HR Wallingford
Working with water

SR 666

Use of SUDS in High Density Developments

Guidance Manual

Report SR 666
Release 4.0
October 2005

RBB Kellagher
CS Laughlan

Document Information

Project	Use of SUDS in High Density Developments
Report title	Guidance Manual
Client	DTI
Client Representative	Russ Wolstenholme, WS Atkins
Project No.	MAS0437
Report No.	SR 666 Environment Agency R&D Technical Report P2-261/18
Doc. ref.	SR666-SUDS Guidance Manual rel 4-0 csl rk4.doc
Project Manager	CS Lauchlan
Project Director	RBB Kellagher

Document History

Date	Release	Prepared	Approved	Authorised	Notes
25/01/05	1.0	rbbk			Draft for consultation
14/03/05	2.0	rbbk			Final draft
02/06/05	3.0	rbbk			Final
02/06/05	4.0	rbbk			Revision of Appendix 3

Prepared R Kellagher

Approved R Kellagher

Authorised

Summary

Use of SUDS in High Density Developments

Guidance Manual

Report SR 666
October 2005

It is accepted that conventional piped drainage systems exacerbate flood risk, detrimentally impact on water resources and associated ecology, and have contributed to the deterioration in the quality of receiving water bodies. The use of sustainable drainage systems (SUDS) to manage surface water runoff from new development is therefore now required in order to meet current planning and regulatory policy.

This guide has been developed to assist developers, their professional advisors and local planning authorities with achieving drainage best practice on all new developments, with specific direction on achieving sustainable drainage solutions for high density sites. The document supports drainage infrastructure planning, conceptual design and construction, and provides guidance on:

- Stormwater management principles;
- Drainage design criteria;
- SUDS component characteristics;
- SUDS component applications;
- SUDS construction issues;
- Safety, amenity and environmental objectives;
- Existing drainage responsibilities and ownership.

Barriers to the implementation of SUDS to date include a lack of clear design and construction guidance, a perceived disparity between planning policy on housing densities and the space required for surface drainage infrastructure on a development site, and the difficulties of securing adoption of SUDS systems to ensure long-term operation and maintenance. This document was conceived to provide specific assistance for developers on these issues with a focus on meeting the drainage needs for high density sites in particular. More detailed information on all aspects of SUDS will become available shortly with the publication of national technical guidance from CIRIA (due mid 2006).

In Scotland, the Water Bill 2005 has introduced SUDS into legislation which allows Scottish Water to take over responsibility for them. In England and Wales, the options for the future management of SUDS are being reviewed by Defra; in the interim it is hoped that this document will provide clarification of a range of issues and thus facilitate discussions between stakeholders.

Acknowledgements

This Guidance Manual has been developed as part of DTI Partners in Innovation Contract CI 39/3/711 C2425. The objective of the project was to produce a guidance manual for use in evaluating and designing SUDS components, particularly for new developments where there are limitations on space availability for SUDS systems. The project work was undertaken by HR Wallingford under project number MAS0437.

The Project Steering Group, which guided the work by HR Wallingford, represented a broad range of stakeholders. The names of the steering group members are listed below.

Andrew Shuttleworth	SEL Environmental Ltd
Barry Winter	Environment Agency
Brian D'Arcy	SEPA
David Balmforth	MWH Ltd
David Brook	ODPM
John Blanksby	Pennine Water Group
Jon Offer	Westbury Homes
Katherine Robinson	Formpave Ltd
Kevin Ritter	Formpave Ltd
Neil McLean	SEPA
Nick Price	Waterman Group Ltd
Paul Shaffer	CIRIA
Peter Martin	Black & Veatch Consulting
Phil Chatfield	Environment Agency
Richard Ashley	University of Bradford
Richard Burrows	University of Liverpool
Steve Evans	Thames Water Utilities (presenting UKWIR)
Steve Wilson	Environmental Protection Group Ltd

Glossary

Attenuation	Slowing down the rate of flow, with a consequent increase in the duration of the flow.
Attenuation storage	Temporary storage required to reduce the peak discharge of a flood wave
Brownfield	Land which has already been built on in the past. Often associated with land that is contaminated.
Curtilage	Land area within property boundaries
Design storm	A storm with a specified profile, intensity and duration.
Detention basin	A basin, normally dry, constructed to store water temporarily to attenuate flows and provide some treatment.
Detention ponds	Ponds similar to Retention ponds, but with a permanent pool volume which is sized to provide a treatment volume of $1xV_t$.
District distributor roads	These roads distribute traffic between the residential, industrial and principal business districts of a town and form the link between the primary road network and the roads within residential areas.
Duration	The time period over which an event occurs.
Extended detention basins	A detention basin designed to retain runoff for an extended period to provide a greater degree of treatment. The hydraulic control requirements to achieve extended detention may be a limiting issue.
Filter drains/trenches	A linear drain consisting of a trench filled with a permeable material, often with a perforated pipe in the base of the trench to assist drainage.
Filter strip	Gently sloping vegetated areas designed to drain surface runoff as sheet flow from impermeable surfaces and remove sediment.
Greenfield	Land that has never been developed, other than for agricultural or recreational use.
Greenfield runoff	The runoff rate and volume from a site prior to development.
Green roof	A vegetated roof surface that provides some retention of rainwater and promotes evapotranspiration.
Infiltration basin	A basin hat is normally dry that is designed to store and infiltrate surface runoff into the ground.
Infiltration trench	A trench, designed to infiltrate surface water into the ground.
In/off line underground storage	Underground voids, often constructed using concrete, grp, steel tanks or plastic void formers. They provide hydraulic attenuation, but do not treat the runoff.

Glossary continued

In-property storage	Storage of rainfall within the curtilage of the property, e.g. in the gutter, roof space or chamber .
Interception storage	Provision of storage to prevent runoff from rainfall of up to 5mm, in order to replicate site responses for small rainfall events.
Linear ponds	An alternative to swales in serving runoff from roadways and hard standings. They are vegeatated open channels which provides storage, conveyance and some treatment. They are particularly useful in flat terrain.
Local distributor roads	These roads distribute traffic within districts. In residential areas, they form the link between district distributors and residential roads.
Long term storage	Storage of stormwater which is normally drained by infiltration that specifically addresses the additional volume of runoff caused by the development compared to greenfield runoff. The objective is to minimise any increase in flooding in the river downstream.
Mini Swale	Small, grass-lined, channels designed to store and treat runoff from small rainfall events and, when full, discharge excess water into the local drainage network.
Pervious pavement	A permeable hardstanding designed to promote infiltration of surface runoff into a permeable sub-base.
Rainfall ratio "r"	The ratio of depths for a 5 year return period event of 60 minute duration and a 5 year return period event of 2 days duration.
Residential access roads	These roads link dwellings and their associated parking areas and common open spaces to distributor roads.
Retention ponds	A pond where runoff is detained to allow settlement and biological treatment of some pollutants, as well as attenuate flows. Sized to provide a permanent pool volume of $4V_t$, where V_t is the treatment volume.
Return period	This indicates the average period, in years, between events of the same intensity or of a greater intensity than a particular event.
Soakaway	A subsurface structure into which water is conveyed. They are designed to dispose of surface water by infiltration into the ground.
Standard Swale	A grass-lined channel designed to convey surface water, as well as controlling and treating the flow.
Temporary storage	Storage of the excess water for high intensity events, where the drainage system is temporarily overloaded.
Treatment storage	Storage provided to enable poor water quality to be improved by sedimentation and other treatment processes.

Glossary continued

Under-drained Swale	A grass-lined channel designed to store water for rainfall events. The stored water percolates down through the base of the swale into a perforated pipe that then discharges the flow into the local drainage network.
Wetlands	A pond that has a high proportion of emergent vegetation in relation to open water and usually has a requirement for a continuous base flow.

Abbrieviations

API_5	Antecedent Precipitation index (over the previous 5 days)
CEH	Centre for Ecology and Hydrology
CIRIA	Construction Industry Research and Information Service
Defra	Department for Environment, Food and Rural Affairs
DN	nominal size (DN) - a numerical designation of size which is a convenient round number equal to or approximately equal to the (pipe) bore in millimetres
FEH	Flood Estimation Handbook (Centre for Ecology and Hydrology (CEH), 1999)
FSR	Flood Studies Report (Institute of Hydrology, 1975)
FSSR	Flood Studies Supplementary Reports (Institute of Hydrology, 1976-1987)
IF	Effective Impervious Area Factor
M_560	The depth (in mm) for a 5-year return period event of 60 minute duration.
NAPI	New Antecedent Precipitation Index
PF	Porosity fraction (soil storage depth)
PIMP	Percentage Impermeable proportion of a catchment or subcatchment contributing to runoff
PPG25	Planning Policy Guidance 25 ‘Development and Flood Risk’, applicable to England
PPG3	Planning Policy Guidance 3 ‘Housing’, applicable to England
PR	Percentage Runoff
SAAR	Standard Average Annual Rainfall (1941-1970)
SOIL	Soil type classification used by Institute of Hydrology, FSR, 1975 and the HR Wallingford and Institute of Hydrology, Wallingford Procedure, 1981
SPR	Standard Percentage Runoff. Used in FSR and FEH equations as a soil runoff performance measure.
SUDS	Sustainable Drainage Systems
V_t	The treatment volume calculated to retain the runoff from 90% of all events.
WRAP	Winter Rain Acceptance Potential, from the FSR. A classification used to indicate the runoff characteristics of the soil type.

Contents

Contents continued

Tables

Contents continued

Figures

Contents continued

1. Introduction and Scope

This chapter provides the context of this guide and who it is aimed at helping.

1.1 INTRODUCTION

The Water Framework Directive (2000/60/EC) has been produced to address the environmental impact of man's water based activities, not least due to stormwater discharges. Over the last 2 decades, there has been a growing recognition of the negative impact of stormwater on receiving waters and the need to minimise its effect. The use of sustainable drainage systems (SUDS) is now recognised as essential in achieving this aim as they provide a range of methods/techniques for partially treating stormwater runoff. The Environment Agency (EA), Scottish Environmental Protection Agency (SEPA) (through NPPG 7 and PAN 61) and ODPM and Defra (through PPG25 in England) and Welsh Assembly Government (through TAN 15 in Wales) are making concerted efforts to get SUDS implemented in all new developments.

In the UK there is growing government pressure to increase housing densities. Planning Policy Guidance note 3 was issued by DTLR (PPG 3, DTLR 2000) which emphasises the need for the footprint of developments to be minimised. The housing density suggested is up to 50 houses per hectare. This will create urban areas with a high proportion of impervious surface and therefore potentially restrict the opportunity to use certain SUDS components that often require more land than traditional drainage systems.

It can be seen that there is a potential conflict between requirements of PPG3 and PPG25 and guidance is needed for Planners and Developers to maximise the effectiveness of SUDS systems within the constraints of meeting the target of providing high density developments.

1.2 SCOPE

This guide provides a complete technical overview of all issues that should be addressed to achieve an effective drainage system.

To ensure it is a useable document, this guide is concise and sources for more detailed information are referenced.

This document addresses all issues from initial planning, through design, construction and adoption of SUDS.

2. Stormwater Management Principles

This chapter describes the SUDS philosophy and the necessity for using SUDS. A summary is provided of the principal hydrological and water quality impacts due to development. It details the advantages of using SUDS and provides an overview of the mitigation potential of each type of SUDS component.

2.1 DRIVERS FOR SUSTAINABLE DRAINAGE

2.1.1 Traditional drainage

The traditional method of draining stormwater from developments has been to use pipe systems. These are designed to prevent flooding locally by conveying the water away as quickly as possibly. This has the potential for exacerbating the flooding downstream, altering stream morphology and also polluting receiving water bodies with metals, hydro-carbons, BOD, nutrients and sediment.

A more sustainable approach to drainage has been evolving to address these problems. This is referred to as SUDS (Sustainable Drainage Systems) in the UK and BMPs (Best Management Practices) in the USA and other countries.

2.1.2 The hydraulic impacts of development on stormwater

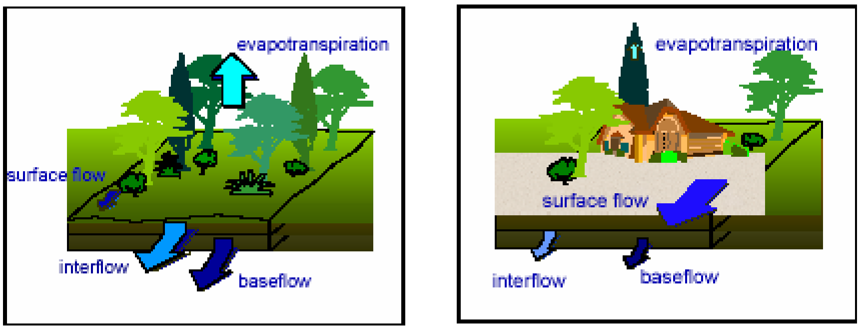
The following section is a brief description of the hydraulic impact of development and a comparison is made with runoff from undeveloped areas.

Development reduces the permeability of the land surface by replacing free draining ground with impermeable roofs, roads and other paved areas. Disposal of stormwater runoff from a development using a piped system results in a significantly different response from rain falling on a greenfield area. Table 2.1 summarises the differences in terms of hydraulic response.

Table 2.1 Stormwater runoff comparison – Development / Greenfield site

Rainfall event	Development response	Greenfield response
Small / frequent rainfall events	• Some runoff • Rapid runoff • River regime modified • Highly polluted • Little infiltration to support river base flows	• No measureable runoff • All rainfall evapo-transpirated in summer • No pollution in runoff • Infiltration for river base flow support in winter
Big / intense rainfall events	• High volume of runoff • Rapid runoff • Flooding exacerbated downstream	• Low to Medium volume of runoff • Slow runoff • Flooding not exacerbated

Figure 2.1 illustrates these changes caused by development.



Courtesy of CIRIA

Figure 2.1 Pre and post development hydrological processes

The alteration of the flow regime in the river (both in terms of the total quantity of runoff and the peak runoff rates) leads to flooding and channel erosion downstream of the development. This also affects the bank-side habitats and the flora and fauna in the stream and results in a reduction of diversity and abundance.

It is anticipated that climate change will exacerbate many of these issues, as summers are predicted to become drier, winters wetter and rainfall generally becoming more intense.

2.1.3 The water quality impacts of development on stormwater

Man creates a large number of pollutants which become entrained in stormwater runoff. These include sediments, oils, grits, metals, fertilisers, pesticides, animal waste, salts, pathogens and litter. These cause environmental damage and can affect public health.

In contrast, natural environments rarely cause any pollution from rainfall runoff (discounting some farming practices). The topsoil and vegetation provide a filtering mechanism for runoff, with most runoff occurring as inter-flow through the soil rather than as direct overland runoff. Table 2.2 summarises the impacts of development on runoff water quality.

Table 2.2 Water quality impacts of development

Water quality pollutants	Environmental Effects
• BOD (decaying vegetation and other organic material).	• Oxygen depletion weakens stream life and affects the release of toxic gases from sediments deposited in the watercourse.
• Nutrient enrichment (e.g. raised nitrogen, phosphorous concentrations)	• Increased nutrient levels promotes weed, algal growth and excessive diurnal oxygen concentrations, eutrophication. Can result in fish kills.
• Pathogen contamination (bacteria, viruses)	• The concentration of bacteria and pathogens found in urban runoff can exceed public health standards for recreational water contact.
• Hydrocarbon contamination (e.g.	• Toxic materials (including hydrocarbons) kill aquatic organisms

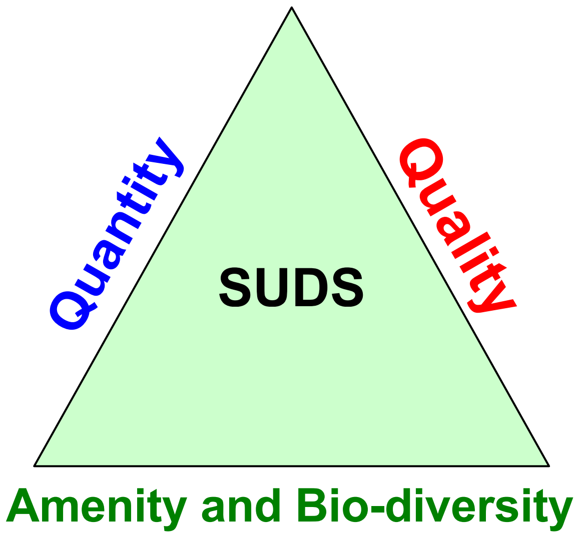
Water quality pollutants	Environmental Effects
TPH, PAH, VOCs, MTBE)	and accumulate in the food chain. Their presence increases drinking water treatment costs.
• Increased levels of toxic materials (e.g. metals, pesticides, cyanides)	• As for Hydrocarbon contamination.
• Sediment (particularly site construction)	• Sedimentation and concretion affecting biota habitat, and stream erosion and deposition.
• Litter	• Aesthetic impact, obstruction of flows and risks to wildlife.
• Raised water temperatures	• Oxygen depletion which weakens stream life and affects the release of toxic gases from sediments deposited in the watercourse

2.2 SUSTAINABLE DRAINAGE SYSTEMS (SUDS)

2.2.1 The SUDS philosophy

Drainage systems need to be developed in line with the ideals of sustainable development to minimise the anthropogenic impact by addressing the various factors that cause environmental stress. Surface water drainage methods that consider quantity, quality and amenity are collectively referred to as Sustainable Drainage Systems (SUDS).

The philosophy of SUDS is to try and replicate the natural drainage of a site prior to development and to treat runoff as effectively as possible to remove pollutants, thus reducing the negative water quality impact on receiving water bodies.



Courtesy of CIRIA

Figure 2.2 The SUDS triangle – reducing the impact of urban drainage on the environment

Appropriately designed, constructed and maintained, SUDS are more sustainable than conventional drainage methods because they can mitigate many of the adverse effects of urban stormwater runoff on the environment. They achieve this through the processes listed in Table 2.3.

Table 2.3 The benefits of SUDS

- Reducing runoff rates
- Reducing runoff volumes
- Reducing the frequency of runoff
- Increasing natural groundwater recharge
- Increasing dry weather flows in watercourses
- Reducing pollutant concentrations
- Contributing to the amenity value of the development
- Contributing to the aesthetic value the development
- Providing ecological habitats
- Reducing water supply demand when stormwater is reused

To qualify as a SUDS component, drainage components should theoretically provide an element of each of the three benefits of hydraulic, water quality and amenity. However this would, by definition, preclude the use of pipes which is normally an integral part of any drainage solution. Rather than constrain the definition of what does or does not comply with being a SUDS solution, it is easier to consider the objective of any drainage scheme as being:

> "To replicate, as closely as possible, the predevelopment runoff characteristics of a site for all rainfall events."

This leads to the consideration of techniques which:

1. Maximise infiltration subject to economic, environmental and physical constraints.
2. Maximise the use of filtration and sedimentation and other treatment techniques to obtain water quality improvements.
3. Provide appropriate levels of attenuation to reduce the rate of runoff.
4. Consider issues of biodiversity, amenity and aesthetics where the opportunity occurs.

2.2.2 SUDS runoff management processes for stormwater

There are several processes that should be used to manage and control the runoff from developed areas. Each SUDS component provides a mix of these features to manage the stormwater runoff.

(a) Conveyance

Conveyance is the transfer of surface runoff from one place to another. Issues to consider are:

- self-cleansing velocities

- erosion
- hydraulic capacity

(b) Attenuation

Attenuation is the reduction in the rate of runoff, which is achieved by the provision of a hydraulic constraint, and the storage needed for temporary detention of runoff. Considerations include:

- head-discharge relationship of the control, including upstream and downstream water level constraints, and
- storage volume needed to meet the hydraulic criteria.

(c) Infiltration

This is the discharge of runoff into the ground. Apart from evaporation and depression storage (losses which are small), and rainwater harvesting use, this is the only means by which runoff volume can be reduced. Issues to consider are:

- capacity of the soil to receive infiltration,
- risk of soil saturation and the possible resulting instability on sloping ground,
- depth to groundwater,
- proximity of groundwater abstractions,
- creating or exacerbating outflows at springs
- risk of pollution mobilisation and transfer,
- risk of blinding due to sediment load,
- risk of settlement (in weakly cemented soils),

(d) Rainwater harvesting

This is the direct capture and use of runoff on site. Rainfall runoff can be stored for domestic use (e.g. flushing toilets), or irrigation of urban landscapes. Issues to consider are:

- size of storage (which is a function of the local hydrology and demand),
- guaranteed level of service to be provided,
- benefits provided in reducing stormwater runoff,
- benefits provided in reducing the demand for treated mains water,
- overflow arrangements (for large storm events),
- possible negative impacts on public health (e.g. mis-connections).

(e) Filtration

This is the reduction of sediment load by means of slow sheet flow through grass or other media. Issues to consider are:

- velocity and depth of sheet flow,
- headloss through filtration media,
- maintenance implications for long term performance of the system.

(f) Sedimentation

This is the settling of suspended solids by providing relatively quiescent conditions. Issues to consider are:

- retention time,
- flow velocity,

- the risk of sediment re-mobilisation,
- maintenance and disposal requirements for long term performance of the system.

