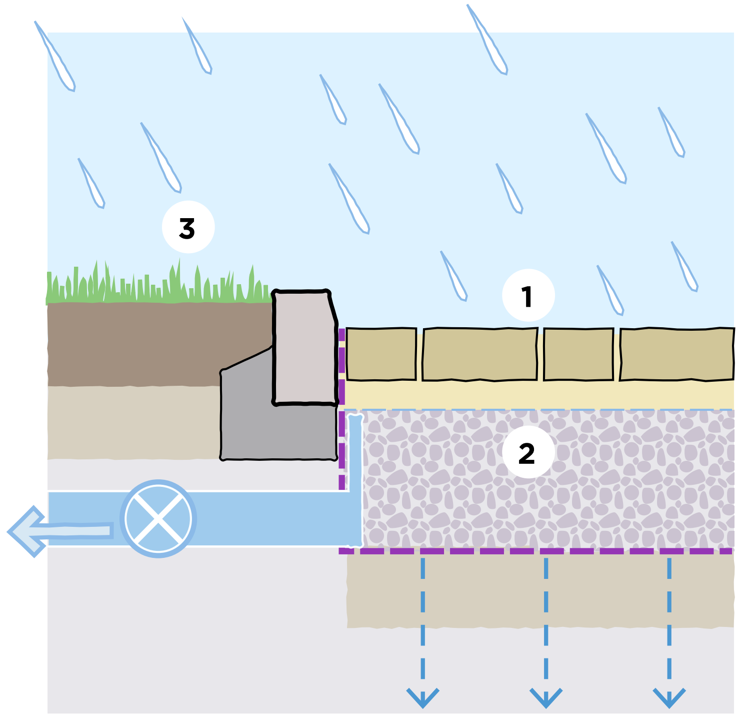
Permeable surfaces enable SuDS designers to direct rainfall straight into a SuDS structure for cleaning and storage or infiltration into the ground.

There are a number of permeable surfaces available. All should have in common:

1. a pervious surface to allow water through the pavement surface
2. an open-graded sub-base layer that provides structural strength to the pavement with about 30% by volume available for water storage.
3. Silt washed off adjacent landscape areas can lead to localised surface clogging. This risk can be managed through design detailing as follows:
    - slope adjacent landscape areas away
    - use paved or turfed surfaces to adjacent areas
    - soil in adjacent planting beds should be min. 50mm below the pavement edge
    - adjacent planting should include dense ground cover to bind the soil in place
    - slopes running toward permeable surfaces should have a depression and ideally an underdrain before reaching the pervious surface.

The design and construction of pervious pavements are covered by guidance in the SuDS Manual (Section 20) and the Interpave website www.paving.org.uk

There are no reported issues with surface clogging under normal use. A dedicated maintenance may be required after between 10 and 20 years of use comprising a brush and suction removal of grit joints and joint replacement.