(g) Other processes
Other forms of water quality treatment (such as nutrient stripping, photolysis, volatilisation, microbial bio-degradation and adsorption) all take place to some degree depending on the SUDS component used.

The removal mechanisms appropriate for each pollutant category are presented in Table 2.4.

Table 2.4 Removal mechanisms for each pollutant category

Pollutant	Removal Mechanisms in SUDS
Nutrients Phosphorous, Nitrogen	Sedimentation, biodegradation, precipitation, denitrification
Sediments Total suspended solids	Sedimentation, filtration
Hydrocarbons TPH, PAH, VOC, MTBE	Attack by soil microflora, sunlight, filtration and adsorption
Metals Lead, Copper, Cadmium, Mercury, Zinc, Chromium, Aluminium	Sedimentation, adsorption, filtration
Pesticides	Biodegradation, adsorption, volatilisation
Chlorides	None
Cyanides	Evaporation, sunlight
Litter	Trapping, removal during routine maintenance
Organic matter, BOD	Filtration, sedimentation, biodegradation

2.2.3 SUDS techniques

There are a wide range of individual techniques that can be used to form part of a SUDS system. These can be broadly categorised on whether their primary use is considered to be pre-treatment, conveyance, source, site or regional controls, and can be ranked in a simple manner, based on their hydraulic and water quality performance potential.

Table 2.5 categorises the main SUDS components in use in the UK. The list is not comprehensive – there are other components (e.g. sand filters) and a range of proprietary drainage components, which can contribute to developing an effective drainage system. Details of each SUDS component are provided in Chapter 4.

Table 2.5 SUDS techniques - their hydraulic, water quality and amenity capabilities

Key to symbols:

⊗ Primary process

⊗ Secondary process

SUDS Technique	SUDS Description	Hydraulic Performance: Conveyance	Hydraulic Performance: Attenuation	Hydraulic Performance: Infiltration	Hydraulic Performance: Water Harvesting	Water Quality Treatment: Sedimentation	Water Quality Treatment: Filtration	Water Quality Treatment: Adsorption	Water Quality Treatment: Biodegradation	Water Quality Treatment: Volatilisation	Water Quality Treatment: Precipitation	Water Quality Treatment: Uptake by plants	Water Quality Treatment: Nitrification	Amenity Benefits: Aesthetics	Amenity Benefits: Amenity	Amenity Benefits: Ecology
Rainwater harvesting (Water butts etc)	Storage for irrigation or domestic use (toilets etc).		⊗ (S)		⊗ (P)										⊗ (S)	
Pervious pavements	Car parks (and potentially minor roads) and other paved surfaces which provide storage of rainwater in the underlying construction.		⊗ (P)	⊗ (P)	⊗ (S)		⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)				⊗ (S)	⊗ (S)	
Filter trenches	Linear drains/trenches filled with a granular material, often with a perforated pipe in the base of the trench.	⊗ (P)	⊗ (P)	⊗ (S)			⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)						
Filter strips	Vegetated strips of gently sloping ground designed to drain water using sheet flow from roads and parking areas.	⊗ (S)	⊗ (S)	⊗ (S)			⊗ (P)	⊗ (P)	⊗ (P)			⊗ (S)		⊗ (S)	⊗ (S)	
Swales	Shallow vegetated channels that conduct and infiltrate runoff. The vegetation filters sediments.	⊗ (P)	⊗ (P)	⊗ (S)			⊗ (P)	⊗ (P)	⊗ (P)			⊗ (S)		⊗ (S)	⊗ (S)	⊗ (S)
Ponds	Areas of permanent water used for storing and treating runoff. They are also used to attenuate runoff. They have a permanent pool and usually some aquatic vegetation.	⊗ (S)	⊗ (P)		⊗ (S)	⊗ (P)	⊗ (S)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (S)	⊗ (P)
Wetlands	Similar to ponds, but the runoff flows slowly and preferably continuously through aquatic vegetation. They tend to be less suited to use as attenuation structures, depending on the types of plants used.	⊗ (S)	⊗ (P)			⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (P)	⊗ (S)	⊗ (S)	⊗ (P)
Detention basin	Vegetated depressions designed to store water to meet specific attenuation requirements.		⊗ (P)	⊗ (S)		⊗ (P)	⊗ (S)	⊗ (S)	⊗ (P)			⊗ (S)		⊗ (S)	⊗ (S)	⊗ (S)
Soakaways	Sub-surface structures that infiltrate runoff.		⊗ (S)	⊗ (P)			⊗ (S)	⊗ (P)	⊗ (S)							
Infiltration trenches	As soakaways, but provided as a trench.		⊗ (S)	⊗ (P)			⊗ (S)	⊗ (P)	⊗ (S)							

Table 2.5 SUDS techniques - their hydraulic, water quality and amenity capabilities (continued)

Key to symbols:

⊗ (primary) Primary process

⊗ (secondary) Secondary process

SUDS Technique	SUDS Description	Hydraulic Performance				Water Quality Treatment								Amenity Benefits		
		Conveyance	Attenuation	Infiltration	Water Harvesting	Sedimentation	Filtration	Adsorption	Biodegradation	Volatilisation	Precipitation	Uptake by plants	Nitrification	Aesthetics	Amenity	Ecology
Infiltration basins	Depressions that store and dispose of water via infiltration.		⊗ (primary)	⊗ (primary)		⊗ (secondary)		⊗ (primary)	⊗ (primary)	⊗ (primary)				⊗ (secondary)	⊗ (secondary)	⊗ (secondary)
Green roofs	Vegetated roofs that reduce the volume and rate of runoff and remove pollution.		⊗ (secondary)				⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (primary)		⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (secondary)	⊗ (primary)
Bioretention areas	Vegetated areas similar to swales, but with emphasis on a variety of vegetation including the use of wetland plants. Greater emphasis on treatment.	⊗ (secondary)	⊗ (primary)	⊗ (primary)		⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (primary)	⊗ (secondary)	⊗ (secondary)
Underground storage	Attenuation tanks to reduce stormwater runoff rate	⊗ (secondary)	⊗ (primary)		⊗ (secondary)											
Propriety drainage units	Range of units: screens, proprietary sedimentation units etc					⊗ (primary)	⊗ (primary)									
Pipes and manholes	Conduits and their accessories normally underground as conveyance measures.	⊗ (primary)														

3. Design Criteria

This chapter details the design criteria that are currently applied to drainage and explains why the criteria are required.

3.1 GENERAL

Chapter 2 discussed the stormwater runoff implications of urban catchments and the opportunities SUDS provide in mitigating these aspects. To allow a drainage system to be designed, criteria need to be set to ensure that:

- Flood protection
  - Adequate flood protection is provided on site
  - Adequate flood protection is provided as a consequence of the development

- Water quality treatment
  - The polluting impact on the receiving water is mitigated

- Operation and maintenance
  - The drainage system operates efficiently with minimal risk of failure and minimal need for maintenance

Additional criteria need to be considered to address issues of the environment, ecology and amenity. These are detailed in Chapter 8.

3.2 FLOOD PROTECTION CRITERIA

There are four possible different causes of flood risk. These are:

1. Flooding from an adjacent watercourse,
2. Exacerbated flooding of the receiving watercourse downstream,
3. Flooding of the site from the site drainage system,
4. Protection against overland flooding from the site on neighbouring areas,
5. Protection against flooding from overland flows from areas adjacent to the site.

The criteria applied to address each of these areas of flood risk are shown in Table 3.1. These criteria can vary depending on the authority or the community involved. 100 year levels of protection are generally used, but these may be raised for particularly vulnerable communities or high value areas.

To provide this flood protection for the site and downstream of it entails:

- provision of adequate conveyance capacity,
- provision of appropriate temporary and permanent attenuation storage, and
- provision of infiltration for volume reduction, where possible.

Table 3.1 Drainage design criteria for flood protection

Criteria	Design Event	Design Objective
1. Protection against flooding from watercourse	Maximum water level for the 100 year event	Protecting property floor levels. 100yr river level + safety factor (often 500mm).
2. Protection of watercourse from exacerbated flooding	100 year 6 hour event	Difference in runoff volume (pre- and post development). Retained on site (Long term Storage)*.
3. Protection against flooding from the drainage system	30 year event	No flooding on site, except where specifically planned and approved.
	100 year event	No flooding of properties. • Long duration events: Floor levels above the maximum flood storage levels on site. • High intensity events: Planned flood routing and temporary flood storage on site.
4. Protection against flooding adjacent areas	100 year event	Flooding managed on site and not passed to other urban areas.
5. Protection against flooding from hinterland drainage	100 year event	Flood routing management of potential flooding from adjacent areas.

**Long term Storage is the term given to detained runoff that is disposed of by infiltration to the ground, or if this is not possible, stored temporarily on site and discharged to the water course at very low flow rates. This storage need not come into effect except for extreme events as the intention is to protect rivers at times of extreme river flooding.*

Long term storage is the name associated with the provision of storage which addresses the additional runoff volume generated by development compared to the predevelopment catchment for the 6 hour 100 year event. This is preferably disposed of by infiltration, but otherwise can be discharged to the river at very low rates of discharge when infiltration is not possible (soil type) or is undesirable (pollution risk etc). The intention is to ensure that this runoff component does not contribute to the flood volume in the river at times of extreme river flows.

3.3 CLIMATE CHANGE CRITERIA

Climate change should normally be taken into consideration and this may vary depending on location. Generally agreed rules relating to climate change allowances are as shown in Table 3.2. In addition, it is now recognised that once a development is completed, extensions and additional paving often take place. This is sometimes referred to as urban creep. The extent to which this takes place depends on the development type and the density of development.

Clear guidance as to an appropriate design horizon for new development has yet to be produced. However between 50 and 100 years is suggested, depending on the implications of climate change.

Table 3.2 Current best practice Climate Change and other safety factors

Climate change / safety factor aspect	Design criteria	Reference
Sea level change (depending on coastal location)	4mm/yr - 6mm/yr in sea level	Defra (2000)
River flow change	20% increase in peak river flows (2050 horizon)	MAFF (2000), Environment Agency (2003)
Rainfall change	10% increase in rainfall intensity	Defra / Environment Agency (2004)
Urban creep*	10% increase in impermeable area	WRc (consultation draft, publication due in 2005)

** The application of an allowance for urban creep will be first officially introduced in the 2nd Edition of Sewers for Scotland (to be published in 2005).*

3.4 WATER QUALITY

The quality of stormwater runoff is an issue for most rainfall events.. The catchment is regularly "washed" by every-day rainfall and therefore the majority of the mass of pollutants is washed off by small storms. The generally low flows in the river at these times means that the pollutant concentrations tend to be high compared to large events during periods of flooding when a high degree of dilution is obtained. This polluted quantity of runoff can be treated in various ways, which are outlined in Table 3.3.

Table 3.3 Water quality treatment methods and suitable SUDS components

Treatment method	Suitable SUDS components
Filtration through a bed of filter medium, in soils or across a vegetated area	Infiltration trenches, Pervious pavements, Filter strips, Filter trenches, Wetlands, Green roofs, Bioretention, Swales
Settling of sediment	Ponds, Wetlands, Detention basins
Biological treatment by micro-organisms growing on filter media, soil particles, vegetation or suspended in a water body	Infiltration trenches, Pervious pavements, Filter strips, Filter trenches, Wetlands, Infiltration basins, Green roofs, Bioretention, Swales, Ponds, Detention basins
Adsorption of particles on plants or filter media	Infiltration trenches, Pervious pavements, Filter strips, Filter trenches, Wetlands, Infiltration basins, Green roofs, Bioretention, Ponds
Dilution for the control of persistent pollutants (only applicable for protecting against process failure and minimising impact)	Swales, Ponds, Wetlands, Detention basins

The concept of Treatment Volume (V_t) was introduced in the SUDS design manual C521 (Martin 2000a). This design parameter is a volume which could theoretically be applied to any SUDS unit, but in practice is usually associated with the sizing of the permanent pool of a pond to allow the various water quality processes described above to take place. V_t is a storage volume which is calculated as being equal to or larger than the runoff volume of 90 percent of all storms occurring in the year. This volume is usually in the region of 12-20mm of rainfall depending on catchment and hydrological characteristics. The empirical formula which was derived is as follows:

$$V_t = 9\ D\ (SPR/2 + (1 - SPR/2).\ I) \qquad (3.1)$$

where:
V_t is in m^3/ha
D is the M_560 rainfall depth from the Wallingford Procedure map
SPR* is the WRAP map SOIL index SPR value obtained from the Wallingford Procedure map, (1981)
I is the impervious fraction of the area

** It should be noted that the parameter SOIL is usually used here and in other equations to denote the use of the value of SPR of the particular SOIL category. It is felt that the use of SPR is less confusing and this has been used in other equations throughout this document for consistency.*

Other literature on BMPs relate the treatment requirements to the mean annual event. The mean annual storm is in the region of 3 to 5mm.

An example of how to estimate the treatment volume that would capture runoff from 90% of storms occurring in a year is provided in Appendix 2. This treatment volume can be reduced if treatment is provided upstream by other SUDS components for some of the contributing area.. Usually the pond size is approximately 1 times V_t, though a definitive position on this matter has yet to be arrived at for the UK.

Treatment volume is used to provide treatment based on experience of the benefits obtained. This hydraulic criterion is used as a surrogate for water quality criteria as it is impossible to specifically design stormwater treatment systems to meet particular water quality parameters concentrations.

The morphological criteria given in Table 3.4 are aimed at protecting the flow characteristics of the receiving river. Again the aim is to replicate greenfield conditions from the development runoff.

Table 3.4 River morphological criteria

Hydraulic processes	Design parameters	Application of design criteria
Rate of discharge	1 year event 100 year event	1 year site discharge rate to ≤ 1 year greenfield peak rate 100 year site discharge rate to ≤ 100 year greenfield peak rate
Volume of discharge	All events	Where possible, through interception and infiltration, prevent direct runoff from the first 5 to 10mm of rainfall.

3.5 OPERATION AND MAINTENANCE

The use of SUDS introduces an element of increased complexity with regard to the site drainage design. The design for self-cleansing velocities in pipes for traditional drainage is relatively simple and well understood. However runoff rates and volumes from swales and pervious pavements, for example, vary considerably depending on the storm event characteristics and antecedent conditions. For ordinary events, flows are much reduced for both aspects. This is not necessarily a problem as the sediment load should be minimal due to the nature of these drainage components. However a system which has a mix of direct runoff (gullies) and SUDS components will need to consider self-cleansing velocities for the elements which may have a significant sediment load. This means that hydraulic models, which can reasonably accurately predict the runoff characteristics of SUDS components, will often be needed to assist in assessing the hydraulic performance of these systems. Table 3.5 suggests pipe velocity criteria that should be applied. The use of 0.3m/s (where it applies) is not aimed at relaxing the gradient requirements of pipe systems, but to take account of the attenuating effects of certain SUDS components and to recognise that 1m/s may be an unrealistic target.

Similarly, maximum velocity is applicable to vegetated systems to prevent erosion, and this is also defined in Table 3.5.

There are a number of issues which should be considered in designing a drainage system to minimise maintenance effort and ensure trouble-free operation. Design criteria relating to specific SUDS components are not covered here, and reference should be made to relevant SUDS design manuals.

Table 3.5 Self-cleansing velocity criteria for pipes serving a SUDS drainage system

Criteria	Runoff characteristics	Design objective
Maximum velocity in vegetated systems	All runoff	< 1.0m/s – 1 year event
Minimum velocity in pipes	Minimal sediment load*	>0.3m/s – 1 year event
	Areas served with direct runoff (gully and pipe systems)	Velocity criteria in Sewers for Adoption 5th Edition

** where sediment protection is provided by an upstream SUDS component.*

4. SUDS Descriptions and Characteristics

This chapter provides a description of SUDS components, their advantages and limitations and the important design issues that need to be considered.

4.1 INTRODUCTION

There is a wide range of different types of SUDS components. Each type is suited for providing a particular drainage facility. It is important to realise that no one SUDS component is particularly better than another, and that a variety of SUDS is usually needed to ensure an effective drainage system for both water quality and hydraulic runoff control.

The following documents should be referred to for a more detailed description of the different SUDS components and their design criteria.

Key industry documents

- Sustainable drainage systems – Hydraulic, structural and water quality advice (Wilson, Bray and Cooper, 2004)
- Source control using constructed pervious surfaces (Pratt, Wilson and Cooper, 2002)
- RP697: SUDS updated guidance on technical design and construction (to be published Feb 2006 by CIRIA and HR Wallingford)
- Sustainable Urban Drainage Systems: design manual for Scotland and Northern Ireland (Martin et al, 2000a)
- Sustainable Urban Drainage Systems: design manual for England and Wales (Martin et al, 2000b)
- Building Regulations Approved Document H (DTLR, 2000)
- Interim Code of Practice for Sustainable Drainge Systems (NSWG, 2004)

The information needed by a developer on the characteristics of each SUDS component must not only be about their drainage behaviour but also how they can be applied in a modern high-density residential development. The following categories are therefore used to describe the benefits and limitations of each SUDS component and a table of the characteristics of each SUDS component according to the following categories is provided.

- Hydraulic performance (small and large events)
- Water quality treatment
- Amenity (social and ecology)
- Land use and availability
- Issues of construction, operation, design and maintenance

Brevity has been applied to this section to ensure a clear overview is provided. Chapters 5 and 6 provide a more detailed examination of design layout and construction issues. Chapter 7 provides more information on detailed design.

To provide an understanding of the relevance of each category, a brief discussion is provided first.

4.1.1 Hydraulic performance (small and large events)

Runoff from the site must be controlled, otherwise spate runoff into the receiving system or river will occur. Small events have no significance with regard to causing flooding, however their characteristics in terms of runoff from the development are very different from greenfield runoff (when effectively none occurs) and they convey the majority of the pollution from the site into the downstream environment.

Large events need to be controlled to minimise spate flood flows and excessive volumes being discharged to the river. Local flooding on the site also needs to be prevented.

4.1.2 Water quality treatment

Water quality treatment is needed to minimise the pollution discharged from the site.

4.1.3 Amenity (social and ecology)

Amenity relates to opportunities the SUDS components provide in terms of aesthetic and other benefits. There is often a degree of conflict between designing for hydraulic benefits, ecological benefits and community benefits.

4.1.4 Land use and availability

Land use, in this context, relates to the space required, the space available and the location where the SUDS component is most likely to be applied on the site.

4.1.5 Issues of construction, operation and design

There are various issues, depending on the SUDS component, which need to be known or are worth emphasising. The coding for each SUDS is very approximate for this category in that construction issues may be a problem where operation is not, or vice versa. It should therefore be used as an indication and more attention should be given to the description of the issues. Chapter 6 provides additional information on construction aspects.

4.2 GENERAL ISSUES FOR ALL SUDS COMPONENTS USING INFILTRATION

Approved Document H to the Building Regulations emphasises the importance of considering infiltration techniques in preference to positive drainage where possible. This means that for marginally suitable soils, during very wet periods, some infiltration components will fill and saturate the surrounding ground if there is no overflow. If an overflow is provided to a positive drainage system that is to be adopted, discussions with the appropriate authority on design criteria are recommended. They may require the normal 10 year criteria to be increased to 30 years. However, a pragmatic approach is recommended, recognising that some infiltration is better than none.

A communal or continuous infiltration system serving a group of properties is not usually recommended, as “failure” will result in flooding taking place preferentially at one location, usually to the detriment of one property. Carefully consideration of failure implications can, however, lead to successful communally based systems. Whether communal or individual units, consideration should be given to overland flood paths and the use of overflows where potential failure of infiltration components might result in flooding. This is a particular issue for high-density developments as terraced properties are commonly built, which limits the relief flow paths for flood flows.

4.3 IN-PROPERTY SUDS (WATER BUTTS, STORAGE FOR DOMESTIC WATER USE)

In-property SUDS refers to those systems that store roof runoff either within the building or in a chamber beside it, all of them having an emphasis on domestic or garden use. Other forms of SUDS, which are used within the curtilage, are detailed separately.

4.3.1 Description

Figure 4.1 Water butt

Table 4.1 In-property SUDS characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

N.B. Water quality benefits are "none" in that they do not contribute treatment to the surface runoff. They are only used where the risk to groundwater pollution is minimal.

Water butts are connected to rainwater pipes and normally store less than 0.5m^3 of water. The size of storage components required for toilet-flushing use is usually 2 to 5m^3 to provide an effective supply for much of the year. The size is related to the hydrology of the area and the water demand placed on the component. It is normally buried adjacent to the house. Treatment of the runoff in the form of filtering is required. Domestic use requires a small electrical pump which raises water to a header tank.

4.3.2 Hydraulic performance (small and large events)

Water butts have no value in providing a reduction in flows downstream from major events, as they cannot be assumed to have any spare storage space to attenuate runoff from a large storm event. They do however have the potential to reduce runoff volume from small events, particularly in summer (as some spare storage capacity can be assumed), which results in less pollution being discharged into the receiving water for a significant proportion of rainfall events.

Their use also theoretically reduces the demand on treated water supply, though in dry periods the stored water is exhausted very quickly if used for garden watering.

Stormwater stored for domestic use provides a significant level of volume reduction for small events, but has limited impact in providing drainage advantages for large events. The systems are very beneficial in reducing water demand for treated water if the storage volume is large enough.

4.3.3 Water quality treatment

In-property SUDS do not provide any significant benefit in treating runoff discharged from the site. This is because most of the pollution in stormwater runoff is from road surfaces.

4.3.4 Amenity (social and ecology)

In-property SUDS have no ecological benefits. There are health risks associated with domestic use, which need to be taken into account. However, there are potentially significant benefits in reducing water supply demand, especially in water scarce regions.

4.3.5 Land use and availability

Virtually no land is required for these components to be used.

4.3.6 Issues for construction and operation

There are no significant construction implications.

Domestic use systems must be robust and easy for homeowners to operate and maintain.

4.3.7 Issues for design

The size of storage for reuse can be calculated based on an assumed demand and a time series rainfall record appropriate to the area. Large storage volumes will result in long retention times which can cause problems of septicity and odour.

Provision needs to be made for an overflow to operate. This may need to be piped to a drainage system.

Systems can be designed on a communal or individual household basis. Ownership issues, treatment and delivery pipework is more of an issue where communal systems are built.

4.4 PERVIOUS PAVEMENTS

Pervious pavements are now becoming more commonly used in the UK They are frequently used for car parks or pedestrianised areas. They have also been used on local distributor roads, and on home zone roads and in cul-de-sac's. They can be used for heavy goods vehicle parks and in container yards, provided structural issues relating to the loading of the system have been specifically addressed. They allow rainfall to pass between the blocks into the sub-base for temporary storage, and infiltration where ground conditions allow.

4.4.1 Description

Figure 4.2 Pervious pavement

Table 4.2 Pervious pavement characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

Pervious pavements are often constructed using concrete blocks which are shaped to provide gaps through which rainfall can pass into the sub-base. Other materials include porous asphalt, porous concrete and a range of concrete or plastic products which allow in-filling with grass or granular material.

The sub-base can comprise granular material of specific size grading or high voids plastic media. The depth of construction is designed to provide structural support for pavement and surface water storage and the granular fill is normally around 350mm, although depths can be designed to be more or less than this value. Treatment can still be achieved in the blocks, bedding layers and geotextile when using plastic sub-base systems.

4.4.2 Hydraulic performance (small and large events)

Pervious pavements have good hydraulic properties with high levels of attenuation when granular fill is used. Runoff volume reduction is very high for small events in dry periods though not particularly good for large events and in wet periods. Pervious pavements can be used to store and attenuate adjacent roof runoff.

4.4.3 Water quality treatment

Water quality from pervious pavements is normally very good with minimal sediment load, and low pollutant concentrations especially if a geotextile is used below the bedding layer for the blocks.

4.4.4 Amenity (social and ecology)

Amenity value is limited, but its use is generally not unattractive, especially as coloured blocks can be used. Vegetation can be planted as the pervious surface allows the runoff to be passed to, and support, the plants.

4.4.5 Land use and availability

As car parking and other hardstandings are essential elements of developments, there is usually no need for additional land to be made available. It is flexible in being able to be used for small or large areas.

4.4.6 Issues of construction, operation and design

The Building Regulations Part H requires infiltration systems to be located 5m from any foundations. However pervious pavements that are serving private car parking areas can be located close to the buildings as they are acting in the same way as if the area had been grassed. If the pervious pavement is receiving additional runoff from roof areas then a lined section for the first metre away from the foundations may be required.

Car parks and roads are often built early in the construction process, at least in part, to provide traffic access and to allow storage of construction materials. As the structure is intrinsically intended to be porous, normal practice of using the area for storage and construction traffic is not possible without specific additional measures to protect the pavement porosity (see chapter 6 for more discussion on this aspect).

In addition to care being needed in the construction process, the design must take account of the need for minimising any soil or sediment being washed or deposited onto the surface once it is in operation.

An advantage of pervious pavements is that the cost of construction is only marginally different to standard pavement construction. As light liquid separators and gully pots are normally not required, this provides additional drainage benefits at very little cost.

4.5 FILTER TRENCHES

Filter trenches are built adjacent to the edge of a road or hardstanding and are used to provide road drainage as an alternative to pipes and gullies. Their principal purpose is to protect the road sub-base from becoming saturated and therefore they are often used in cuttings.

Table 4.3 Filter trench characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

4.5.1 Description

Filter trenches normally comprise a coarse single size stone, or specific stone mix, wrapped in a geotextile with a perforated pipe at the base of the trench. They are relatively commonly used in the UK. They are included as being a SUDS component due to their hydraulic and water quality advantages.

4.5.2 Hydraulic performance (small and large events)

Filter trenches provide some degree of attenuation and volume reduction, particularly for small events.

4.5.3 Water quality treatment

Water quality of the effluent is much improved compared to a pipe and gully system, although it is less effective than some other SUDS components.

4.5.4 Amenity (social and ecology)

Amenity value is limited, perhaps even being slightly negative.

4.5.5 Land use and availability

The land take is small but requires a strip of land adjacent to roads on which they are used. Filter trenches are not normally appropriate for estate roads and therefore their potential for application is limited in developments. Innovative design to avoid stone scatter by covering the surface has been used elsewhere in the world, but maintenance implications of any solution have to be carefully considered.

4.5.6 Issues of construction, operation and design

Filter trenches, which normally have granular material exposed at the surface, provide a maintenance issue in residential areas and are therefore rarely used. Where they are used under the pavement in conjunction with gully inlets, the risk of blockage in the long term is significant.

The upper layer can consist of stone or a bonded mix on a geotextile membrane to avoid problems of stone scatter and blinding by sediment, which can be removed and replaced as necessary to maintain free-draining conditions.

They should be sited away from the immediate road edge to avoid potential sideways movement of the road pavement into the trench.

4.6 FILTER STRIPS

Figure 4.4 Filter strip

Table 4.4 Filter strip characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

Filter strips are vegetated strips of land designed to accept runoff as overland sheet flow from paved surfaces. Their purpose is to provide treatment of runoff by encouraging settlement of fines as flow passes over the surface.

4.6.1 Description

Filter strips are usually several metres wide and encourage filtration of particulate material. They act as a pathway between the runoff and the collection system.

4.6.2 Hydraulic performance (small and large events)

Filter strips provide some degree of attenuation and volume reduction, particularly for small events.

4.6.3 Water quality treatment

Water quality of the stormwater for small events is good depending on the quality and width of the filter strip.

During extreme events, and before vegetation is fully established, scouring can occur, and water quality benefits will be minimal until the filter strip is rehabilitated.

4.6.4 Amenity (social and ecology)

Amenity value is positive in providing green open areas. There is limited ecological benefit due to the regular maintenance requirement and the need to provide a smooth plane surface.

4.6.5 Land use and availability

The land take is very significant and virtually impossible to apply in a high density residential area. However there may be some instances where it can be used.

4.6.6 Issues of construction, operation and design

The gently sloping area needs to be carefully constructed and maintained to ensure sheet flow takes place. Erosion can easily occur.

4.7 SWALES

Figure 4.5 Swales

Swales are vegetated shallow depressions normally located beside roads. Their purpose is to both convey and treat runoff.

Table 4.5 Swale characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High			green			red			
Medium	blue		green			red			red
Low	blue	blue	green	green	green	red	black		red
None	blue	blue	green	green	green	red	black	yellow	red

4.7.1 Description

The term "swale" covers a range of different drainage designs. The standard or conveyance swale is a shallow vegetated channel of around 400mm deep, up to 5m wide at ground level and 1m wide across the base. This receives sheet flow off roads and hardstandings and conveys it to a point where it is discharged into a pipe network or other structure. The length of the swale is limited primarily by its conveyance capacity and characteristics, as erosion of the base needs to be avoided.

Two other forms of swale exist. The first is termed a mini-swale as it need only be one metre wide, 100mm deep and is usually built in short lengths. It receives runoff and stores the water for infiltration, but once it is full, any additional water is discharged into the primary drainage system through an inlet of some kind.

The third type of swale, a storage or under-drained swale, is similar in size to a standard swale but, instead of having an outfall, it is served by a small perforated pipe located immediately below the swale. This design provides storage of runoff and allows percolation of flow into the pipe and the adjacent ground.

4.7.2 Hydraulic performance (small and large events)

The hydraulic performance of all the swales is good for small events, but only the under-drained swale is likely to be effective in providing good attenuation and volume reduction for large events.

4.7.3 Water quality treatment

Water quality of the stormwater for small events is good for all swale types. The under-drained swale is likely to be the most effective, particularly for larger events when a standard swale may have problems with erosion if gradients are significant. Mini-swales will still provide significant water quality benefits in spite of their limited hydraulic capacity.

4.7.4 Amenity (social and ecology)

Amenity value is positive in providing green open areas. There is limited ecological benefit due to the regular maintenance requirement.

4.7.5 Land use and availability

The land take is very significant for standard and under-drained swales. Although very desirable for treating road runoff, the demands of site planning for meeting PPG3 housing density requirements may often preclude their use over much of a site. However their importance in addressing both the volumes of runoff for small events and improving water quality from road runoff, makes these components very desirable in terms of protecting the receiving environment from the most polluting urban surfaces.

4.7.6 Issues of construction, operation and design

Swales are most effective when built with very gentle gradients. In this situation they provide a great deal of storage, good treatment and erosion is unlikely to take place. Although they can be built with longitudinal gradients of 1:20 and steeper, their benefits rapidly diminish as sediment washoff tends to collect at the end of the swale, killing the vegetation and causing an unsightly area. Frequent check dams should be used on any steep sites.

There is a need to balance the requirement to have sheet flow runoff into a swale with protecting the structure from vehicles. The use of kerbs results in point flow inputs, which may cause erosion problems.

Velocity of flow in a swale needs to be kept low to encourage sedimentation. Road layouts therefore need to use the contours of the site appropriately, unless constructed as a series of nominally level, stepped channels.

As swales are normally shallow structures, pipes used to convey flow under a road or driveway into the next swale, need to be designed to be strong enough with the minimal depth of cover available. These pipes offer opportunities for blockage and also erosion. Other solutions such as proprietary channels and gratings offer alternative options which may be appropriate in some situations.

4.8 PONDS

Figure 4.6 Retention pond

Table 4.6 Pond characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

Ponds are bodies of largely open water into which stormwater runoff is passed for treatment and attenuation. There are two categories and these are referred to as Detention ponds and Retention ponds, the difference being the duration that runoff is retained in the pond, which is a function of the volume of the permanent pool.

4.8.1 Description

A Retention pond is a wet pond where runoff is retained for some days to allow settlement and biological treatment of some pollutants, as well as providing attenuation of the stormwater flows. The permanent pond volume is based on an effective rainfall depth normally in the range of 40 to 60mm. Side slopes should be shallow for safety and aesthetic reasons. An impenetrable planting barrier around the edge of the pond is often included for safety reasons, though there is a counter argument which suggests that safety requires access to be possible. Maximum permanent pool depths are in the region of 1 to 2m, but ponds can often be much shallower.

A Detention pond is almost identical to a Retention pond, but it has a permanent pool volume based on only 10 to 15mm of effective rainfall. The additional retention period of a Retention pond is generally believed to improve treatment of stormwater runoff. However this is not always the case, particularly where eutrophication is a possibility.

The use of a series of ponds is more advantageous than one large pond for hydraulic, water quality, ecological and operational benefits.

4.8.2 Hydraulic performance (small and large events)

Ponds may provide some volume reduction through infiltration and even evaporation. However their main hydraulic benefit is their facility for limiting discharge flow rates. This advantage applies to all sizes of event. Their ability to limit discharges to low flows is really only effective for catchments larger than 3ha. For smaller catchments throttle sizes need to be small and consequently the risk of blockage increases. For small catchments, where permitted, outflow structures are based on the principle of a riser pipe with a limited number of small perforations. Care is needed to provide protection from floating debris of all sizes.

4.8.3 Water quality treatment

The water quality treatment efficiency of ponds is high assuming they are well designed to prevent short-circuiting. Long narrow ponds or ponds in series provide better water quality, more wildlife diversity and higher levels of attenuation than a single pond of the same volume.

4.8.4 Amenity (social and ecology)

Amenity value of ponds is high for well designed ponds, both aesthetically as well as providing good ecological benefits.

Safety can be a concern and must be addressed by good design and education.

4.8.5 Land use and availability

The land take of ponds is significant. They require large areas of public open space. In addition, they may be required to be some distance from any property for reasons of safety. However, ponds located closer to properties and in view of residents are safer than ponds that are not overlooked.

4.8.6 Issues of construction, operation and design

Ponds can be very useful in providing protection to the environment during construction by trapping the high loads of sediment in stormwater runoff. If they are used for this purpose, facilities to remove sediment need to be incorporated into the design. Rehabilitation of the pond (removal and disposal of sediment and other detritus) will need to be carried out prior to adoption by the relevant authority.

The design of the pond should specifically cater for future maintenance requirements. This includes the potential impact on the receiving environment in carrying out sediment removal or vegetation management. It should also consider the types of equipment that are likely to be used (reach distance from the bank) and also the operation and maintenance access and space needed for the equipment and supporting vehicles to operate.

It may be appropriate to provide areas for deposition and consolidation of the excavated material.

If the ponds are intended to provide infiltration capability around the perimeter, the construction process must avoid damaging the ground.

The hydraulic design of a pond outlet needs to consider the head-discharge relationship including any downstream backwater effects where the receiving water level can rise sufficiently to affect the outflow rate.

Ground water levels (in winter) need to be established to determine the depth to which ponds or basins can be excavated, or choosing the permanent pool water level. Groundwater should be at least 1m below the base of the pond unless it is lined.

Multiple ponds in series are preferable to a single large pond for maintenance reasons as the need for specialist (large) equipment / plant required for maintenance is avoided.

The use of a liner should be considered where water levels need to be maintained or the groundwater requires protection.

4.9 LINEAR PONDS

Figure 4.7 Linear pond

Linear ponds (which are similar in many ways to the simple ditch) are similar to retention ponds but are used as an alternative to swales in serving runoff from roadways. Ponds are designed specifically for hydraulic criteria whereas linear ponds are constrained by the space and opportunity to use them.

Table 4.7 Linear pond characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting benefits	Construction Issues
High	[blue]		[green]						
Medium	[blue]		[green]				[black]		[red]
Low	[blue]	[blue]	[green]	[green]	[green]	[red]	[black]		[red]
None	[blue]	[blue]	[green]	[green]	[green]	[red]	[black]	[yellow]	[red]

4.9.1 Description

A linear pond is a vegetated channel of around 1.0m or more deep with relatively steep side slopes. A small depth of permanent water is retained in the channel at all times and wetland type vegetation will grow in this region. The linear pond receives gully or sheet flow runoff from roads and conveys it down to a point where it is discharged into a pipe network or other structure.

4.9.2 Hydraulic performance (small and large events)

The hydraulic performance of linear ponds is good, providing conveyance, attenuation and storage for runoff.

4.9.3 Water quality treatment

Water quality treatment of the stormwater is good for small events, particularly due to the presence of wetland type vegetation in the base of the channel.

4.9.4 Amenity (social and ecology)

Amenity value is positive due to the provision of terrestrial and aquatic habitat. Safety may be an issue. They can also provide physical security in a less intrusive way than a fence.

4.9.5 Land use and availability

The land take for linear ponds is slightly less than that required for swales and they can be used alongside roadways to treat runoff.

4.9.6 Issues for construction, operation and design

Linear ponds are very useful in providing drainage facilities for areas with very flat gradients. In addition issues of inlet design for runoff and outlet structures are much easier to provide than for swales due to extra depth of the component.

Maintenance is much reduced compared to swales with vegetation needing attention only on an annual basis.

4.10 WETLANDS

Figure 4.8 Wetland

Table 4.8 Wetland characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

Wetlands are similar to ponds but are dominated by aquatic vegetation. Their design tends to be more complex. Their main purpose is to maximise water quality treatment.

4.10.1 Description

The main difference between ponds and wetlands, apart from the emphasis on vegetation, is the need for continuous flow into the wetland to ensure healthy plants. This is currently a particular problem for ownership as land drainage responsibilities are separated from those of providing urban drainage services.

4.10.2 Hydraulic performance (small and large events)

Although wetlands potentially provide identical opportunities to control runoff as ponds, in practice they may not provide the same degree of hydraulic benefit. This is because plant management requires a more controlled water level range. However, many wetland plants do not mind periodic inundation for up to 48 hours and therefore substantial attenuation can be achieved. A good knowledge of appropriate plant species and their tolerance to water level change is needed if the wetland is used as the main attenuation system. In addition, as the plants require a constant base flow, the stormwater inflow should be supported by land drainage or other inflow.

4.10.3 Water quality treatment

The water quality of the effluent can be better than for attenuation ponds, but this is dependent on effective management of the system. Plant die off in winter can pose problems of nutrient release. Drying out of the wetland must be avoided to maintain good treatment. Careful management is therefore needed to ensure a high quality of effluent.

4.10.4 Amenity (social and ecology)

The amenity value of wetlands is less than ponds as open water is considered to be more attractive. Although wetlands are ecologically beneficial, this depends to a large extent on the design, plant type and diversity. Variation in depth, open water and vegetation cover maximises the opportunity for bio-diversity.

4.10.5 Land use and availability

The land take of wetlands is significant. They need to be located in large areas of public open space.

4.10.6 Issues of construction, operation and design

Wetlands have similar construction and operational needs to ponds. However there is generally a need for greater technical detail with regards to the provision of appropriate growing media for the aquatic plants, depth of flow and consideration of water level range.

4.11 DETENTION BASINS

Figure 4.9 Detention basin

Detention basins are dry depressions aimed primarily at providing attenuation storage, but they also to provide reasonable treatment of stormwater runoff.

4.11.1 Description

Detention basins are normally grassed depressions or areas surrounded by embankments that store stormwater temporarily to limit the discharge rate of stormwater passing downstream.

Table 4.9 Detention basin characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Reuse Benefits	Construction Issues
High									
Medium									
Low									
None									

4.11.2 Hydraulic performance (small and large events)

Detention basins have an advantage over ponds in providing stormwater attenuation and volume reduction in that they can be provided in a smaller space. The maximum depth of attenuation storage is usually greater and initial runoff losses are higher. Similar to ponds, the level of attenuation is limited by the minimum throttle size, depending on the stipulations of the adopting authority.

4.11.3 Water quality treatment

The water quality of the stormwater is generally not as good as for ponds, but it is generally quite effective, subject to shape. A problem particular to basins is the difficulty of avoiding silt being re-mobilised and washed out by a large storm and possibly causing a pollution incident.

Although the concept of detention time to achieve water quality improvements can be applied to basins, extended detention requires either very small orifice sizes or very large areas to be drained. In practice where water quality is an important requirement, a pond is usually used.

4.11.4 Amenity (social and ecology)

The amenity value of basins tends to be limited, though they still provide green open spaces. However, the debris left in the bottom of the basin tends to be unsightly, making their use more suited to less visible locations. Vegetation growth tends to look unattractive unless well managed. Ecological benefits are provided, although these are generally less than for wetlands and ponds.

4.11.5 Land use and availability

The land take of basins is relatively small compared to ponds and wetlands. Because they can be effective in smaller areas, they can be located around a site, although being less attractive than ponds, they are not normally placed in highly visible areas.

4.11.6 Issues of construction, operation and design

Basins have no particular construction issues. As with ponds, they provide an opportunity to manage site pollution, although rehabilitation is likely to need carrying out once the site is established. Maintenance is required to keep outlets free of blockages and keep negative aesthetic elements to a minimum.

4.12 SOAKAWAYS AND INFILTRATION TRENCHES

Figure 4.10 Soakaway

Table 4.10 Soakaway and infiltration trench characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

N.B. Water quality benefits are "none" in that they do not contribute treatment to the surface runoff. They are only used where the risk to groundwater pollution is minimal.

A soakaway is a subsurface structure into which surface water, normally from roofs, is conveyed. An infiltration trench is identical except that soakaways tend to be round and deep, whereas infiltration trenches are linear structures and are shallower. They are both designed to dispose of surface water by infiltration.

4.12.1 Description

A soakaway can be constructed using perforated concrete rings with a granular surround and base, however most nowadays are constructed using plastic units. This provides a combination of large storage volume and high surface area for infiltration. Soakaways for small dwellings comprise a void of around one cubic metre lined with a geotextile and filled with granular material.

4.12.2 Hydraulic performance (small and large events)

Soakaways are normally designed to provide at least a 10 year return period level of service. In practice the conservative design assumptions (such as 100% runoff and a safety factor applied to the infiltration rate) mean that a higher level of service is commonly provided. Soakaways provide significant drainage benefits for volume reduction of runoff for both small and large events.

Infiltration trenches have two additional benefits over soakaways. The first is that the hydraulic requirements often result in a smaller volume of excavation due to the volume to surface area ratio providing a higher level of infiltration capacity. The second advantage is that where the groundwater level may preclude the use of a soakaway, an infiltration trench might still be feasible.

To protect the component it is useful to provide a trap to prevent detritus and sediment passing into the soakaway resulting in long term clogging and eventual blockage.