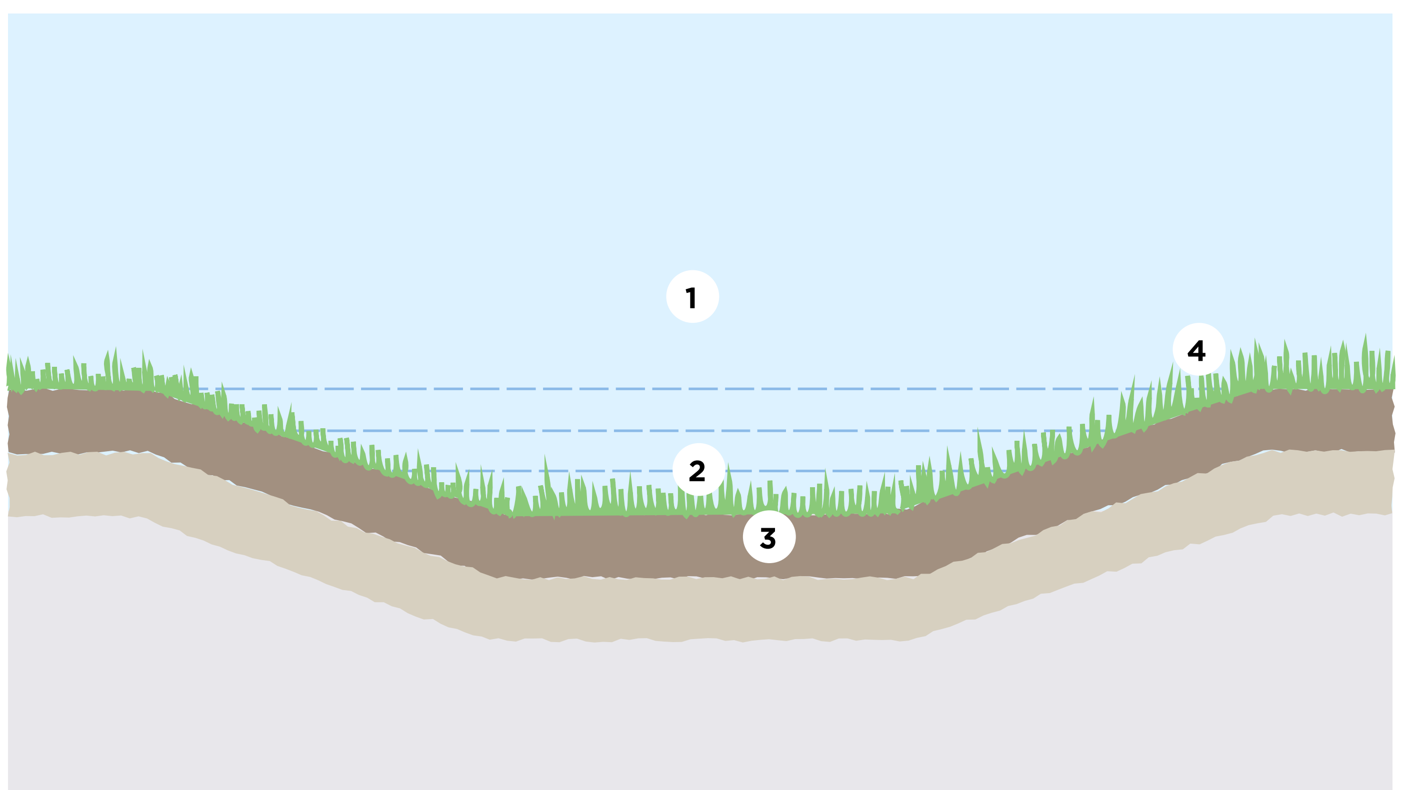


Soft landscape areas are set below kerb level at this permeable paving installation. Almac Car Park, Limerick, Ireland.

Swale

Swales are shallow, flat bottomed vegetated channels which can collect, treat, convey and store runoff.

1. The basic profile is a 1 in 3 or 1 in 4 side slope to a flat base falling at no more than 1 in 50 to prevent erosion.
2. Base width less than 1m wide will increase the risk of erosion and ditch forming, conversely, base width wider than 3m a meandering channel can develop.
3. 150mm clean topsoil over subsoil. Ripping or light harrowing will improve establishment of the swale by providing a key for the topsoil, encourage deep rooting and assist infiltration.
4. Where swale vegetation is kept less than 100mm, the shoulders at the top of the swale can be 'scalped' leaving bare soil. The shoulders should therefore be rounded to prevent this happening.
5. Where inlet flows are concentrated to points through an upstand kerb an erosion apron may be needed.