4.12.3 Water quality treatment

The water quality of roof runoff into the ground is usually not a concern for polluting groundwater. Use of soakaways for other paved surfaces needs to consider issues of the sensitivity of the groundwater (groundwater zones), and the characteristics of the runoff.

4.12.4 Amenity (social and ecology)

There is no amenity or ecological benefit from the use of soakaways. However, recharging of groundwater is an important aspect and meets the Building Regulations requirements to consider the use of infiltration before other drainage options.

In addition, there are financial benefits for householders, as the surface water element of the drainage charge is not made to properties drained by soakaways.

4.12.5 Land use

The land take of soakways is small. However Approved Document H to the Building Regulations requires soakaways to be located 5m from foundations. High density developments may have some difficulty in complying with this stipulation. It is possible that infiltration trenches, with their reduced depths, could have this distance requirement relaxed. Some of the reasons for this rule include:

- Certain soils are susceptible to shrinkage through the wetting and drying process.
- Softening of soils can occur when water is present.
- There is a loss of fines caused by wash out and consolidation of loose soils by water percolation.

4.12.6 Issues of construction, operation and design

Soakaways and infiltration trenches have no particular construction issues other than constraints related to soil types and groundwater.

Design of drainage systems should always first consider using infiltration for roof drainage in compliance with Building Regulations Part H.

4.13 INFILTRATION BASINS

Figure 4.11 Infiltration basin

Table 4.11 Infiltration basin characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

N.B. Water quality benefits are "none" in that they do not contribute to the surface runoff. They are only used where the risk to groundwater pollution is minimal.

An infiltration basin is a dry basin, in an area that has highly permeable soils. The base might be stripped or vegetated. Occasionally, a constructed component using sand and gravels is placed over the soil.

4.13.1 Description

An infiltration basin aims to dispose of runoff from most events by infiltration, but large events are catered for by way of additional storage and an overflow. They usually serve runoff from all types of surfaces and therefore sediment loads and potential risk of blinding need to be considered in both the design and the management of the system. The base of the component may require scarifying on an occasional basis. The use of granular material and sands, with geotextiles, provides an alternative approach to maintain the infiltration capacity of the system.

4.13.2 Hydraulic performance (small and large events)

The long term performance of these components is dependent on how well the maintenance regime manages sediments. These components, if operating correctly, are highly effective in reducing runoff volumes for both small and medium-sized events.

4.13.3 Water quality treatment

Use of infiltration basins for road and other paved area runoff needs to consider issues of the sensitivity of the groundwater and the characteristics of the runoff. Provision of light liquid separators should be considered for areas likely to be contaminated by oils and fuel.

4.13.4 Amenity (social and ecology)

The amenity or ecological benefits of these components is related to their design. There is a significant risk that the aesthetic effect will be negated due to accumulated washoff of sediments and general debris. Regular maintenance is likely to be needed.

4.13.5 Land use and availability

The land take of infiltration basins is usually high, depending on the design criteria and the soil porosity. By definition the characteristics of these components is for the provision of large flat areas to achieve disposal of the runoff.

4.13.6 Issues of construction, operation and design

The area to be used for infiltration must be carefully protected from construction activity and traffic. In addition, great care must be exercised in minimising sediment runoff into the basin. It is suggested that the best way to ensure these requirements is to build the basin very late in the programme of the development, and provide alternative means of drainage for the period of construction. Covering the surface with a geotextile to trap sediment arising from construction activities may be appropriate.

4.14 GREEN ROOFS

Figure 4.12 Green roof

Table 4.12 Green roofs characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High	[blue]		[green]				[black]		
Medium	[blue]		[green]		[green]		[black]		
Low	[blue]	[blue]	[green]	[green]	[green]		[black]		[red]
None	[blue]	[blue]	[green]	[green]	[green]	[red]	[black]	[yellow]	[red]

Green roofs are a multi-layer system that covers the roof of a building with vegetation over a drainage layer (Wilson et al 2004). They are used for a range of reasons (insulation for noise, heat and cold) and not just drainage where it provides some attenuation and volume reduction.

4.14.1 Description

Green roofs can be used on both flat and pitched roofs, although the roof pitch is normally less steep than a traditional domestic roof. The construction involves light weight growing media and a water proof liner. The plants normally used are Sedums which are extremely robust in coping with both drought and a big temperature range. Green roofs, though still rare in UK, are becoming more common in the UK, particularly in London and they are a key component of SUDS applications in some other countries. As roofs comprise a large proportion of the urban hard surface, green roofs are likely to play an increasingly important part in providing a more sustainable urban environment.

There are two main types of green roof (British Council for Offices, 2003).

- Extensive roofs – where the entire roof area is covered in low-growing, low maintenance plants.
- Intensive roofs – these are landscaped highly managed environments that can even include trees.

Intensive roofs tend to be used in city centre areas where land is at a premium and high value roof gardens are built.

4.14.2 Hydraulic performance (small and large events)

Green roofs are effective in providing both attenuation and reduction of runoff for small events. These advantages are reduced for larger events in terms of hydraulic reduction and attenuation. Where runoff passes to soakaways, an interception chamber is needed to trap vegetative matter and sediments. Where reuse is considered, green roofs are at a disadvantage compared to traditional roofs as runoff volume is reduced and the water quality requires more attention.

4.14.3 Water quality treatment

The water quality from green roofs is good in the majority of roofs where high mineral content substrate is used because the runoff is filtered. The higher the mineral content in the substrates used, the better the water quality.

4.14.4 Amenity (social and ecology)

For sedum only roofs there is little amenity or ecological value as they provide a limited environment for flora and fauna. Green roofs are generally positive aesthetically, although as they are yet to be used widely in UK, their aesthetic value has yet to be established.

Intensive type roofs are often designed to be accessible and may also include water features and storage of rainwater for irrigation. These types of roofs have a higher amenity value but have high maintenance costs.

4.14.5 Land use and availability

Green roofs require no land take.

4.14.6 Issues of construction, operation and design

The implication for construction of using green roofs is minimal, although expert organisations should be involved. The season will influence requirements to ensure the plants get established properly. The time needed to build a green roof is slightly longer than for a standard roof and provision should be made for this.

Green roofs may not be suitable for collection and reuse of stormwater as bacteria and organic load can be relatively high. The reduced volume of runoff for small events means that larger storage components would be required to provide the same level of service in terms of reuse. Calculation of the runoff yield from the many small rainfall events that take place is much more uncertain.

4.15 BIO-RETENTION

Figure 4.13 Bio-retention area

Table 4.13 Bio-retention characteristics for different categories

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction Issues
High									
Medium									
Low									
None									

Bio-retention areas are effectively small storage basins with forms of vegetation other than grass. They are often provided in the form of an attractive border adjacent to the paved area that they serve.

4.15.1 Description

Where swales generally use grass as the vegetation cover, bio-retention areas use a range of appropriate vegetation, often wetland type plants, for treatment of runoff. They therefore can range from flower borders, through to marshy grasses. Conveyance is not normally an aspect of bio-retention, so an overflow structure is usually provided to address larger volumes of runoff.

4.15.2 Hydraulic performance (small and large events)

Bio-retention sites tend to provide effective storage for small events and a degree of attenuation for large events. Their hydraulic effectiveness depends very much on their design.

4.15.3 Water quality treatment

The water quality from bio-retention areas can often be better than for swales. However where it is used as a vegetated border, horticultural practices will affect the water quality to some degree.

4.15.4 Amenity (social and ecology)

The amenity value is potentially high, depending on its design and management. The ecological benefits will also vary for the same reason.

4.15.5 Land use and availability

Bio-retention areas are generally limited to relatively flat areas. However, they can be any size to suite the environment. As they are relatively flat depressions, the land take is large relative to the hydraulic benefits provided.

4.15.6 Issues of construction, operation and design

There are minimal construction implications for use of bio-retention areas. However care should be made not to compact the ground during construction.

Mulches should not be used, as they reduce available storage and can block overflows and downstream systems.

4.16 SUMMARY OF SUDS PERFORMANCE CHARACTERISTICS

The performance characteristics of the different SUDS components are summarised in Table 4.14 which brings together the performance characteristics described in each section of this chapter.

Table 4.14 Summary table of performance characteristics for SUDS components

Priority	Hydraulic benefits - small events	Hydraulic benefits - large events	Water Quality Benefits	Amenity Benefits	Ecological Benefits	Land Take	Land Availability	Rainwater harvesting Benefits	Construction & Operation
Water butt/storage	Yellow	Red	N/A	Yellow	Red	Green	Green	Green	Yellow
Pervious pavement	Green	Green	Green	Yellow	Red	Green	Green	Green	Yellow
Filter trench	Yellow	Yellow	Yellow	Red	Red	Yellow	Yellow	Red	Yellow
Filter strip	Yellow	Red	Yellow	Yellow	Yellow	Red	Red	Red	Yellow
Swales	Green	Yellow	Green	Yellow	Yellow	Red	Yellow	Red	Yellow
Ponds	Green	Green	Green	Green	Green	Yellow	Red	Yellow	Green
Linear ponds	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Red	Green
Wetlands	Green	Yellow	Green	Yellow	Green	Red	Red	Red	Yellow
Detention basins	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Green
Soakaways	Green	Green	N/A	Red	Red	Green	Green	Red	Green
Infiltration trenches	Green	Green	N/A	Red	Red	Green	Green	Red	Green
Infiltration basins	Green	Yellow	N/A	Yellow	Yellow	Red	Red	Red	Red
Green roofs	Green	Red	Green	Yellow	Yellow	Green	Green	Red	Yellow
Bio-retention	Green	Yellow	Green	Green	Yellow	Red	Yellow	Red	Yellow

Key:

Red	Worst
Yellow	Useful
Green	Best

Water quality benefits are not included for infiltration units as they are not part of the surface runoff system. It is presumed that they are only used where the potential for groundwater pollution is minimal.

5. Application of SUDS

This chapter looks at methods of applying SUDS in high-density developments and the locations in which SUDS can be used. It also draws attention to issues that need to be considered when using each type of SUDS component.

SUDS components can replace or complement traditional pipe and gully drainage systems on a development site. The type of SUDS system that is appropriate in any location depends on the catchment it serves, the soil type and the space available. The following section looks at the opportunity and suitability for SUDS use and their benefits. These benefits are the direct benefits in terms of water management. Secondary amenity and other benefits, such as soundproofing and insulation provided by green roofs, are not detailed.

5.1 DEVELOPMENT LAND USE

Due to pressure for new development and the demand for housing, particularly in the south of England, guidance note PPG3 was issued by the DTLR (DTLR, 2000) which emphasises the need for the footprint of developments to be minimised.

PPG3 suggests a housing density of between 30 to 50 dwellings per hectare (net), which is higher than traditional residential developments which are in the range of 15 to 20. It also emphasises the need for a range of housing types to be built within the development and requires a reduction in the provision of car parking spaces (see Appendix 6).

The implications of this policy that affect the use of SUDS are therefore:

- A high proportion of impervious surface area within a site,
- Reduced land availability for surface drainage structures,
- Smaller gardens with reduced opportunity to use soakaway techniques,
- ‘Communal/ mews’ parking areas,
- An emphasis on planned communal public open space.

To meet all the planning requirements results in housing which is either terraced, and fronts onto the road, or in housing built around a courtyard. This is illustrated in Figure 5.6. The layout of the housing dictates, to a large extent, the types of SUDS components that can be used.

Brownfield development is preferred to building on greenfield areas. Housing density in these areas is often even greater than 50 house per hectare, with little or no green space provision. This difference also links through to a difference in approach to SUDS use in these situations.

The choice of infiltration based SUDS on previously developed land is sometimes constrained due to previous contamination of the soil. Infiltration can be used on contaminated sites provided the contaminants are not mobilised. For example, soakaways can be located below the contaminated soil.

The different types of land area available and the proportion of each type of land use typically found in new residential developments is given in Figure 5.1. The figure also shows the SUDS components that might be considered in each land use category.

Approximately 60% of the area of a new development site is made up of impermeable surfaces and 40% remain green space (20% private and 20% public). The degree of impermeability can be significantly greater, particularly in commercial and industrial areas.

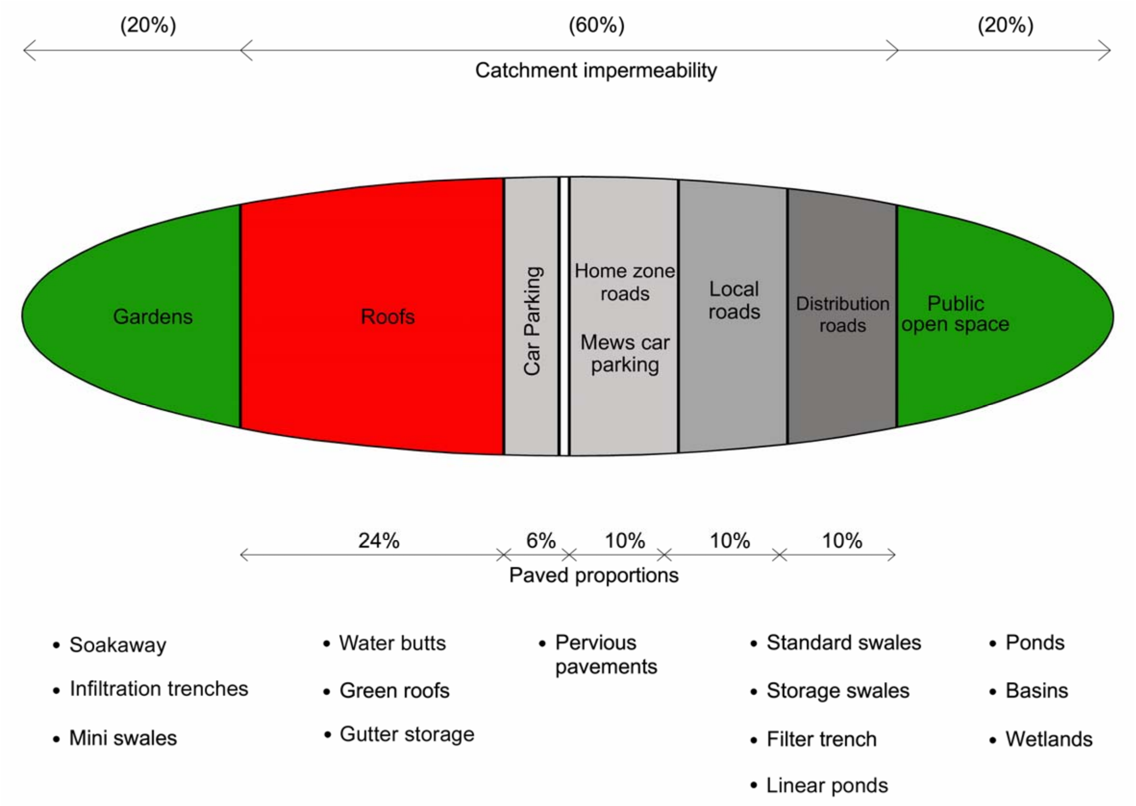


Figure 5.1 Typical division of land use for new developments and opportunities for SUDS use

5.2 INTEGRATED DESIGN

It is important to recognise that, although the hydraulic criteria currently imposed as a discharge consent (typically as part of a planning condition) can usually be achieved by a single pond at the downstream point of the drainage system, a more cost effective and efficient system, both in terms of water quality and hydraulics, can be achieved using a mix of SUDS components placed in series and distributed through the development.

A large pond at the low point in the site can be very attractive. However it means that much of the public open space must be located there, thus constraining the master-plan design for the site. In addition, the outfall from the low point from the site may be hydraulically affected by the level of the receiving drainage system or stream.

Other issues such as sediment deposition and removal from a downstream pond can be minimised with the use of other appropriate SUDS components upstream of it. Theoretically there is a hierarchy of SUDS components in terms of hydraulic efficiency (both by volume reduction or attenuation) (see Appendix 7, Laughlan, 2004). In practice the constraints on type of SUDS that can be used (due to soil type, site location etc) means that there is a limited choice of components for any particular part of the development.

As an initial guide, the priority for drainage design should be to maximise the use of infiltration systems (and water harvesting if appropriate) across the site and to make the most of opportunities to use pervious pavements (as they take no extra land) where the use of this system can be allowed. The resulting demands on attenuation and flood storage will then be much reduced. The use of an attenuation pond at the outfall should preferably be a series of small ponds rather than a single pond for water quality, ecology and maintenance reasons. However it is recognised that a single large pond will generally be considered as being of greater aesthetic value. This drainage approach allows more flexibility with regard to the layout of the site and the location of public open space.

Figure 5.2 provides a flow chart of decision guidance which will assist in highlighting the use of appropriate SUDS for a development.

Figures 5.4 and 5.5 provide an indication of the opportunity to use SUDS components in a high density development. The emphasis on communal parking can be seen and the opportunity this provides to use pervious pavements. Where pervious pavements can be used for footways and home zone roads, the opportunity significantly increases. The figures also show that the possibilities for the use of swales are limited to distributor roads due to the frontage of buildings being so close to their access roads.

Much of the green area is provided as private gardens behind the dwellings. If soil characteristics are suitable, infiltration techniques should be used to make use of these areas.

5.3 IN-CURTILAGE AREAS

In-curtilage, or private land within a development makes up around 50% of the overall area of the development and therefore suitable SUDS should be considered for use in these areas if stormwater runoff is to be dealt with effectively. Of this area, nearly half is taken up by the footprint (roofs) of the properties.

The selection of appropriate SUDS therefore needs to consider not only issues of hydraulic performance but also the risks related to private SUDS ownership, particularly the risks of change of use and minimal maintenance.

5.3.1 Applicable In-curtilage SUDS components

The opportunity for the use of SUDS within a private property is related to three surface categories found within the curtilage boundary. These are:

- Roofs
- Gardens
- Parking areas

Roof areas

The runoff from the roof area can be harvested using SUDS components such as gutter storage, waterbutts, chambers and green roofs.

As groundwater issues and the use of infiltration are very important, Figure 5.3 is provided to assist with decisions on the use of infiltration components. This figure is from CIRIA Report C521 (CIRIA, 2000)

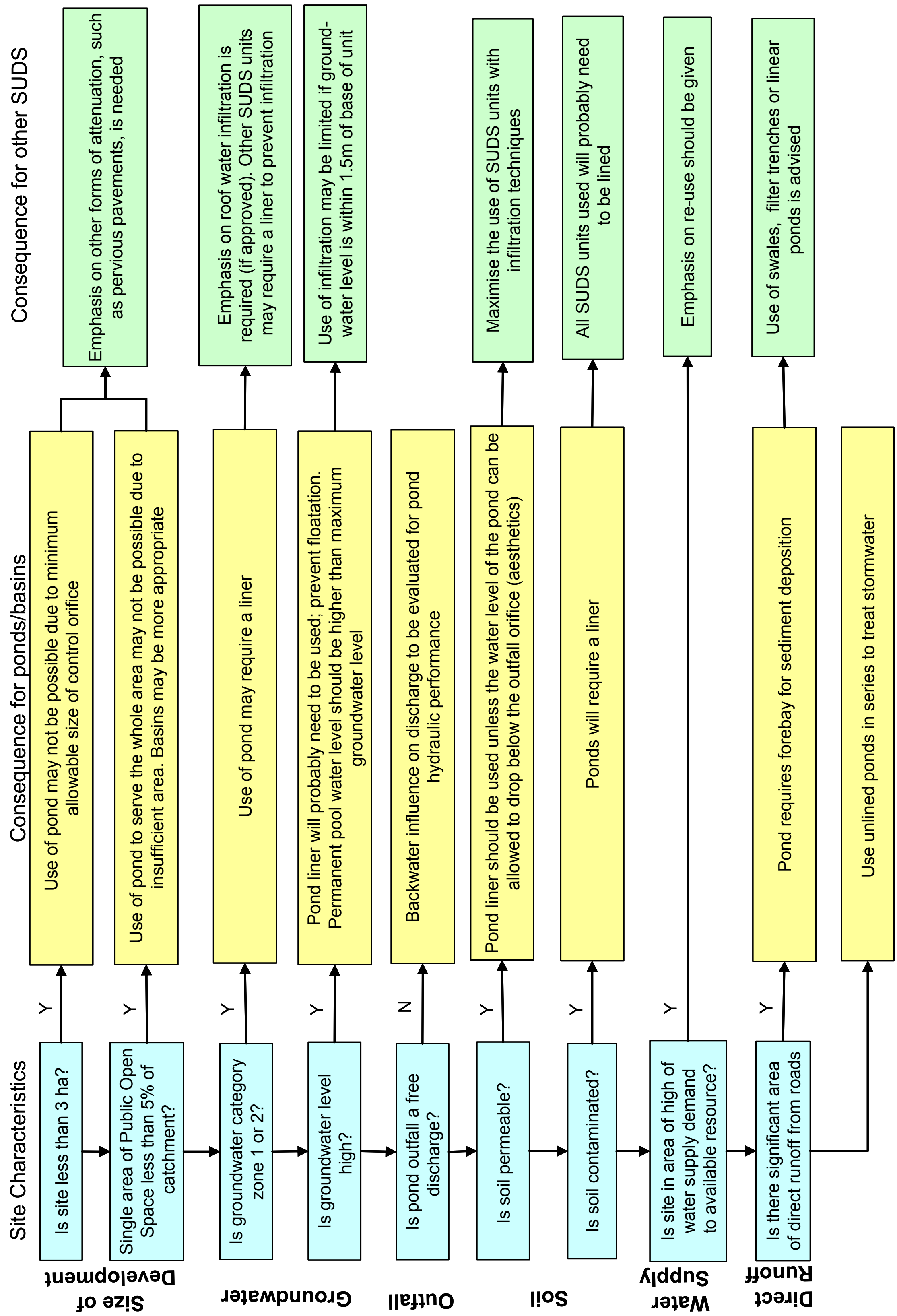


Figure 5.2 Decision guidance for use of appropriate SUDS components

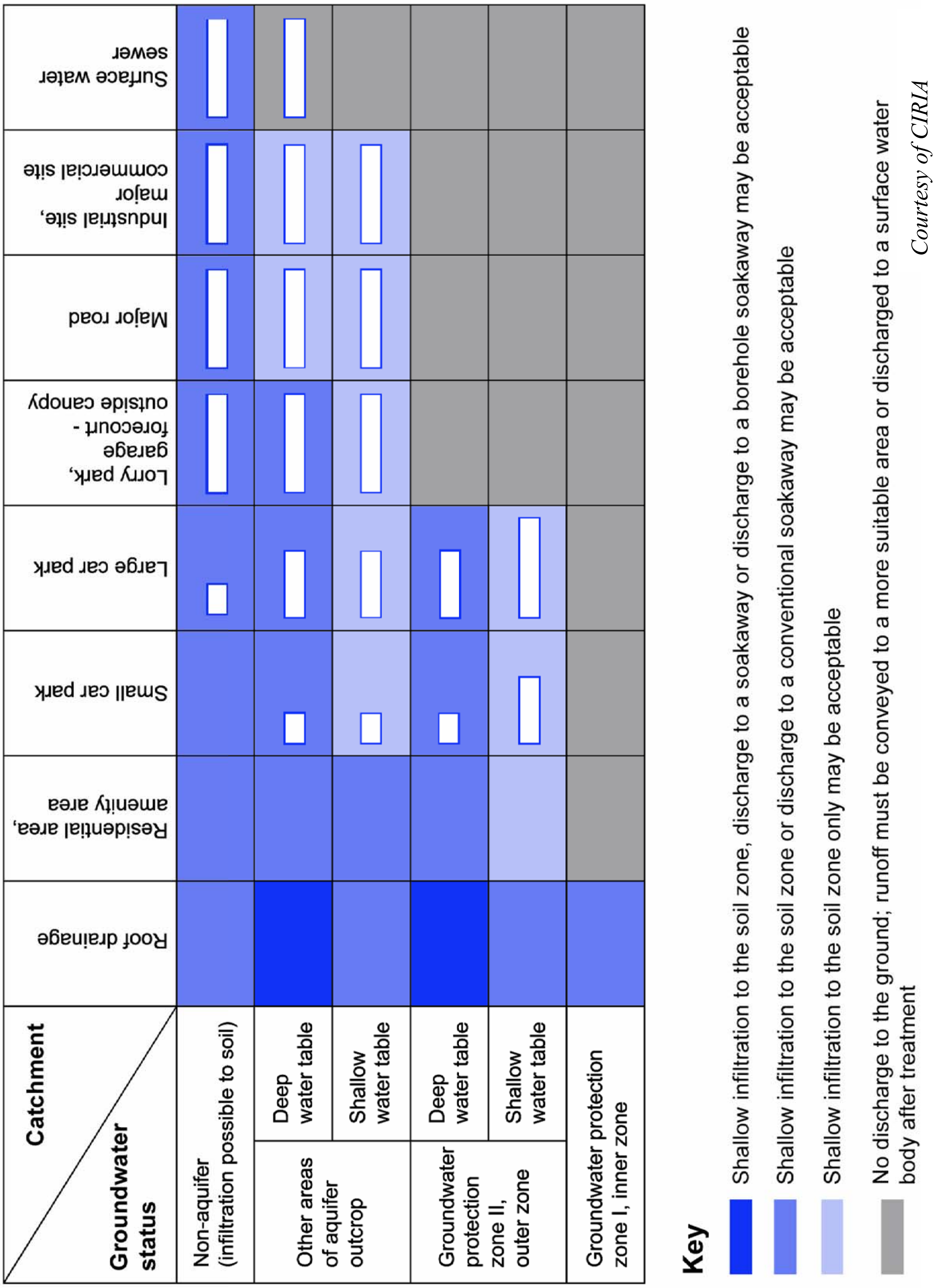
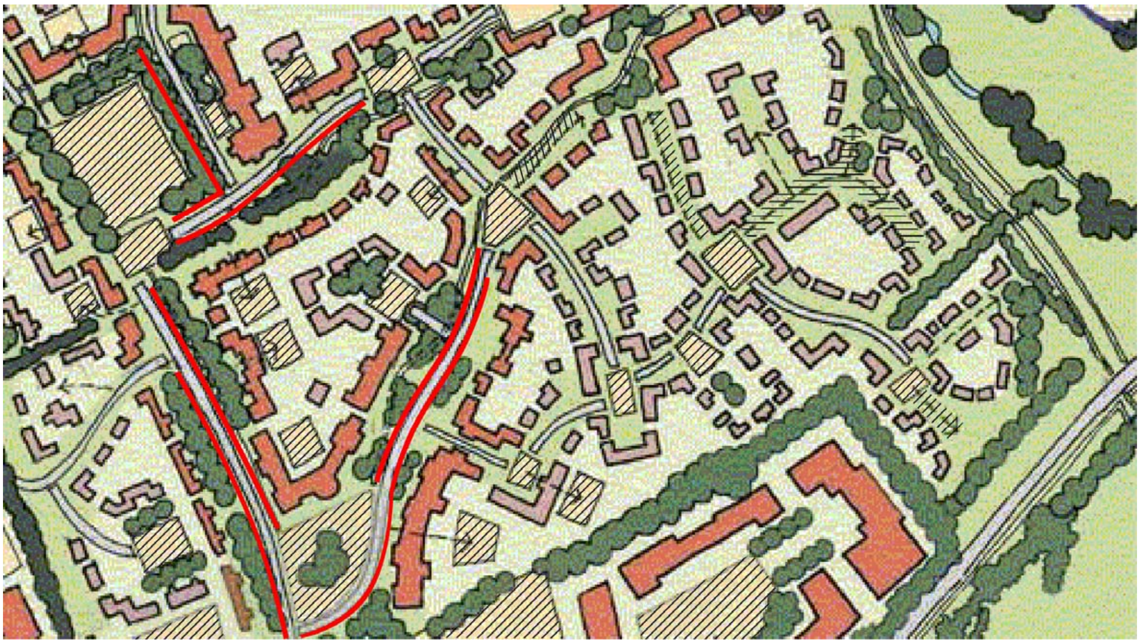


Figure 5.3 The use of SUDS and infiltration



possible location of swales along roadways
possible location of pervious pavements

Original schematic courtesy of WSP Group

Figure 5.4 Possible location of SUDS components in a new development

Gardens

Infiltration systems (soakaways, infiltration trenches) can be placed in garden areas to deal with the runoff from the roof surface. Approved Document H to the Building Regulations recommends that infiltration systems should not be located within 5m of the foundation of the property. This is particularly relevant where deep soakaways are used and in areas with problematic soils. In these situations the opportunity to use infiltration in PPG3 compliant developments may be limited.

However where soils are less of a problem and with shallow based systems, such as infiltration trenches, this distance can often be reduced.

Mini swales, serving the local road, can be located in private gardens where there is sufficient space between the road and the property. The design of many high density developments provides very little space between the house and the road pavement, therefore there is often no option for using this SUDS component (see Figure 5.6).

Consideration of the risks of change of use, fertiliser and weed killer application, also need to be made.

Driveway (car parking)

Although there is emphasis on reducing car parking provision, there is often some off-road car-parking within private properties. Permeable pavements can be used and roof runoff can be passed into the sub-base. The same constraints on distance from the house for using infiltration theoretically apply as discussed earlier due to requirements in the Building Regulations Part H. However, as the depth of a pervious pavement is only in the region of 350mm, some authorities allow infiltration from pervious pavements as close as 1m to the foundations or right up to the foundations if the pervious pavement is only taking direct rainfall. There is rarely a need to provide an overflow due to the high storage capacity of such components assuming overground flow which will not affect the property.

possible location of swales
receiving stream
possible location of pervious pavements

Original schematic Courtesy of Roger Evans Associates

Figure 5.5 Possible location of SUDS components in a new development

Lined pavements with a low level outflow to positive drainage, where they are considered necessary, are still useful as the discharge is heavily attenuated in the granular media.

The risk of car-parking areas being modified or sealed is relatively high. Methods of ensuring such changes do not take place need to be considered where pervious pavements are used in private properties.

Figure 5.6 House frontage directly onto the road

5.4 ROADWAYS

Roadways make up approximately 30% of the land area within a new residential development. Design Bulletin 32 (Department of the Environment and Department of Transport, 1992) defines the different roadways as described below. In larger developments (greater than 20 ha) the percentage of space is relatively evenly divided between these different types of roadway, with each roadway type making up around 10% of the overall site area. In smaller developments, particularly brownfield sites, the predominant roadway type is access roads.

District distributors
These roads distribute traffic between the residential, industrial and principal business districts of a town and form the link between the primary road network and the roads within residential areas.

District distributor roads are not a road type found within a residential development. Only local distributor roads, major residential and minor residential access roads are of relevance.

Local distributors
These roads distribute traffic within districts. In residential areas, they form the link between district distributors and residential roads.

Residential access roads
These roads link dwellings and their associated parking areas to distributor roads.

Home Zone roads
Included as a subset of minor residential access roads are "home zone" roads. In the UK the term "Home Zone" is used for "a street where people and vehicles share the whole of the road space safely, and on equal terms; and where quality of life takes

precedence over ease of traffic movement." (Home Zone design guidelines, Institute of Highway Incorporated Engineers, 2002)

Home zone roads have low traffic speeds (10 to 20 mph) and volumes (recommended traffic flow of no more than 100 vehicles in the afternoon peak). In addition, residential buildings in a home zone should have an "active front" to the street, which means that front gardens are absent or minimal in these areas.

Communal parking areas
The provision of parking areas can take a range of forms such as on-street parking, off-street parking, or communal parking areas. The allocation of space for parking varies considerably between different developments, but there is an advised maximum amount of 1.5 parking spaces per property. In new developments where high density living is promoted, communal parking spaces are often provided as the principal parking provision.

5.4.1 Applicable SUDS components for roads

Permeable pavements
Roadways, cycleways, footways and parking areas provide opportunity for using permeable pavements. At present their use is normally limited to car parking, but there are instances of their application in home zone road. This means that permeable paving could be applied to at least 10% of the total surface area within a development site, and possibly significantly more if their use on more heavily trafficked roads becomes more accepted.

Figure 5.7 A Home Zone road with pervious pavement

Pervious pavements do not take up any additional space compared to a traditional road surface and therefore do not have any additional land-take. They are particularly useful in home zone areas where traditional kerb and gully drainage systems detract from the integration of the roadway and pedestrian surfaces (Figure 5.7).

Swales and linear ponds
Other types of SUDS that could also be used to serve road runoff include filter trenches, swales and linear ponds. These systems are located beside the roadway. Swales or linear ponds can also be located in landscaping areas in car parks and other similar locations. These SUDS systems can only be used where the house frontage is set back from the road.

5.5 PUBLIC OPEN SPACE

Up to 20% of a residential development site is provided as public open space. The Town and Country Planning Act 1990 defines open space as land provided as a public garden or used for the purposes of public recreation. More recent government policy statements (DTLR, 2002 – PPG17) provide a broader definition such that open space can include incidental open space and landscaping as well as open spaces serving a wider area, and significant landscape buffer strips.

PPG 17 includes the following definitions that are relevant to open spaces in new developments that may be of public value:

- natural and semi-natural urban green spaces - including woodlands, urban forestry, scrub, grasslands (e.g. downlands, commons and meadows) wetlands, open and running water, wastelands and derelict open land and rock areas (e.g. cliffs, quarries and pits);
- green corridors - including river and canal banks, cycleways, and rights of way;
- outdoor sports facilities (with natural or artificial surfaces, either publicly or privately owned) - including tennis courts, bowling greens, sports pitches, golf courses, athletics tracks, school and other institutions playing fields, and other outdoor sports areas;
- amenity green space (most commonly, but not exclusively in housing areas) - including informal recreation spaces, green spaces in and around housing, domestic gardens and village greens;
- provision for children and teenagers - including play areas, skateboard parks, outdoor basketball hoops, and other more informal areas (e.g. 'hanging out' areas, teenage shelters);

Public open space is often made up of a number of small open spaces amongst other land uses, though large developments do usually have one or two large areas, often specifically aimed at recreational use.

In Scotland the term “open space” covers “greenspace consisting of any vegetated land or structure, water or geological feature in an urban area and civic space consisting of squares, market places and other paved or hard landscaped areas with a civic function” (Scottish Executive, 2003).

There are, however, no definitive rules for the provision of different types of public open space or how SUDS may be incorporated into public open space areas.

Figure 5.8 Communal parking areas

Figure 5.9 Linear pond

In England, PPG17 (refer Table 5.1) does mentions that Local Authorities should recognise that most areas of open space can perform multiple functions and they should take this into account when applying the open space policies. SUDS are not directly referred to.

However, the open space functions, as defined in Table 5.1, do indicate that SUDS are an appropriate use of open space areas. For example, ponds and wetlands do provide habitats for flora and fauna, if well designed they are a visual amenity and as they are green spaces they can improve the quality of the urban environment.

The companion document to PPG 17 (ODPM) notes that different types of open space may also include areas of running or static water such as ponds, fountains, rivers, canals, lakes and reservoirs. Water can make a major contribution to the quality and nature of the greenspace and be an important component of the urban drainage system or vitally important for recreation and biodiversity contribution.

In Scotland the Planning Policy Guidance NPPG 11 recommends that for new general purpose housing 1.62 hectares of land per 1000 people (or 0.4 hectares per 100 houses) should be made available as open space. This should comprise 0.81 hectares of amenity open space and 0.81 hectares of recreational open space. The detail of how this open space is allocated is left to the Local Authority. This distinction can be considered as being “passive” and “active” respectively; terms which are now becoming more prevalent in defining green space.

Table 5.1 Functions of public open space in PPG 17 (ODPM, 2002).

Function	**Definition**
Strategic functions	Defining and separating urban areas; better linking of town and country; and providing for recreational needs over a wide area.
Urban quality	Helping to support regeneration and improving quality of life for communities by providing visually green spaces close to where people live.
Promoting health and well-being	Providing opportunities to people of all ages for informal recreation, or to walk, cycle or ride within parks and open space or along paths, bridleways and canal banks. Allotments may provide physical exercise and other health benefits.
Havens and habitats for flora and fauna	Sites may also have potential to be corridors or stepping stones from one habitat to another and may contribute towards achieving objectives set out in local biodiversity action plans.
As a community resource	As a place for congregating and for holding community events, religious festivals, fẽtes and travelling fairs.
As a visual amenity	Even without public access, people enjoy having open space near to them to provide an outlook, variety in the urban scene, or as a positive element in the landscape.

Planning documents in England and Scotland also make reference to various other open space considerations. For instance, the National Playing Fields Association (NPFA, 2001) recommends that land is set aside for outdoor play, games, sports and other physical recreation. They suggest a minimum standard for outdoor playing space of 2.4 hectares for 100 houses, comprising 1.6 hectares for outdoor sport and 0.8 hectares for children’s play.

PAN 65 (Scottish Executive, 2003) provides an example of the use of SUDS in public open space. In Dunfermline open space was provided as a series of attractive ponds. The ponds were an important component of the drainage system, provided pollution control and ecological benefits as well as being a significant amenity feature and forming a major part of the landscape structure of the area.

Planning guidance for Wales and Northern Ireland do not make specific reference to the use of SUDS in public open space areas.

5.5.1 Applicable SUDS components in public open space

Because of the space requirements of some SUDS components open space areas are particularly suitable for their use. However, in most instances the Local Authority must be satisfied that the SUDS component is a suitable use of the public open space and of benefit to the community.

Ponds and Basins
Ponds generally need relatively large areas of open space. A pond that serves all the runoff from a development site will require between 2% to 4% of the overall catchment area (which is approximately 10% to 20% of all the available open space area). Basins take around half the land required by ponds. These SUDS components can therefore only be located in developments where there is appropriate provision of public open space.

Depending on the adopting authority, the type of open space used is usually limited to passive or amenity provision, to limit the maintenance element to the requirements of the SUDS as a drainage system rather than in providing a community play area.

It is important to note that the size of these components can be significantly reduced where other SUDS components (particularly storage and infiltration systems) are used further up the system.

Infiltration basins are not often used due to the requirement of highly porous soils and the maintenance implications of preventing blinding of the component with fine sediments.

Such SUDS components often serve the stormwater drainage of large areas of the development. Due to controls on their outflow rates, they are usually used to limit the discharge from a site before it enters any downstream drainage system or watercourse.

Wetlands
Wetlands are designed primarily as treatment systems as vegetation can suffer from the varying water levels which are a feature of hydraulic attenuation structures. Therefore their use in residential areas is less common due to land take as well as the operation and maintenance implications.

Swales, Linear ponds and Filter Trenches

Other SUDS components such as swales, linear ponds and infiltration trenches, which serve runoff from roadways, are normally located in public open space adjacent to roadways.

General

SUDS components can be incorporated into areas of private property and public open space land use. The dual use of land, where specific consideration is given to providing areas which are rarely inundated, is to be encouraged subject to appropriate consideration of safety issues.

Care should be taken when locating SUDS components in public open space areas that are also within the floodplain. Any SUDS located in a floodplain should not have an adverse effect on floodplain storage. Also, the risk to the operation and maintenance of the SUDS component, if flooding occurs, should be considered.

6. Construction Issues

This chapter provides guidance on principal issues that relate to construction of SUDS systems.

Guidance on the design and construction of SUDS (CIRIA, 2006) gives more detailed information on construction of SUDS systems. SUDS are a combination of civil engineering structures and landscaping practice. Due to the limited experience of building SUDS in the water industry, there are a number of key issues which need to be particularly considered as their construction requires a change in approach to some standard practices. Useful documents that provide particular guidance on SUDS construction issues are:

- Specification for highway works (Highways Agency et al, 1998)
- National building specification landscape specification (www.thenbs.com)
- Sewers for Scotland, 2^{nd} Edition (WRc, 2005)
- Water for Scotland (UKWIR, 2004)
- National SUDS Working Group – framework document (NSWG, 2003)
- National SUDS Working Group – interim code of practice (CIRIA, 2004)

Further guidance on construction issues can be found in the following documents:

- CIRIA Report 609 (Wilson, Bray and Cooper, 2004)
- CIRIA Report 116 (Hewlett et al, 1997)
- CIRIA Book 10 (Hall, Hockin and Ellis, 1993)
- CIRIA Report C532 (Masters et al, 2001)

Information is also given in the pollution prevention guidance produced by the Environment Agency and SEPA.

Key aspects of SUDS construction require changes to conventional construction practices, and these are described in Box 6.1.

Box 6.1 Construction considerations for SUDS

1. The phasing of construction may need to be modified to ensure constructed SUDS components operate properly. For many SUDS, the final construction should take place towards the end of the development programme, unless adequate provision can be made to protect the component. However it should be recognised that vegetation takes time to become established, and if they can be suitably protected, early construction will facilitate adoption by the organisation which is to own / maintain the drainage system.

2. The contractor and all relevant operatives should have an understanding of the mechanism and purpose of the SUDS components to ensure appropriate construction practice and protection is carried out.

Box 6.1 Construction considerations for SUDS (continued)

3. Traditional car parking and other paved areas are usually partially constructed during the initial stages of the development to provide storage and access on the site. However, if pervious surfaces are to be used in these areas, the construction process needs to be modified to prevent sediments from clogging the structure. Guidance on this is provided in Section 6.1.
4. If a pervious pavement is to be lined, the use of hardcore for structural purposes below the level of the liner can be applied. However the use of hardcore is not advised if infiltration is intended, due to the high proportion of fines.
5. Ground levels adjacent to pervious pavements must be set such so as to prevent any overland sediment washoff during high intensity rainfall events, or groundwater seepage during prolonged wet periods.
6. No traffic should be allowed on to the pavement if it is likely to introduce sediments onto the pavement surface from dusty or muddy areas.
7. Sensitive ground, such as chalk, may require the use of total exclusion zones to prevent compaction and other damage of the ground that will affect the infiltration performance of any infiltrating SUDS component. This may include protection from runoff during construction if the component is located at a low point on the site.
8. When excavating materials such as chalk, surfaces must not be smeared to avoid blocking fissures and pores.
9. The construction of swales, basins and ponds at an early stage in the construction will assist in managing runoff and help settle out the high volumes of sediments created during construction. However, complete reinstatement of these components will be required once construction is finished. It should be noted that the maintenance period is likely to stipulate establishment of landscaping vegetation, and sediment removal some time after site works have been completed.
10. The importance of good landscaping is emphasised. As SUDS systems are surface systems, attention to detail and aesthetics must be given a high priority. The seasonal and physical requirements of planting and establishing vegetation and prevention of soil erosion must be programmed appropriately.
11. Appropriate operative skills with an understanding of all aspects of vegetation should be obtained. In particular, the use of nutrients and mulches should be minimised and a particular soil mix will often be needed for the SUDS component.
12. Green roofs will not only require the consideration of appropriate season and skills, but the time needed to plant the roof areas needs to be specifically allowed for.