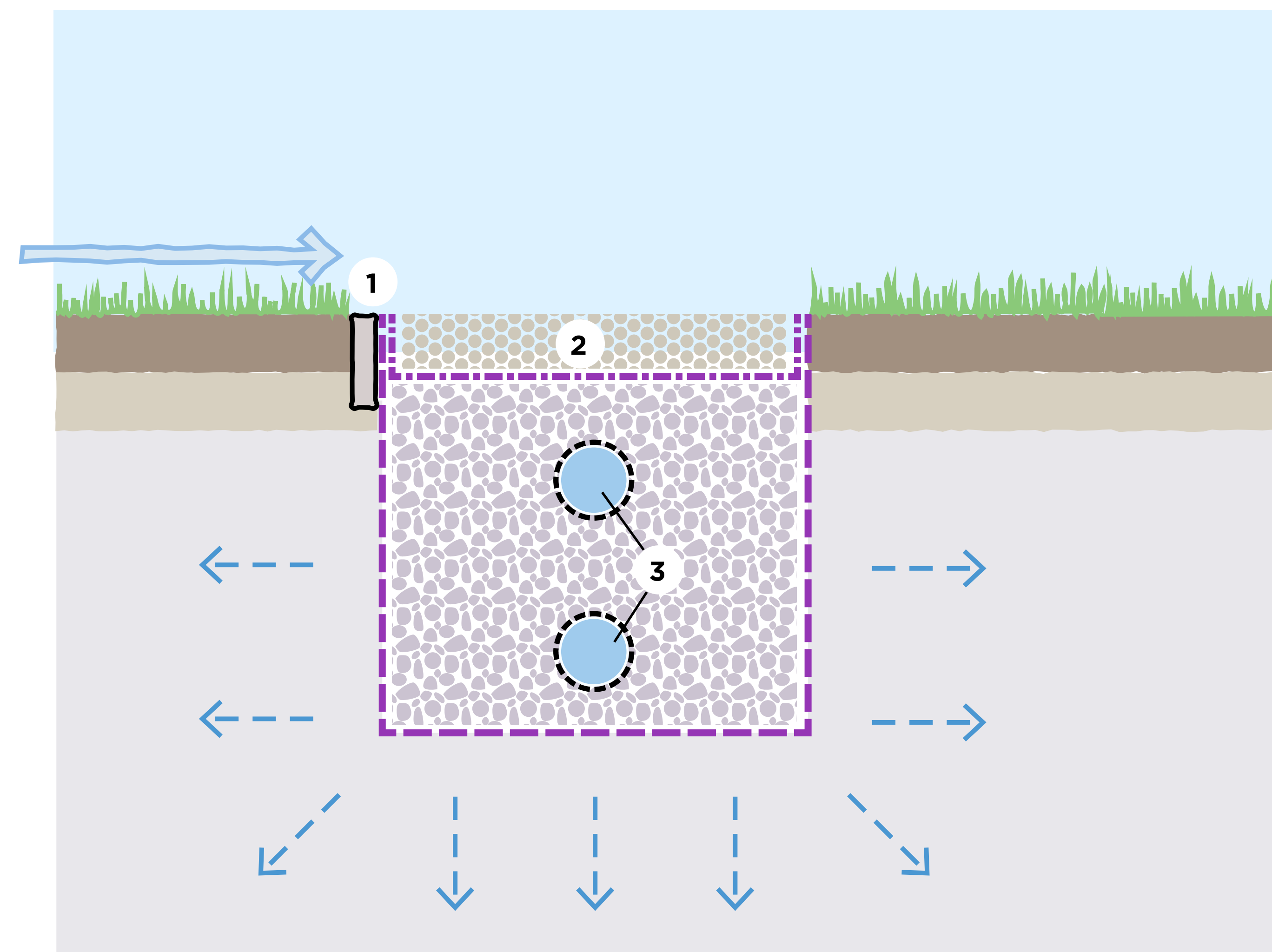


Filter drains

Filter drains, sometimes called a French drain after Henry Flagg French (1813-1885), is an open stone filled trench.

1. Runoff should ideally cross the long edge of the trench as a sheet. This may require a temporary level timber board along the leading edge to prevent erosion of unconsolidated soil.
2. A sacrificial top layer may be considered at the top of the drain to trap any silt for simple removal. Alternatively, a grass filter strip placed in front of the filter drain will reduce potential for clogging.
3. A lower perforated pipe will assist discharge and an upper perforated pipe can act as an overflow. However, neither may be necessary depending on the design and location.

Most filter drains are designed with geotextile lining. Many geotextiles are susceptible to blinding from fine materials in soils. An alterative liner is the use of hessian which will biodegrade over time by the time soils around the filter drain will have stabilised.



Channels and rills

Sett Channels and rills keep rainwater at or near the surface. This is important as it allows water to flow directly into SuDS features reducing cost, trip hazards and the inconvenience of deep structures in the landscape.

In some places a grated surface channel may be more appropriate but the mesh size should not be too small or the grating will be prone to blockage.

Collecting runoff from a road can be more difficult where there is a path present and a flush kerb inlet or chute gully may be needed.

Use of pipes

Although SuDS are delivered without the requirement for extensive piped networks, short lengths of pipe can still be very useful in providing connections under roads, footpaths and other crossing points. Key points to consider are as follows:

- Short lengths of pipework should allow direct rodding from one end of the pipe to the other without the need for internal chambers.
- Inlets and outlets should be designed so that they are not prone to blockage.
- An exceedance flow path should be integrated into the development surface above pipework to ensure that unpredictable flows are directed SuDS immediately after the crossing.
- The depth of the downstream component should not be artificially increased due to a requirement for structural cover over pipework. Different pipe materials or concrete surround can be considered to minimise cover - as used for driveway crossings at the Devonshire Hill project above.

A planted rill at Bewdley School Science Block.

A granite sett channel collecting and conveying runoff at Holland Park, London.