6.1 CONSTRUCTION ADVICE FOR PERVIOUS PAVEMENTS

Fundamental to the construction of residential developments, is the use of the site road system to provide access within the site to assist in the construction process. Not only is this a construction necessity, it can also be a requirement of the highway authority, to mitigate the deposition of mud onto the public highway. It can also be a condition of planning.

To prevent damage to the pervious pavement and its long term operation, protective measures need to be introduced. The following is suggested.

- Following the construction of deeper services such as sewers (below formation), install the sub-base layers.
- In lieu of the top geotextile layer (if designed) and the bedding and paving, an additional tarmac running layer is installed. This provides support for construction and residential traffic and protects the permeable base of the road.
- Following the completion of construction activities on the dwellings, at the time when final wearing courses are normally applied, the tarmac layer is normally removed. Leaving the tarmac layer in-situ and puncturing it at a minimum of 1.0m centres is sometimes practised, but as this concentrates the flows, the risk of blockage is increased and is therefore not recommended. It also provides a horizontal plane reducing the friction resistance to horizontal forces (braking).
- Finally the geotextile, bedding layer and paving are installed as normal.

Note that if the tarmac layer is retained, the difference between temporary and final surface level is significant and should be specifically considered in the design. If removed (sacrificial layer), the difference is much less. It also minimises hydrocarbon contamination of the runoff passing through pavement, if the final running surface is concrete blockwork.

7. Drainage design and performance assessment

Detail design and evaluation of the drainage system performance is presented in this chapter. The use of SUDS, together with discharge consent requirements, means that drainage design needs to consider a number of issues to ensure the system will operate without undue maintenance requirements and provide an environmentally appropriate solution.

7.1 INTRODUCTION

In virtually all cases, development sites will not be allowed to install a traditional drainage system with unrestrained runoff to the receiving water or drainage system. The system will normally be required to provide:

- discharge rates and volumes no greater than those prior to development,
- attenuation storage, and
- a range of different treatment methods and volume reduction techniques.

The principle being applied by current design criteria is to endeavour to produce runoff from a development that has similar discharge characteristics to the pre-development state.

The introduction of these criteria and the use of a range of SUDS components should not be at the expense of increased maintenance requirements or an increase in the risk of failure.

These criteria mean that a more complex approach is required for drainage design compared to traditional surface water pipe-based systems. However to try and provide assistance with the design, some rules of thumb and design charts are provided to assist with the design of the drainage system. It should be noted that, due to the variety of SUDS components and their different performance characteristics, it is likely that proof of the hydraulic adequacy of the system will usually require a hydraulic model to be used at the stage of detailed design.

7.2 DESIGN PROCESS

7.2.1 Initial design

The design process is normally undertaken in 2 stages. An initial analysis is carried out to assist in:

- development of a drainage strategy (required as part of a Drainage Assessment),
- assessing likely drainage land-take and an indication of the direct drainage costs,
- defining the flow conveyance through the site, and
- discussions with the local authority, maintenance stakeholders and the environmental regulator.

Subsequent detailed design and evaluation will then be needed to demonstrate that the system performs as required.

The initial assessment for a site should consider the stormwater constraints imposed by the catchment and the opportunities for use of appropriate SUDS (and in particular, infiltration techniques) based on the site characteristics. Distribution of storage across the site using a range of SUDS components is desirable, as this results in a reduction of the storage volume of the final attenuation structure and allows more flexibility in the design of a development.

An outline design of the conveyance process to be used across the site is necessary. This must include consideration of any downstream constraints created by receiving water levels.

The plan area requirements of the storage components and their location should be considered, recognising that there might well be spatial constraints due to the need to meet housing density requirements.

Figure 7.1 outlines the design process for the drainage system. The stages in yellow define the storage needs of the site.

Initial evaluation of storage requirements can be found in “Preliminary rainfall runoff management” (Environment Agency, 2004). There is supporting software available for this guide available from the Environment Agency. Storage issues are discussed further in Section 7.5.

Initial sizing of pipework can be based on a constant rainfall intensity of 30mm/hr to 50mm/h. The lower intensity would apply to the north of the country, while 50mm/hr would be more appropriate to the south and east with an allowance for climate change. Where pipework serves SUDS components which attenuate the runoff, these sizes will be conservative / over sized.

7.2.2 Detailed design

Detailed drainage design and analysis involves the evaluation of the performance of the whole drainage system. Due to the range of SUDS components and their very different hydraulic characteristics, a detailed evaluation requires a detailed model that can replicate the system accurately. Approximations can be made depending on the analysis objective, but to obtain a complete picture of performance, all SUDS components and pipework need to be modelled.

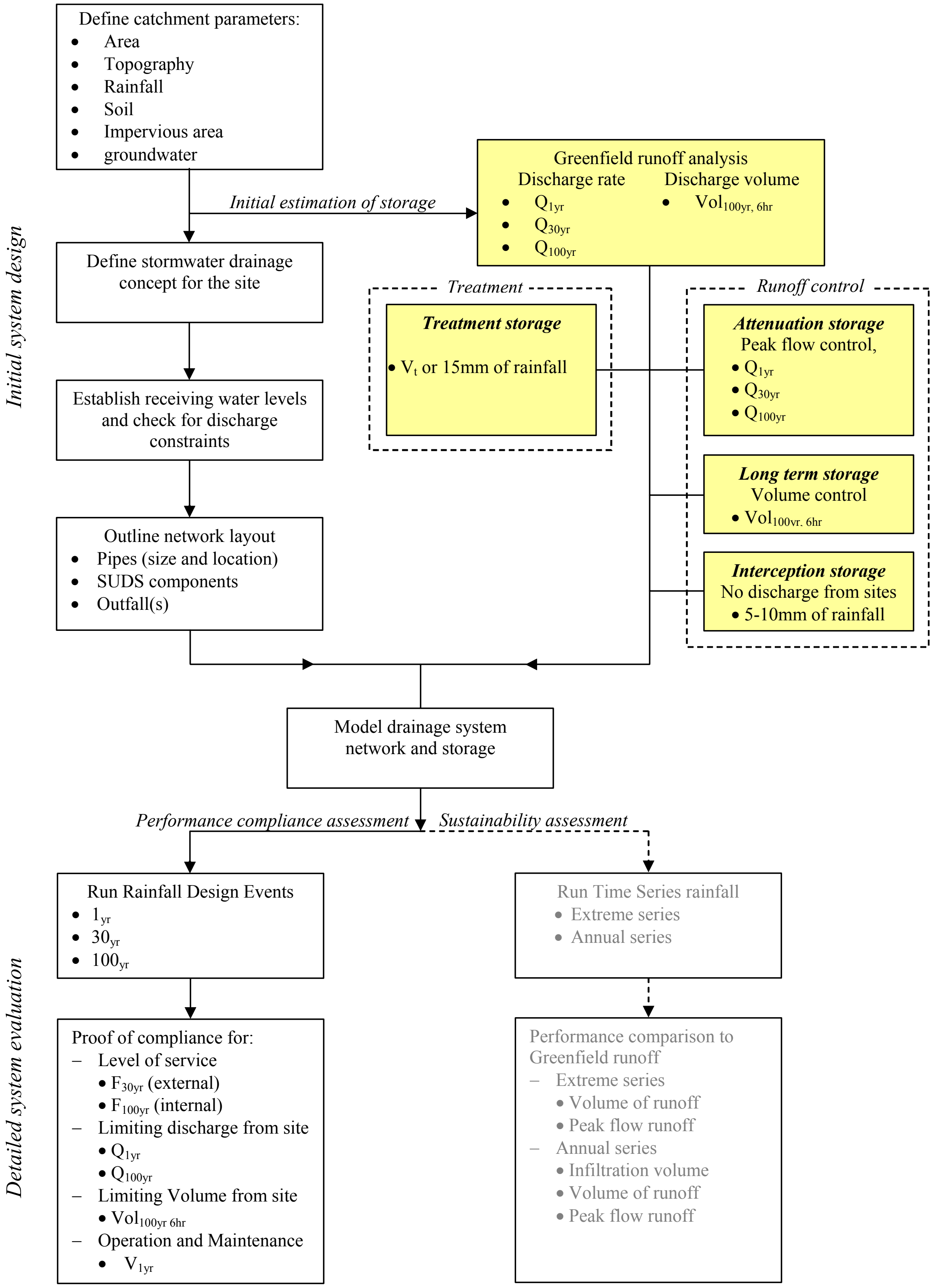
The model needs to be able to:

- predict flow rates and velocities for all parts of the system providing conveyance,
- predict depths of storage in all storage components,
- take account of infiltration rates and volumes,
- predict flood flows and routes due to exceedance of the system capacity,
- take account of downstream backwater effects.

The detailed design process is shown on Figure 7.1 and comprises two possible sets of analyses. These are:

- use of a range of designs storms to:
  - show that the system is robust (self cleansing and erosion velocities)
  - prove an adequate level of service against flooding is provided, and
  - demonstrate compliance to discharge consent stipulations.
- Use of an extreme and an annual rainfall time series to show that the drainage system is sustainable (as measured against greenfield runoff for the site) by assessing:
  - annual infiltration volumes to groundwater
  - extreme event flow rates and volumes discharged to the river
  - frequent event flow rates and volumes discharged to the river

The second set of assessments is (at present) not a requirement of drainage system performance evaluation. Figure 7.2 illustrates the various components of a drainage system and the various hydraulic performance issues.



Q_{1yr} *Peak discharge rate for 1 year return period*
F_{30yr} *Flooding volume (and location) for 30 year return period*
Vol_{100yr} *The volume of storage for 100 year return period*
V_{1yr} *Velocity of conveyance systems for 1 year return period*

Figure 7.1 Schematic of the drainage design process

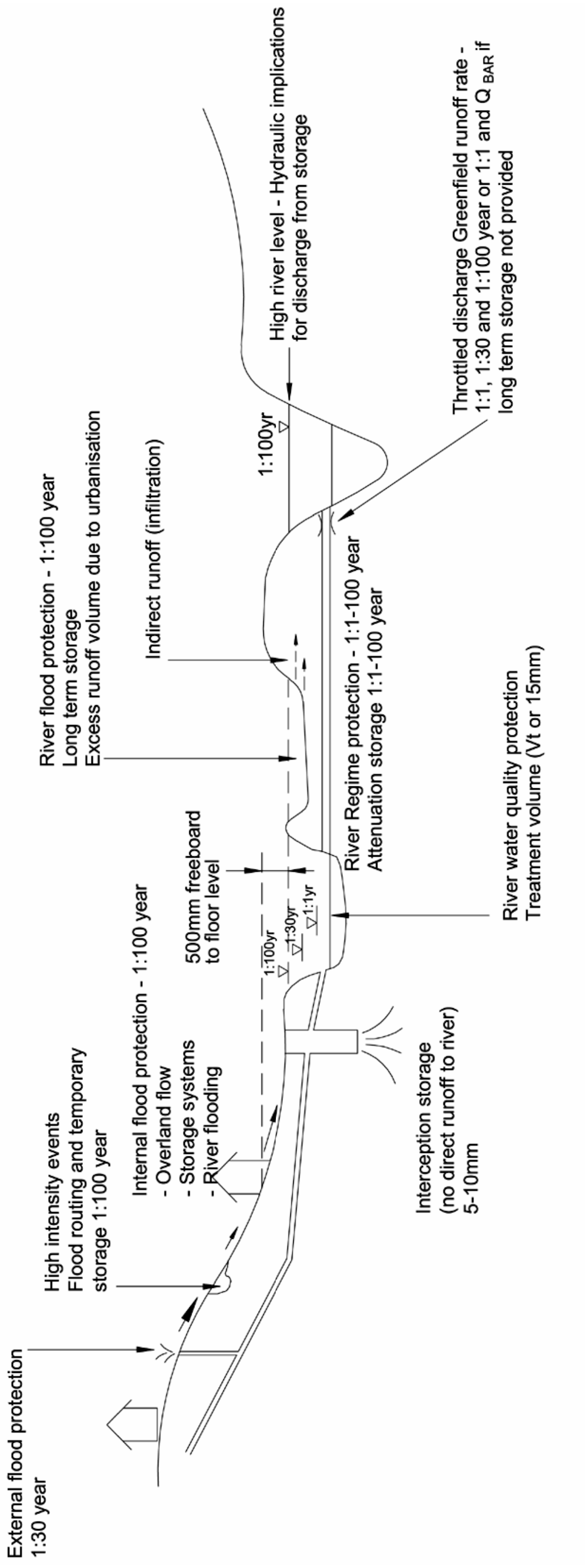


Figure 7.2 Drainage system performance requirements

The traditional approach to drainage system performance assessment since the introduction of the Wallingford Procedure in 1981 has been to use design storms of various return periods and durations. In general this provides a suitable method for assessing system performance and is much more computationally efficient than using time series rainfall.

However it should be recognised that SUDS systems are more complex than traditional pipe systems and that design storms only provide an approximate assessment of their performance. In addition, due to the emphasis on sustainability and water quality, the use of time series rainfall provides much more information on the performance of the drainage system. In due course it is likely that larger developments are likely to need to demonstrate that their drainage proposals are "sustainable".

Each of the three types of system performance measurements is detailed in turn. Some guidance rules of thumb and figures are also to be provided to give some assistance with the initial design of the drainage system.

The evaluation of sustainability will then be summarised briefly in outline for information purposes.

7.3 LEVEL OF SERVICE FLOOD PROTECTION

The detailed design of the stormwater networks, including all SUDS components, should comply with the Sewers for Adoption 5th Edition (WRc, 2001) criteria for:

- No flooding at 30 year event
- Consideration of extreme events (normally 100 year event) for flood routing and the location and extent of flooding.

Sewers for Adoption 5th Edition does not specify the return period of what constitutes an extreme event. It is normally a requirement to consider events of at least 100 years and take a risk based approach to check on the consequences of any "failure" that might take place.

These criteria normally result in consideration of short high intensity storms at 30 year and 100 years to check on local flooding and overland flow. With traditional pipe based systems the critical duration is usually 15 to 30 minutes. However the use of SUDS tends to result in more storage provision and the critical duration event will generally be longer. As SUDS performance will vary between component types and is also influenced by topography, it will be important to run a range of durations to evaluate all parts of the drainage system.

Maximum depths of flooding on storage areas will be dictated by longer critical duration events than for assessing the peak flow rate of flood flows. Consideration of flood depth is important to ensure that floor levels in properties are at a suitable level.

The use of SUDS introduces a number of other design issues related to flooding that need to be considered. These are:

- Robustness of the component
- Implications of reduction in performance or failure

The use of ponds and basins may result in the construction of embankments for water retention, the possible failure of which needs to be considered. Other SUDS components may have a risk of reduced hydraulic performance over time. Specific consideration should be given to the probability and consequences of failure of any part of the drainage system. Flood routing due to possible failure should be evaluated for all system elements where this might have a significant impact.

In particular, although the use of SUDS within the private curtilage is desirable to maximise the use of source control opportunities, there are particular risks related to possible change of use by the house-holder in the long term. A risk evaluation should be made to assist in the selection of appropriate design options.

7.3.1 Simple design methods

Pipes

As stated in Section 7.2.1 the sizing of pipes is often based on a constant rainfall intensity ranging from 30 to 50mm/hr. It is normally found that this provides an adequate level of flood protection, when tested in a model.

Gradients of pipes need to achieve 1m/s to meet the criterion set by Sewers for Adoption. A simple rule of thumb is that gradients can be the inverse of the diameter size, with a minimum gradient of 1:500. Thus a 150mm pipe can be laid to a minimum gradient of 1:150 and still achieve self cleansing velocity; however preferred (traditional) gradients of 1:DN/2.5 (i.e. 100mm pipe at 1:40) provide a more acceptable contingency against low flows, less than perfect workmanship and ground movements.

These gradients may also meet the more relaxed velocity criteria (Chapter 3) of 0.3m/s downstream of SUDS systems which provide high levels of attenuation. However this will be a function of the design of the SUDS component and levels of SUDS workmanship that may be reasonably anticipated. This suggested criterion is only applicable where sediment loads are considered to be minimal to avoid risk of blockage.

Pervious Pavements

Standard pervious pavements constructed with granular media will provide around 100 year return period level of protection with a "surcharge" loading of an additional area equal to twice that of the paved area with quite constrained outflow rates. The level of service is lower in the wetter areas of the north and west.

Swales

Similar to pervious pavements, the storage volumes in swales (with relatively flat gradients) are large, so that even with highly constrained outflow discharge rates they provide very high levels of service against flooding.

Linear ponds

Linear ponds provide both the advantages of high volumes of temporary storage as well as excellent conveyance facility in flat terrains, thus generating a high level of service.

7.4 SYSTEM ROBUSTNESS – OPERATION AND MAINTENANCE

System performance for normal operation needs to be evaluated to ensure that maintenance requirements are minimal. Pipe flow requires to be self cleansing in accordance with Sewers for Adoption 5th Edition, while flows in vegetated components (swales etc) should be as low as possible to prevent erosion as well as to maximise sediment deposition.

Pipe full flow should have a minimum velocity of 1m/s for a 1 year event where areas are served by a pipe and gully system. However, pipe systems serving pervious pavements and other components providing high levels of attenuation will rarely provide sufficient flow rate to achieve 1m/s for a 1 year event. Fortunately, the sediment yield from these SUDS components is very low and therefore reduced velocities are acceptable. It is suggested that these can be as low as 0.3 m/s.

Flows in vegetated channels should preferably be in the region of 0.1-0.3m/s for frequent rainfall events, and be no more than 1m/s for a 1 year event.

It should be recognised that drainage modelling of SUDS systems is unlikely to be as accurate as modelling pipe networks due to the effects of vegetation and soil types.

Light liquid separators also act as effective sediment traps, as well as providing protection against hydrocarbon pollution. However where high sediment volumes are likely, it is normal to use proprietary products to deal with the sediment load prior to flows passing into the liquid separator.

7.5 STORAGE TO MEET DISCHARGE CONSENTS

The design criteria for development runoff are normally based on runoff being controlled to mimic, as far as is practicable, the original greenfield runoff behaviour, unless the situation is such that some or all of these can be relaxed. This requires the greenfield runoff characteristics for the site to be estimated, so that the performance requirements of the drainage system can be set. There are two hydraulic characteristics of greenfield runoff that need to be considered. These are:

- greenfield runoff rate, and
- greenfield runoff volume.

In addition, although not quantified, the water quality characteristics of the runoff should be addressed.

These criteria result in the requirement for 4 types of storage. These are:

- Interception storage
- Attenuation storage
- Long term storage (for river flood protection)
- Treatment volume storage

Interception storage

Interception storage comprises the prevention of any runoff for the first 5 to 10mm of rainfall into the receiving water. In practice although certain parts of the site might achieve this criterion, it is unlikely that all paved runoff will be prevented from causing any discharge for these frequent events. However if greenfield runoff is to be replicated, then this criterion is an important one to achieve, as greenfield sites rarely produce any runoff for the many small rainfall events that occur.

Any interception storage provided reduces the attenuation storage requirement and also, depending on how the long term storage is provided, reduces the long term storage volume requirement.

Attenuation storage

Having determined the peak rates of runoff for greenfield conditions, the attenuation storage volumes needed to meet this criterion can be determined. This can be done by using:

- a drainage system computer model, or
- estimate an initial assessment using the Environment Agency guide (Environment Agency, 2004) and supporting software tool. The guide is in the form of look-up tables and graphs to provide an initial estimate of storage volume, or
- a coarse rule of thumb (Table 7.4) which should be treated with extreme caution, but which provides an indication of the order of magnitude of attenuation storage needed as a function of soil type.

Appendix 3 provides additional information on alternative storage volumes.

Long term storage

Long term storage is the term given to the additional stormwater runoff volume which is generated by the development compared to what used to be discharged from the greenfield site. The water stored in this location should preferably be infiltrated or discharged to the receiving river at a rate of less than 2l/s/ha. The reason for this requirement is to limit any significant increase in flood risk in the river downstream during extreme events. Therefore activation of the storage need not take place except during extreme rainfall although this is may be difficult to achieve in practice. This means that the flood storage area need not necessarily be in the form of a drainage structure. Good planning design of the site will enable an appropriate area to be flooded when necessary.

Long term storage is effectively a component of the attenuation storage volume. Appendix 2 provides an illustration of the analysis carried out to calculate the various storage volumes required.

Treatment storage

Treatment storage has been described earlier in Section 3.4 and is normally provided as the permanent pool volume of the attenuation pond(s).

Figure 7.3 shows the various components of storage and illustrates how the various storage components integrate.

7.5.1 Simple design methods – interception storage

The criterion for interception storage is to provide interception of all runoff for the first 5 to 10mm. As the first millimetre of rainfall can be assumed as just wetting the ground, Table 7.1 summarises the minimum and desirable volumes of runoff which should be intercepted. This is based on an assumption of a paved proportion of 70% and a runoff factor of 60% (which is appropriate for small events).

Table 7.1 Interception volume for a typical development

Interception volume from 5mm of rainfall (m^3/ha)	Interception volume from 10mm of rainfall (m^3/ha)
17	38

Swales

It should be noted that if mini swales are provided along 50% of the road length on each side of the road, that 100mm depth of storage provides more than 15mm of effective storage for road runoff. This provides very significant water quality benefits without a large take-up of land.

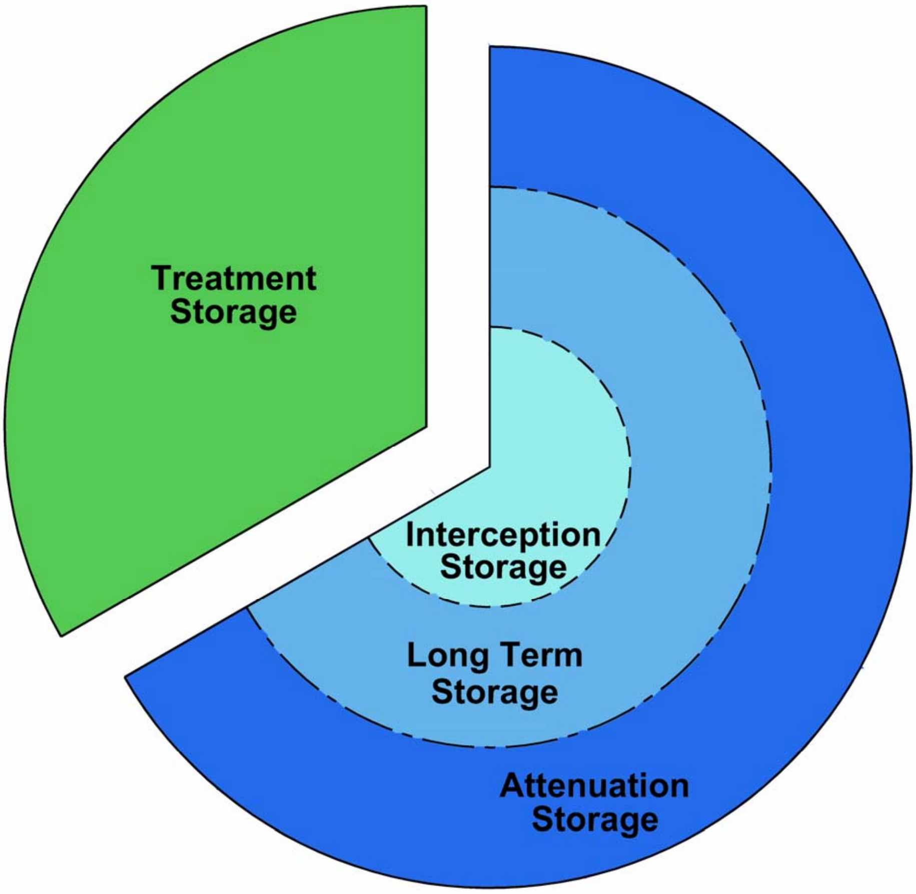


Figure 7.3 Storage components for stormwater runoff control

7.5.2 Simple design methods – long term storage

Long term storage is a simple calculation of storage volume based on the 100 year 6 hour event. Figure 7.4 shows the 100 year 6 hour map of UK and Figures 7.5 and 7.6 show the additional runoff volume per hectare for a range of soil types and level of impermeability (extent of pavement and roofs) of the site.

Assuming that Figure 7.5 applies, (that no runoff takes place from pervious areas after development), the volumes in Table 7.2 can be derived. This provides an estimate of the long term storage based on 80% runoff for a 70% level of impermeability.

Table 7.2 Long term storage for a typical development

SOIL type	Storage volume (m^3/ha)
1	320
2	180
3	130
4	60
5	20

Greenfield runoff is generally much less than the runoff generated after the site has been developed. This difference becomes proportionally less as rainfall events become more extreme such that heavy clay catchments generate similar greenfield runoff volumes to that produced by the development. However greenfield areas with permeable soils always generate much less runoff events for extreme events.

The estimation of runoff volume from greenfield areas is based on FSSR 16 (NERC, 1985), which is detailed in Appendix 1. However this closely approximates to an assumption that runoff volume is equal to the standard percentage runoff (SPR) value for the given soil type. Table 7.3 gives the SPR value for each of the 5 soil types used in the formula. See Table 7.6 for a description of the different SOIL types.

Table 7.3 SPR values for different SOIL values (from FSR)

SOIL	SPR value (runoff factor)
1	0.1
2	0.3
3	0.37
4	0.47
5	0.53

As runoff is approximately proportional to rainfall depth, it is not easy to design a drainage system to make it generate the same greenfield runoff volume for every rainfall event. Therefore for simplicity this criterion is applied to the 100 year 6 hour rainfall. There is usually no criterion for frequent rainfall events as there is effectively no direct runoff from these events on greenfield catchments. The use of 6 hours, rather than another time period, is selected based on the fact that small catchments have critical rainfall durations of around 4 to 6 hours. A development in a small catchment is likely to have significantly more impact than one in a large catchment and therefore provides some justification for use of this event duration. Figure 7.4 provides the values of 100 year 60 hour rainfall depths for the 7 hydrological FSR regions across the UK.

Calculation of long term storage is simple, but requires a decision as to whether the unpaved areas are assumed to contribute runoff or not. The following formula allows assumptions to be made as to whether some or all of the paved and pervious areas contribute runoff. The formula assumes that only 80% runoff occurs from paved areas, but 100% runoff can be assumed if it is felt that a more conservative assumption is needed.

$$Vol_{xs} = RD.A.10\left[\frac{PIMP}{100}(\alpha 0.8) + \left(1 - \frac{PIMP}{100}\right)(\beta.SPR) - SPR\right] \quad (7.1)$$

Where:

Vol_{XS} is the extra runoff volume (m^3) of development runoff over greenfield runoff
RD is the rainfall depth for the 100 year, 6 hour event (mm)
PIMP is the impermeable area as a percentage of the total area (values from 0 to 100)
A is the area of the site (ha)
SPR is the "SPR" value for the relevant SOIL type
α is the proportion of paved area draining to the network or directly to the river (values from 0 to 1)
β is the proportion of pervious area draining to the network or directly to the river (values from 0 to 1)

This formula can be simplified by assuming that either all the pervious runoff continues to contribute as it did in the greenfield conditions, or that none of it contributes. The difference in additional runoff volume calculated is quite significant even for quite heavily developed catchments.

If all the paved area is assumed to drain to the network and all the pervious areas are landscaped not to enter the drainage system or river, this formula simplifies to:

$$Vol_{xs} = RD.A.10\left(0.8\frac{PIMP}{100} - SPR\right) \qquad \text{(Eqn. 7.2)}$$

But where all pervious areas are assumed to continue to drain to the river or network the formula becomes:

$$Vol_{xs} = RD.A.10\left(0.8\frac{PIMP}{100} - \frac{PIMP}{100}.SPR\right) \qquad \text{(Eqn. 7.3)}$$

Figures 7.5 and 7.6 illustrate the difference in runoff volume for these two extremes (fully disconnected / fully connected pervious surfaces) for the five different soil types for any development density. To obtain a volume the y-axis value is multiplied by the catchment area and the rainfall depth. These graphs demonstrate the great effect soil type has on long term storage volume, the importance of using infiltration to disconnect impermeable areas from the drainage network and the need to be efficient in designing the general landscape to prevent runoff from pervious areas.

7.5.3 Simple design methods – Attenuation storage

Attenuation storage is a function of climate, soil and site development characteristics. It is therefore impossible to provide a simple guidance look up table which is accurate. However for the purpose of providing an indication of the order of magnitude, Table 7.4 provides an indication of the typical volumes of storage that are likely to be required as attenuation storage. It is stressed that these estimates are only to be treated as being indicative and more detailed analysis will be needed when the drainage system is designed. Appendix 3 provides more information for attenuation storage volumes.

Table 7.4 is followed by an explanation of the process for calculating a more accurate estimate.

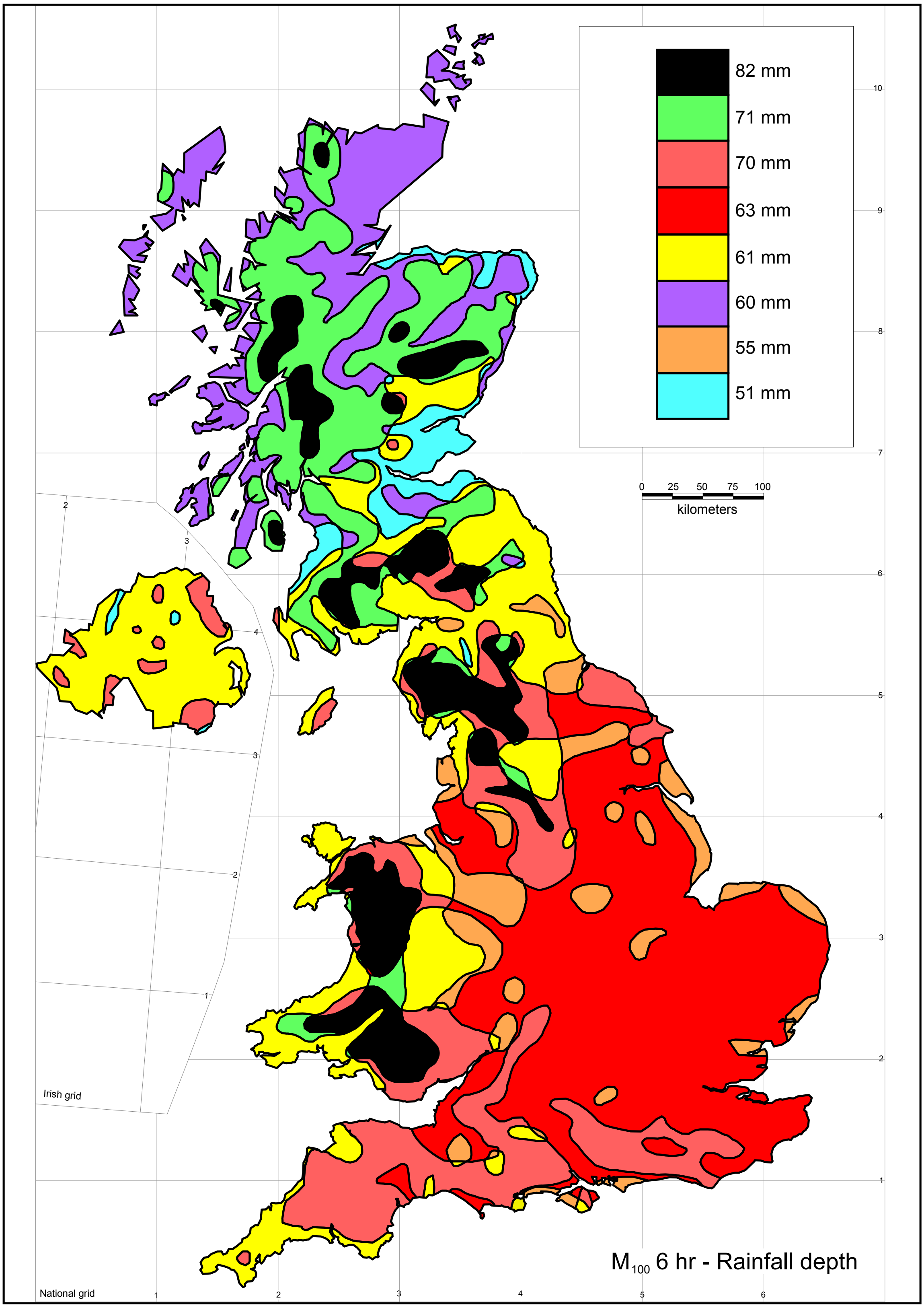


Figure 7.4 100 year 6 hour rainfall depths for hydrological FSR regions across the UK

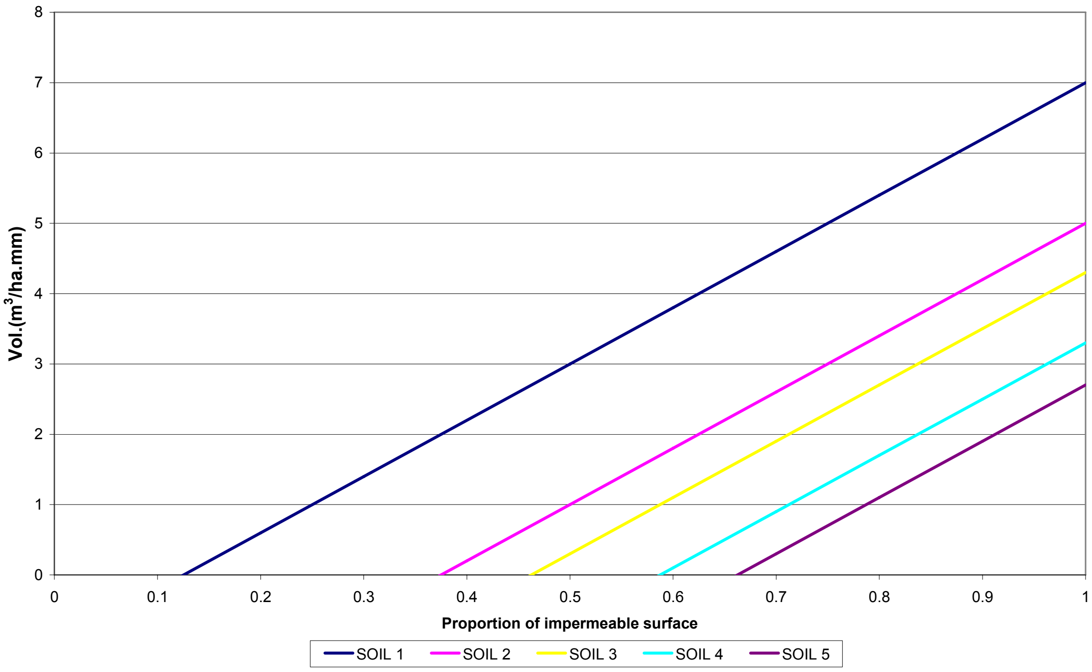


Figure 7.5 Additional runoff volume caused by development where all pervious areas are assumed not to drain to the drainage network (Eqn. 7.2)

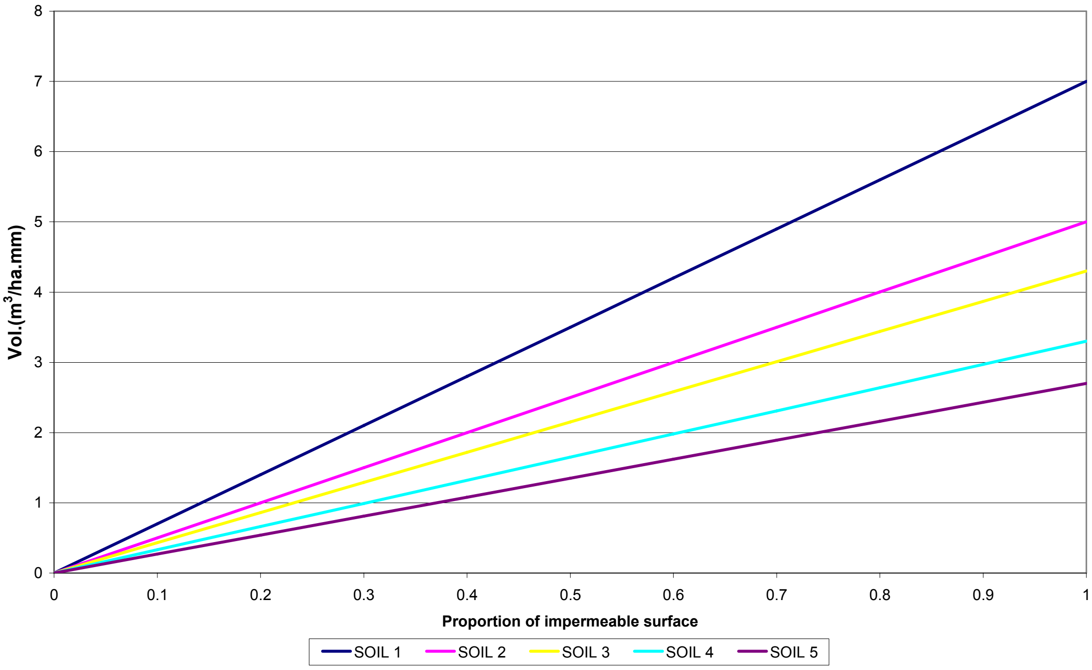


Figure 7.6 Additional runoff caused by developments where all pervious areas are assumed to drain to the drainage network (Eqn. 7.3)

Table 7.4 Approximate attenuation storage volumes required for a typical site for a 100 year event

SOIL type	Volume of storage (m^3/ha)
1	450
2	420
3	390
4	330
5	250

These estimates are based on average runoff control rates and present day rainfall. In the case of SOIL type 1, although the greenfield runoff rate is usually calculated to be less than 1l/s/ha, this figure is usually used as a minimum for reasons of practicality.

It can be seen from these figures that if it is assumed that the attenuation volume is on average 1m deep, the catchment proportion needed for storage ranges from 4.5% for SOIL type 1 down to 2.5% for SOIL type 5. This draws attention to the needed to distribute storage as much as possible in upstream components such as pervious pavements. Subject to the design approach, the distribution of storage can proportionally reduce the volume required by the final attenuation structure. In addition the provision of interception and long term storage will also reduce the attenuation requirements and therefore the land take of such structures.

The calculation of attenuation volume requires an analysis of greenfield runoff rate.

Greenfield runoff rate

The regulatory authority will normally require the rate of runoff from a development for a range of return periods up to and including the 1 in 100 year return period to be no greater than the greenfield runoff rate for the same range of return periods.

The recommended methods for estimating greenfield runoff rates for development sites are outlined in Table 7.5. Appendix 1 provides an example of determining the runoff characteristics of a greenfield site.

Table 7.5 Recommended greenfield runoff rate estimation (SUDS Interim Code of Practice)

Development size	Method
0 – 50ha	The Institute of Hydrology Report 124 Flood estimation for small catchments (1994) (Institute of Hydrology, 1994) should be used to determine peak greenfield runoff rates. Where developments are smaller than 50ha, the analysis for determining greenfield discharge rate should use 50ha in the formula but linearly interpolate the flow rate value based on the ratio of the development area to 50ha. FSSR 2 and FSSR 14 regional growth curve factors should be used to calculate greenfield peak flow rates for 1 and 100 year return periods.
50-200 ha	IH Report 124 should be used to calculate greenfield peak flow rates. Regional growth factors to be applied.

Table 7.5 Recommended greenfield runoff rate estimation (SUDS Interim Code of Practice) *continued*

Development size	Method
Above 200ha	IH Report 124 can be used for catchments that are much larger than 200ha. However, for schemes of this size it is recommended that the Flood Estimation Handbook (FEH) (Institute of Hydrology, 1999) should be applied. Both the statistical approach and the unit hydrograph approach should be used to calculate peak flow rates. However, where FEH is not considered appropriate for the calculation of greenfield runoff for the development site, for whatever reasons, IH 124 should be used.

Other methods for estimating greenfield runoff are available, for example MAFF Report 345 (MAFF, 1981). A brief overview and comparison of these other methods is given in Kellagher (2004). It should be recognised that the level of accuracy for predicting the runoff rate for any undeveloped small catchment, using IH 124 or any other formula, is limited. The use of this formula is only important in that it provides a consistent, easy to use method for assessing appropriate limiting discharge control volumes.

The equation given in IH 124 is based on the Flood Studies Report (Institute of Hydrology, 1975) work with measurements from a few additional catchments. It predicts a value for the mean annual flood, Q_{BAR}.

$$Q_{BAR} = 0.00108 AREA^{0.89} SAAR^{1.17} SPR^{2.17} \quad (7.4)$$

where:

Q_{BAR} is the mean annual flood flow from a rural catchment in m^3/s

AREA is the area of the catchment in km^2.

SAAR is the standard average annual rainfall for the period 1941 to 1970 in mm.

SPR* is the SPR value for the SOIL index, which is a composite index determined from soil survey maps that accompany the Flood Studies Report. Details are given in Table 7.6.

** The term SOIL is normally used in this equation, to refer to the equivalent SPR value. The term SPR has therefore been substituted to reduce the potential for confusion.*

Table 7.6 SOIL Index descriptions (from the Flood Studies Report, Institute of Hydrology, 1975)

SOIL Index	Description of soil type
1	• Well-drained permeable sandy or loamy soils and shallow analogues over highly permeable limestone, chalk, limestone or related drifts. • Earthy peat soils drained by dikes or pumps. • Less permeable loamy over clayey soils on plateaux adjacent to very permeable soils in valleys.
2	• Very permeable soils with shallow ground water. • Permeable soils over rock or fragipan, commonly on slopes in Western Britain associated with smaller areas of less permeable wet soils. • Moderately permeable soils, some with slowly permeable subsoils.