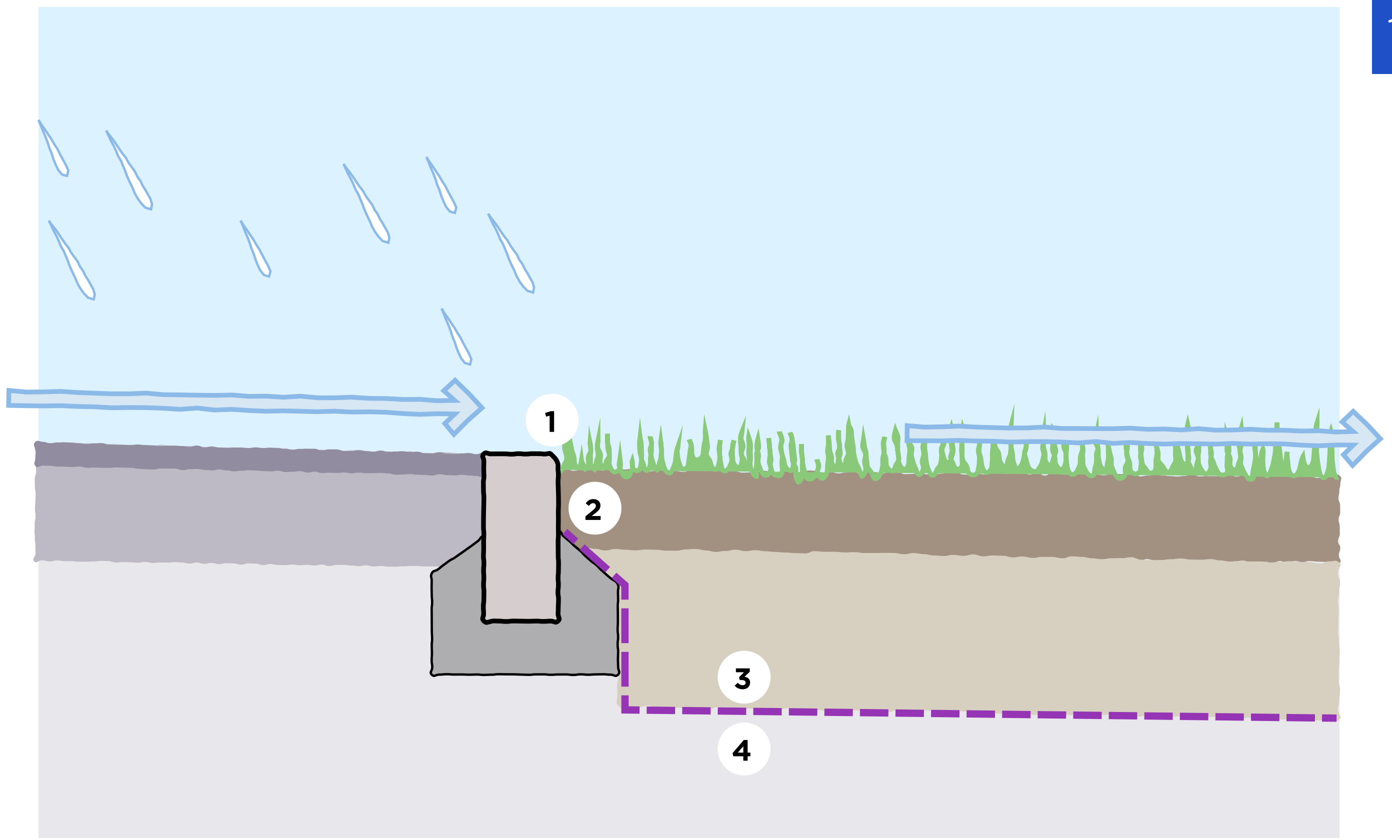
Concrete pipe surround has been used here to provide minimal cover for a driveway crossing at Devonshire Hill, Haringey.

Detailed Design

Filter strips

The hard edge from a pavement to a filter strip is generally defined by a kerb. Filter strips are effective at removing silt at source and will connect to SuDS feature such as a swale after a short distance.

1. Provision of a small drop across the edge of the kerb allows runoff to move freely off the pavement.
2. The concrete haunch should be finished at minimum of 100mm below the surface to ensure good grass growth up to the edge of the pavement.
3. Free draining soils - a protective liner should be situated at least 300mm below clean sub-soil for an agreed distance offset from the pavement to prevent pollution migrating through subsoils to groundwater.
4. Clay soils - runoff will flow across the surface with limited potential for infiltration negating the requirement for a liner.



Basins, wetlands and ponds

1. Reasonably clean water, through use of source control, should flow into site control components at or near the surface in a channel or swale.
2. Where a pipe entry is unavoidable it should flow through a safe and visually neutral headwall, such as a mitred concrete headwall or stainless steel gabion basket inlet.

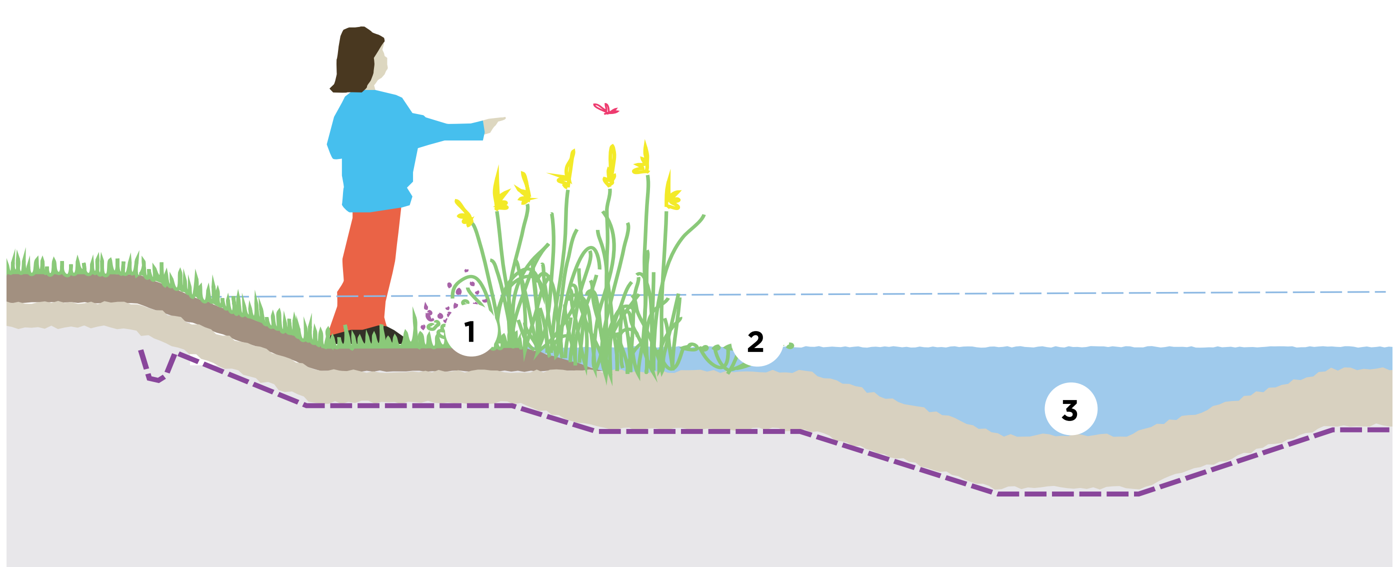
Avoid using riprap as a form of erosion control, as loose stones easily move around and cause a nuisance for maintenance teams.

This basin at Springhill Cohousing in Stroud can be used throughout the year.

Facing: An example of 'safety be design': these children are doing a dance and movement class in a SuDS storage area at Red Hill School.

The safety considerations in basin, wetland and pond design should be considered carefully.

1. The profile of the structure should allow easy and safe access for people and maintenance machinery. Slopes should not exceed 1 in 3 or 1 in 4 and in larger basins access ramps with a more gentle slope should be considered. The idea of a series of slopes and level benches is now accepted as an appropriate detailing for SuDS basins and ponds.
2. The overall depth of temporary storage should not normally exceed 600mm as this depth is critical for a feeling of safety in water. The bottom of the temporary storage dry basin should slope gently so that most of the time the base is firm and dry. Shallow micropools and wetland habitat should be integrated carefully into the basin as they will not be visible when the basin is full of water.
3. Permanent pond depth need not exceed 600mm as this is a common depth of natural ponds and where most biological activity occurs. However, a depth 600mm without regular maintenance means that vegetation will cover the pond in time. Most wetland edge plants cannot colonise beyond 1.2m depth of permanent water. Therefore, an deeper area in the centre of the pond, with surrounding shallower benches can be considered if open water is desired. Effective storage of 600mm over permanent water depth of 1.2m provides a total potential stored depth of 1.8m and the design must take this into account.



4. All hard engineered structures should be set back 1m from permanent water edge, which will prevent drowning in the event of concussion.
5. Protective fencing will not keep children out of ponds and merely acknowledges a dangerous condition. Well designed ponds should be easy to exit and accessible for rescue if this is required.
6. Pond depths and profiles should not be designed for ease of open water swimming. This can be achieved by varying the profile of the pond throughout.
7. Where unsupervised toddlers may be expected a 600-700mm picket fence should be considered as this stops most toddlers and allows adults to easily step over the fence for rescue.
8. There must be an acceptance by the community that open water is part of a landscape character. It is useful to sensitively communicate health and safety messages identifying the presence of permanent and temporary water using well designed informative signage.
9. The use of 'danger – deep water' signs and lifebuoys should be avoided, as they imply that risks have not been sufficiently catered for by design.

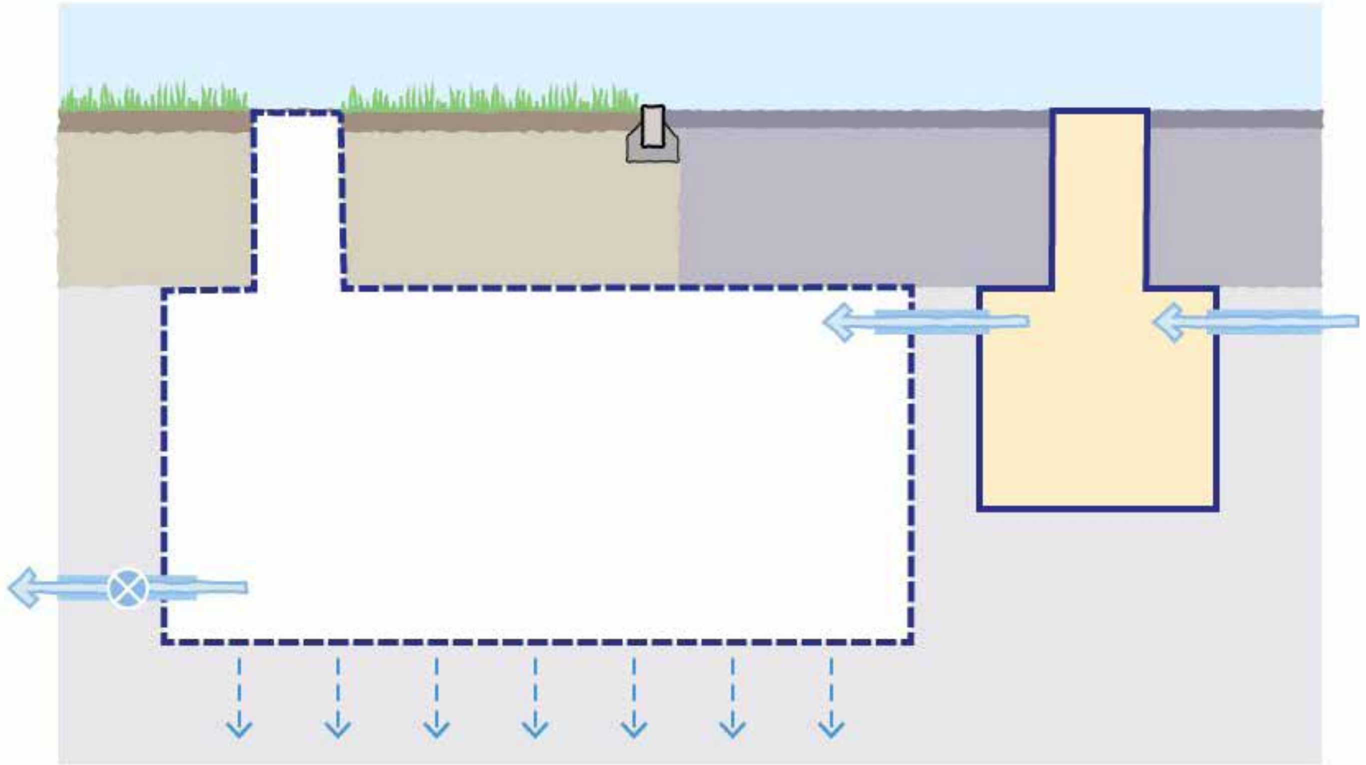
This project failed to adequately consider health and safety when designing attenuation features into a residential pocket park. There is now no public access allowed. There should be no need for such measures if properly designed.

9.11.5 Storage structures

Attenuation storage in underground structures is currently utilised throughout construction industry with may applications being in the form of geocellular tanks. Simply providing underground tanks should not be confused with a full SuDS approach; however, they can form part of the SuDS management train.

The introduction of geocellular structures is still relatively recent in the construction industry and the long term implications of their use is still being understood. The SuDS manual (Section 21.1) clarifies that:

- *Where storage is in an underground tank, failures and blockages tend not to get noticed, which may mean that the consequences of failure can be catastrophic.*
- *Underground storage tanks do not have inherent treatment capacity and therefore require integration with a SuDS management train.*
- *Geocellular systems and plastic arches tend not to be easily accessible for inspection or cleaning, so very effective upstream treatment is required to ensure adequate sediment removal.*
- *The structural design of geocellular systems tends to be more complex and there have been a number of collapses of these systems caused by inadequate design. (see Mallett et al, 2014, and O'Brien et al, in press) (see C737)*



In addition, to the statements from the SuDS Manual the following should also be considered:

- There are risks of structural failure due to construction loading, which may exceed design life loading that the designer may not be aware of.
- There are a wide range of attenuation products each with its own loading characteristics. Surety must be provided that a specified product is not swapped for one of inferior quality during the construction phase.
- Guarantees and warranties are dependent on the survival of product manufacturers.

Where underground storage is preferred after a full exploration of the available options the designer should demonstrate that:

- Robust silt removal has been provided through means of filtration (bioretention, permeable pavement) or other source control SuDS components. Catchpits will not be accepted as a demonstrable form of silt removal. The SuDS manual (Section 4.1) clarifies that sediments within catchpits can be remobilised and washed downsteam. Equally, gullypots are suggested by Table 26.15 to provide negligible to zero treatment (Ellis et al, 2012).
- Underground structures require structural design consideration even if they are not receiving vehicular loading. CIRIA report C737 outlines the design requirements for geocellular tanks. The SuDS Manual (Table 21.1) provides a summary of the structural design requirements using a risk classification system (Scored between 0-3). Designers should demonstrate that the classification system has been followed and present the appropriate level of design information accordingly.

Design Note:

Where the stated design life of the tank does not meet the design life of the development, the design should demonstrate how the structure will be replaced whist maintaining the functionality of the drainage system and the scheme. Consideration should also be given to funding mechanism for undertaking these replacement works.

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9.12 Management of the SuDS landscape

9.12.1 The principles of SuDS management

All designed landscapes require some level of management. Where maintenance is not carried out development will evolve towards woodland or an urban wasteland.

This document introduces a **'passive maintenance'** approach for SuDS. This does not imply no maintenance but rather that much of the care for SuDS is site management rather than dedicated SuDS maintenance.

Hydrocarbons and other organic based pollution such as which wash off hard surfaces is broken down by natural processes (**passive treatment**), within many SuDS components meaning that there is no long term build up of organic pollution. Heavy metals and inorganic pollutants are trapped within Source controls at low concentrations and therefore form no threat to amenity features or aquatic environments.

This is different to 'intervention' maintenance which is required for conventional drainage to remove toxic liquor from gully sumps or oil and grit from interceptors and separators which can be costly and in many cases not completed, rendering the treatment function redundant. Intervention maintenance can also be required for SuDS to remove silt, however through the use of source controls this requirement will be minimised.

Importantly, where SuDS form part of a landscape (which would be present regardless of SuDS), this minimal attention should be considered as site care and not dedicated SuDS care. The cleaning of gullies and pipe work is not needed which reduces overall management costs.

Passive maintenance is therefore linked to integrated SuDS design.

Hopwood Park MSA M42.
A light tracked excavator removes aquatic vegetation to de-water next to the wetland, before moving to a wildlife pile.

9.12.2 The SuDS Management Plan

A SuDS Management Plan is a document that describes the development, the place of SuDS in managing rainfall and can include landscape maintenance. It will describe the aspirations for the development and expected changes over time including any future expansion or redevelopment.

The plan will provide a brief explanation of SuDS, how the SuDS infrastructure on the site operates and the benefits of retaining functionality of SuDS.

SuDS management will be explained including anticipated changes over time.

The management plan will include a Schedule of Work covering the following:

- maintenance tasks identifying frequency of undertaking
- waste management requirements (including EA exemption)
- a pricing schedule for the maintenance contractor where appropriate with any specification notes required to explain technical details.

Site management usually requires an element of regular site attendance, often monthly, which corresponds with most SuDS maintenance. Occasional and potential remedial maintenance should also be covered by the plan.

- Regular maintenance – SuDS visits should be at a monthly frequency to match everyday site management visits.
- Occasional maintenance – covers tasks where the frequency cannot be predicted accurately or is infrequent.
- Remedial maintenance – covers work that cannot be anticipated or is a result of design failure. Damage may include, for instance, rutting where unexpected vehicle access has occurred on wet ground. Replacement of items which have a defined lifespan, such as geocellular tanks should be covered here or provisions made elsewhere.

Design Note:

Information in the management plan should be conveyed in a manner that is understandable to Site Operatives. Use of technical terms and unnecessary information should be avoided.

The Maintenance Schedule and key plan identifying locations of key features should not exceed a double sided A4 which can be laminated and retained in the operatives work van.

9.12.3 Example of SuDS and Site Maintenance

Type	Activity	Normal site care (Site) or SuDS-specific maintenance (SuDS)	Suggested frequency
Regular Maintenance			
LItter	Pick up all litter in SUDS Landscape areas along with remainder of the site – remove from site	Site	1 visit monthly
Grass	Mow all grass verges, paths and amenity grass at 35-50mm with 75mm max. Leaving cuttings in situ	Site	As required or 1 visit monthly
Grass	Mow all dry swales, dry SUDS basins and margins to low flow channels and other SUDS features at 100mm with 150mm max. Cut wet swales or basins annually as wildflower areas – 1st and last cuts to be collected	Site	4-8 visits per year or as required
Grass	Wildflower areas strimmed to 100mm in Sept or at end of school holidays – all cuttings removed Or Wildflower areas strimmed to 100mm on 3 year rotation – 30% each year – all cuttings removed	Site	1 visit annually 1 visit annually
inlets & outlets	Inspect monthly, remove silt from slab aprons and debris. Strim 1m round for access	SuDS	1 visit monthly
Permeable paving	Sweep all paving regularly to keep surface tidy	Site	1 visit annually or as required
Occasional Tasks			
Permeable paving	Sweep and suction brush permeable paving when ponding occurs	SuDS	As required - estimate 10-15 year intervals
Flow controls	Annual inspection of control chambers - remove silt and check free flow	SuDS	1 visit annually
Wetland & pond	Wetland vegetation to be cut at 100mm on 3 – 5 year rotation or 30% each year. All cuttings to be removed to wildlife piles or from site.	Site	As required
Silt	Inspect swales, ponds, wetlands annually for silt accumulation	Site & SuDS	1 visit annually
Silt	Excavate silt, stack and dry within 10m of the SUDS feature, but outside the design profile where water flows. Spread, rake and overseed.	Site & SuDS	As required
Native planting	Remove lower branches where necessary to ensure good ground cover to protect soil profile from erosion.	SuDS	1 visit annually
Remedial Work			
General SuDS	Inspect SuDS system to check for damage or failure when carrying out other tasks. Undertake remedial work as required.	SuDS	Monthly As required

9.12.4 Silt and waste management

Silt and sediment removal is often considered a major element of SuDS management. In most cases where SuDS features are located at the surface silt accumulates slowly and can be removed easily. Management of silt becomes more difficult and costly at the end of the management train, particularly in ponds and wetlands.

Where silt has accumulated in SuDS components downstream or the design has specifically included a silt collection feature, for instance in SuDS retrofit schemes, it is important to monitor silt accumulation visually and by simple monitoring.

Silt removed from most low to medium risk sites can be de-watered and land applied within the site but outside the SuDS component profile. The EA will not pursue an application for an environmental permit where the requirements of Regulatory Position Statement 055 are met.

Silt management and removal from site should follow the protocols set out in the SuDS Manual Chapter 32 p699

SuDS vegetation green waste can be managed in the same way as site green waste, either on site in wildlife piles, compost arrangements or taken off site.

The use of composted green waste or chipped woody material should be considered for raingardens, bioretention or any other planted feature on site.

Any waste considered to be contaminated should be evaluated as set out in the SUDS Manual Chapter 33 – Waste management p709

EA Regulator Position Statement 055
www.gov.uk/government/uploads/system/uploads/attachment_data/file/525315/LIT_9936.pdf

Sheffield Grey to Green : an excellent council-led SuDS project with SuDS advice from McCloy Consulting and Robert Bray Associates.

Acronyms used in this guide :

AEP	Annual Event Probability
AONB	Area of Outstanding Natural Beauty
BGS	British Geological Survey
BRE	Building Research Establishment
CCA	Climate Change Allowance
CDM	Construction (Design & Management) Regulations
CIRIA	Construction Industry Research and Information Association
Cv	Coefficient of volumetric runoff
DEFRA	Department for Environment Food & Rural Affairs
EA	Environment Agency
FEH	Flood Estimation Handbook
GWSPZ	Groundwater Source Protection Zone
IoH	Institute of Hydrology
LASOO	Local Authority SuDS Officer Organisation
LLFA	Lead Local Flood Authority
LPA	Local Planning Authority
NPPF	National Planning Policy Framework
NSTS	Non-Statutory Technical Standards
PPG	Planning Practice Guidance
RefH2	The Revitalised Flood Hydrograph Model
SAC	Special Area of Conservation
SFRA	Strategic Flood Risk Assessment
SSSI	Site of Special Scientific Interest
SuDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan
WaSC	Water and Sewerage Company
WFD	Water Framework Directive

McCloy Consulting

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Sustainable Drainage Consultants
Landscape Architects