Table 7.6 SOIL Index descriptions (from the Flood Studies Report, Institute of Hydrology, 1975) *continued*

SOIL Index	Description of soil type
3	• Relatively impermeable soils in boulder and sedimentary clays, and in alluvium, especially in Eastern England. • Permeable soils with shallow groundwater in low lying areas. • Mixed areas of permeable and impermeable soils in approximately equal proportions.
4	Clayey or loamy over clayey soils with an impermeable layer at shallow depth.
5	Soils of the wet uplands: (i) with peaty or humose surface horizons and impermeable layers at shallow depth, (ii) deep raw peat associated with gentle upland slopes or basin sites, (iii) bare rock cliffs and screes, and (iv) shallow impermeable rocky soils on steep slopes.

What should be particularly noted is that Q_{BAR} is virtually proportional to area and annual rainfall depth, but is significantly influenced by soil type.

Q_{BAR} is factored using the regional growth curves for UK to produce peak flow rates for other return periods. This information is available in Flood Studies Supplementary Reports 2 and 14 (NERC, 1977 and 1987) produced by the Institute of Hydrology. Table 7.7 summarises the factors for the 1 year and 100 year return periods for each hydrological region.

Table 7.7 Hydrological region factors for Q_{BAR}

Region	Factor for 1 year return period	Factor for 100 year return period
1	0.85	2.47
2	0.87	2.61
3	0.86	2.10
4	0.83	2.61
5	0.87	3.50
6	0.85	3.16
7	0.85	3.16
8	0.78	2.40
9	0.88	2.20
10	0.87	2.10

It is advised that the formula for determining the peak greenfield runoff rate should not be applied to areas that are less than 50 hectares. As many developments are smaller than this size, this constraint is avoided by calculating Q_{BAR} for 50 hectares and linearly extrapolating flow rates for smaller areas. This is a reasonably conservative application of the formula.

Table 7.8 Typical values of Q_{BAR} for SAAR of 700mm and a site of 50ha

SOIL type	SOIL type 1	SOIL type 2	SOIL type 3	SOIL type 4	SOIL type 5
Q_{BAR} (l/s)	8.4*	91.1	143.6	241.4	313.3
Q_{BAR} (l/s/ha)	0.2*	1.8	2.9	4.8	6.3

A minimum value for Q_{BAR} of 1l/s/ha is normally applied for practicality.

A limitation of the IH 124 method is the lack of a slope function. This may be particularly significant for small steep catchments and therefore in these instances the use of appropriate alternative methods for estimating greenfield runoff rates, such as MAFF 345, might be considered. If IH 124 is applied the results may be overly conservative.

7.5.4 Simple design methods - Runoff treatment

The final form of stormwater storage is the provision of treatment storage which has been described in Section 3.4 and is revisited here. Theoretically this can be provided by a number of SUDS components, but in practice it usually refers to the permanent pool volume in an attenuation storage pond. The objective of the permanent pool is to enable sedimentation to take place and also make use of any biological or chemical processes that might usefully treat the runoff. The size of the storage is often calculated using Equation 7.5 and then factored by as much as four times, though this is not now regarded as appropriate in most cases. It is currently recommended that the permanent pool should normally be approximately a factor of one times the treatment volume.

$$V_t\ (m^3/ha) = 9 \times D(SPR/2 + (1 - SPR/2) \times I) \qquad (7.5)$$

Where:
I = fraction of the area which is impervious
D = M5-60 rainfall depth (5 Year Return, 60 minute duration)
SPR = SPR value for SOIL classification (from Flood Studies Report or the Wallingford Procedure WRAP map)

V_t is thus a function of local hydrological characteristics, soil type and the level of impermeability of the catchment.

Depending on where this formula is applied, this volume approximates to the runoff from rainfall of between 12 to 20mm of rainfall. The intention is that this provides at least 24 hour retention for 90% of all rainfall events. The treatment volume for 15mm of rainfall at 80% runoff and an impermeable fraction of 70%, with all the paved area needing treatment is 84m^3/ha.

Current research suggests that a small base flow might be useful in preventing anaerobic conditions developing, particularly in hot dry periods, and that the retention volume can be too large as much as too small.

Although the treatment volume will have been determined at initial design stage, a check needs to be made that the relevant assumptions have not changed in the evolution of the design. Detailed design needs to consider the hydraulics of the final arrangement to ensure that no jetting or short circuiting of flows takes place.

7.6 REFINEMENT OF STORAGE VOLUME AND SYSTEM PERFORMANCE ASSESSMENT

Although initial analyses methods provided a quick assessment of the various storage requirements needed for managing stormwater runoff, a detailed model will be needed to take into account the head-discharge relationship of all the storage components.

Where there is a risk of backwater effects, these need to be considered, particularly with outfalls to rivers. It should be noted that the critical duration of storage systems is often of the order of 12 to 24 hours. Rivers rise to their maximum flood level in similar events and therefore there is likely to be a significant degree of dependency. Before carrying out a joint probability assessment, it is suggested that an initial simple approach is taken by assuming that the water level in the receiving stream is at its maximum level for the critical duration event for the pond. A more detailed joint probability assessment may be needed if the implications for the storage system volume are very significant.

Compliance to the criteria of 1 and 100 year discharge limits needs to be demonstrated by running the model with a range of rainfall events of various durations for each return period and showing that discharge rates do not exceed the consent values.

7.6.1 Long term storage design

Where long term storage is provided as a temporary floodable area, consideration needs to be given to ownership and clean up responsibilities as well as the hydraulic drainage mechanisms. Under-drainage should be provided to ensure a relatively rapid return to its original state is achieved if public open space is flooded.

Compliance should be demonstrated using a detailed model by showing that the long term storage volume is retained for the 100 year event. The critical duration event is unlikely to be 6 hours, but likely to be similar to the critical duration for determining the attenuation storage volume.

7.7 FUTURE ADDITIONAL MEASURES OF SUSTAINABILITY OF DRAINAGE SYSTEMS

Although not required at present, the growing emphasis on water conservation, water quality and infiltration for groundwater replenishment, means that there will be a need to use time series rainfall to show the system characteristics on these issues.

The use of time series rainfall also has the benefit of showing the actual performance of the system as the different hydraulic characteristics of the SUDS components will be more accurately represented. This type of assessment will allow a more appropriate comparison to be made between greenfield conditions and the development drainage system for all storms, thus allowing a more accurate evaluation as to whether greenfield conditions have been reasonably replicated.

It is therefore anticipated that time series rainfall will become a feature of detailed design in due course, particularly for large developments.

8. Safety, Amenity and the Environment

This chapter looks at the opportunities SUDS provide for enhancing the amenity in a development and other environmental benefits. As many SUDS components involve storage of water which is accessible by the public, safety is also an important issue to address.

8.1 INTRODUCTION

The design of SUDS components must take into account a range of factors which may require trade-off compromises to be made to ensure that all the constraints of safety, amenity and the environment are all satisfied. Issues affecting these choices include maintenance costs, performance failure risk and liability.

The chapter is structured to look at each of the topic areas separately and then a summary is provided with a matrix to provide guidance on issues where decisions need to be made where there is potential conflict.

8.2 AMENITY

Amenity is a general term that it is useful to define. The Oxford English Dictionary (Oxford University Press, 1989) defines amenity as:

- “Something that contributes to physical or material comfort,”
- “A feature that increases attractiveness or value especially of a piece of real estate or a geographical location.”

As environment has been separated out, amenity can be considered to comprise aesthetics and potential for public use.

8.2.1 Aesthetics

All SUDS components, except underground infiltration systems, have elements of amenity, in that they are all visible to the public and therefore careful consideration should be given to their aesthetic impact. For example pervious pavements can make use of coloured blockwork to provide patterns as well as drawing attention to the purpose of the area. Thus car parks can differentiate parking bays and traffic lanes, or an area can be laid to provide artistic relief. There are very few negative implications for making use of this facility, although the concept of what is artistic is subjective and therefore may not be universally approved.

Vegetative components such as swales and ponds have considerable potential for being aesthetically enhanced. However the decisions relating to vegetation use will have implications for maintenance and possibly performance of the system. The ecological value of any component is dependent on the choices made. It should be noted that what might be considered to be aesthetically very pleasing to the public is often not an optimum solution for ecological diversity.

Another aspect on the choice of vegetation is the need for a safe environment. The design of ponds may involve the use of barrier planting which might be located within the pond margin or immediately adjacent to the pond edge. It is also considered important to have an open and clear view of a pond, not just because open water looks attractive, but also because it is considered to be a good safety feature, as children can be seen and appropriate action can be taken.

8.2.2 Active and passive public areas

Public open spaces are provided for people to enjoy in a variety of ways. These range from dog walking through to football and play areas. Open space can therefore be considered as being either active or passive areas. As ponds and basins can take up a significant part of the public open space, consideration needs to be made with regards to dual use of the land and activities that will be carried out adjacent to the SUDS component.

It is often suggested that large basin areas, that are normally dry, should be available for public use to maximise the value of the land. In practice the location of SUDS on an active area such as a football pitch has implications for which maintenance responsibility would have to be defined and agreed. The drainage authority who has responsibility for the basin is unlikely to want to be involved with areas which require high levels of maintenance, such as weekly grass cutting, for recreational reasons. In addition, the activity itself may detract from the effectiveness of the SUDS component and there may be safety aspects with regard to the pollutants in sediments. Active play areas located immediately adjacent to ponds might be considered to be unsafe, especially where it is targeted at young children.

There are also some concerns with regards to passive use of these areas. Due to the pressure of green space availability, dog walking tends to result in faeces adjacent to the pond with implications for both health and pollution. Even the provision of park benches encourages litter and food which can result in additional nutrients, encouragement of the local rat population and increased maintenance in ensuring a clean and tidy area.

It can be seen therefore that the design of the area adjacent to ponds and basins needs to be carefully carried out to encourage activities that are safe and discourage activities which are either unsafe or might cause operational problems.

8.3 ENVIRONMENT

The meaning of environment can be very wide. In this context environment refers primarily to the ecological and water quality benefits of SUDS, both within the SUDS component, adjacent to it and the receiving water body. Good ecology is measured in terms of bio-diversity of both flora (vegetation) and fauna (normally macro-invertebrates, but also insects and birds).

Water quality performance of a SUDS component is not just a function of the design of the component, but is related to the hydrological conditions, both dry periods and rainfall events, as well as the land that it drains. There are ways in which the water quality can be optimised and these will have implications for the ecology.

The water quality of stormwater using normal SUDS design techniques for a site will never be “pure”. Theoretically, given enough attention and space, the water quality at the outfall can be very good. However this is unlikely to be a requirement for most SUDS drainage systems for new developments, though designs will aim to meet the requirements of the Water Framework Directive (2000/60/EC). It should be recognised that the water quality in the SUDS components will affect the diversity of the flora and fauna. Although there has been a limited amount research on the subject, it is encouraging to note that the diversity can be quite high with the standard application of SUDS systems.

8.3.1 Optimising ecological diversity

The ecological value of most SUDS components is relatively small. Vegetative systems include swales, ponds and basins, and of these, ponds are by far the most important with regards to ecological value for an area. In fact ponds, natural or otherwise, provide a much higher level of diversity compared to other aquatic environments (HR Wallingford, 2003).

Swales can become bio-retention areas where the topography is relatively flat. However marshy areas, with unrestrained vegetation growth, look untidy and are unlikely to be aesthetically acceptable. The traditional approach of having regular mowing of a grassed component results in poor bio-diversity but generally meets with approval by the public.

Basins, when they are not directly within public view, such as in the centre of roundabouts, can be attended to far less frequently. This has advantages for maintenance costs as well as the ecology. However basins located in full public view will probably need to have a more managed appearance.

Much of the diversity in the aquatic environment is around the margin of the pond, particularly in the shallow water zone. Thus to maximise the value of a pond in terms of the ecology requires a virtually horizontal border at the pond edge and a shallow zone immediately within the pond. This border should not be "engineered" to be uniformly smooth. Local humps and bumps and a variety of materials such as wood and rocks all adds to the potential for diversity. Another advantage of this approach is that a muddy periphery will deter most people from walking into the pond. The disadvantage of this design is the inefficient use of land in meeting the hydraulic requirements for attenuation of the stormwater runoff.

Water quality treatment processes are maximised in the shallow zone, although as sedimentation is the most important process, the shallow margin only provides secondary water quality benefits.

The vegetation around the pond needs to be considered in terms of bio-diversity value and also as providing a barrier to ingress into the pond. These plants are not only diverse in themselves, but also provide the habitat for the macro-invertebrates and other animals.

A critical problem for urban stormwater ponds is the prevalence of invasive species. Once these take hold they can dominate the environment and wipe out diversity in the area. These species can be introduced intentionally or otherwise, and the proportion of urban ponds with this problem is of considerable concern. Box 8.1 advises on invasive species to be avoided.

The recommended approach is for allowing natural colonisation of the pond from native species. Where it is located next to natural open space, this colonisation can be quite rapid. Unfortunately this is rarely an acceptable solution as the adoption of the pond will often require establishment of the vegetation. Also, the need to provide a barrier means that certain species will need to be encouraged to grow.

Appropriate skills need to be used to ensure that pond design and planting is optimised. Expert guidance is available from a number of sources and information on plants that are local to any area is available from HR Wallingford (2003).

Box 8.1 Invasive alien wetland plants which pose a high risk to the environment. These plants should be excluded from all SUDS planting schemes (HR Wallingford, 2003)

- New Zealand Pigmy weed (*Crassula helmsii*)
- Parrot's-feather (*Myriophyllum aquaticum*)
- Floating Pennywort (*Hydrocotlye ranunculoides*)
- Water fern (e.g. *Azolla filiculoides* and close relatives)

Box 8.2 Issues associated with planting SUDS ponds (HR Wallingford, 2003)

- Ensure that the contract for all planting up of schemes specifies the requirement for 'native species of local provenance'.
- Where possible work with local plant suppliers to develop appropriate ranges of native plant species of local provenance.
- Include only common species (unless the scheme is part of a recognised conservation project to protect populations of a particular uncommon plant).
- Include only species which are characteristic of local ponds.
- Focus particularly on the more inconspicuous, but ecologically valuable, aquatic grasses, especially Creeping Bent and the Sweet-grasses (*Glyceria* species) which provide good invertebrate habitats.
- Ensure that an experienced botanist assesses planting schemes before projects are signed-off to check what has actually been planted (as opposed to specified). Check again for the presence of invasive species after one year.
- Contractors should be responsible for removing any unspecified material and make good any damage incurred to other plants.
- Check aquatic suppliers' premises in order to ensure that highly invasive species are not rampant and "growing wild" in their propagating areas (as has been observed at some sites).

Multiple ponds provide an opportunity to alter both the depth and shape of the pond, but more importantly, the water quality process of ponds in series results in a much better effluent quality and creates different communities of species. An additional advantage is that the maintenance activities such as vegetation control and sediment extraction, which cause some degree of disruption, will have much reduced impact on the pond community. A second advantage is that shock loads of pollution, such as accidental spillage, can be accommodated more effectively.

8.3.2 Water quality

The processes by which water quality improvements are obtained from SUDS systems range from biodegradation, sedimentation and filtration through to phytolosis. The most important of these are sedimentation and filtration. Different levels of water quality improvement are provided by different SUDS components.

Appropriate use of SUDS can result in discharges with sediment and BOD concentrations of the order of 20mg/l. Further polishing of the effluent to a higher standard is achievable, but at the cost of additional land take and SUDS components.

8.4 SAFETY

Safety is a crucial element for all engineering design including SUDS. This section looks at safety in terms of each SUDS element. In some instances guidance from appropriate authorities is not clear or contradictory, as there can be a difference of opinion as to the best way to maximise safety. However the guidance is usually straightforward and consistent.

It is presumed that all issues pertaining to CDM regulations are followed.

8.4.1 Swales and Bio-retention

Swales are shallow ditches that are normally placed besides roads, and the preferred mechanism for accepting runoff is sheet flow. In not providing kerbs there is some risk of damage to the swale edge either from deliberate parking or accidentally leaving the carriageway. In the case of the latter, the implication of vehicle speeds should be considered.

For these reasons, the use of kerbs is probably advisable in many instances, but this means that there is a risk of erosion in passing flows from the road into the swale. Trials, which have used multiple entries of small pipes through the kerb using shallow water collection components, have generally been shown not to work. The most effective way of introducing runoff into the swale is to use drop kerbs at frequent intervals. The spacing of these gaps should be frequent such that only half the length of the road edge is kerbed.

The chance of drowning in swales is remote if they are primarily designed as conveyance components. Components that are designed to store stormwater for a significant period of time, such as under-drained swales, may need to be evaluated in terms of the risk of drowning even though depths of water are usually very shallow.

8.4.2 Pervious pavements

Pervious pavements are no different to ordinary road surfaces in terms of safety except they have the advantage of not having standing water on a flat pavement.

Pervious pavements are often designed with a geo-textile layer close below the block work. Vehicles, particularly heavy goods vehicles, which brake heavily or turn sharply, can disrupt the pavement as the geo-textile provides a plane of reduced friction allowing blocks to move. Appropriate design can minimise this issue.

8.4.3 Ponds

Health

The risks associated with ponds are readily acknowledged as being both health related in terms of disease vectors and that of drowning. Aspects that relate to health include:

- West Nile virus
- Malaria

- Weils disease
- blue-green algae
- infected cuts from glass or other sharp objects

though some of these are not endemic in UK.

One of the difficulties facing designers is that there is no complete checklist to consider all the possible health-related issues. A good example is that of West Nile virus which has recently become a problem in America. Whereas previously good practice involved the use of plenty of vegetation, this new health problem is exacerbated by the existence of vegetation, and ponds are being modified to address this problem.

In addition to these relatively serious aspects, there are nuisance elements such as midges and flies to consider. In general terms where water is free moving, stirred by winds or induced currents, and low in nutrients, vector water-borne diseases are minimised.

Appropriate fencing

This is a subject area which is heavily debated with positions held by experts that are sometimes contradictory. At one extreme there is the provision of fencing such that access would be extremely difficult to achieve even by fit athletic persons. At the other extreme is the provision of no fencing at all. Between these two points of view there are two further recommendations which are; to use a one metre high fence, or just an indicative barrier which can be stepped over. Overall, the choice of whether to fence a pond should be based on a risk assessment for the location and communication with appropriate stakeholders.

The arguments related to the choice of fence are as follows.

1. A very high fence is likely to be overcome in some way because it is there to be beaten. In today's society there seems to be a tendency to treat all symbols of authority as a challenge.
2. No fence, on the other hand, prevents no challenge and soft measures of persuasion such as barrier planting and educational signs can provide good deterrence. However, a two-year-old toddler would tend not to be dissuaded by such features, but parents would recognise the risk and should act accordingly.
3. A one metre high fence addresses the issue of preventing small children from entering the pond, but by the age four or five it is unlikely that such a fence would prevent their access. The one metre fence would not be seen as a strong sign of authority, but allows adults to gain easy access where there is a need to provide assistance or retrieve some personal object.
4. A mini fence provides no real obstruction for small children but does give a message to adults and older children which is not a challenge. It is also much less obtrusive and therefore does not detract from the amenity value of the pond.

Examples of most of these options have been built. There has only been one recorded fatality in UK in a SUDS pond, so there is no statistical basis upon which to make a judgement. Inspection of the use of ponds as an amenity shows that mothers and toddlers will regularly use paths around a pond to go for walks. Although they recognise that the pond is a potential risk, few demand the provision of fences. Conversely where fences exist, particularly those that do not look attractive, this often results in considerable local disapproval due to the perceived risks associated with the pond. It would seem therefore that the no fence solution might be the best option with as much emphasis as possible on education and other forms of safety provision. However each site will need to have the risks evaluated and would need to take into account the culture of the local population and its likely age profile, as well as the physical factors of location and pond design.

Pond configuration

It is generally acknowledged that a safer pond is one that is more distant from housing, but is overlooked. Unfortunately in high density developments, the maximum distance possible may only be tens of metres. Additional deterrence can also be provided by locating the pond on the far side of a road. Pond location is unlikely to be a matter of great choice.

Pond ground slopes

The slope of the ground adjacent to the water's edge and immediately within the pond needs to be kept as flat as possible to prevent people from slipping into it. The acknowledged compromise between the trade-off between land take and safety is to use maximum gradients in the region of 1:3 or 1:4. Steeper slopes might be acceptable at higher levels when the frequency of the water at that level is rare. Water levels above the 2 or 10 year event may be regarded as being sufficiently infrequent to provide a minimal risk of drowning for the brief time at which water is at this level or above.

Pond depths

It is generally felt that deep water provides a much higher risk of drowning than shallow water. However as the minimum water depth required to prevent aquatic vegetation growth is over one metre, the difference in level of risk in designing an attenuation pond to have a maximum water level of two or three metres does not significantly change the risk of drowning. The important aspect is to provide prevention measures which deter entry into deep water.

Lifesaving equipment

The provision of lifebelts is normally recommended along with suitable signage. These need to be strategically located and sufficiently frequent to be useful. However perhaps the most useful aspect of this strategy is their existence, which draws attention to the potential risk of drowning and is a simple way to get this message across to the public. Vandalism may be a problem with providing this type of safety equipment.

Educational information

In addition to providing warnings of risk aspects related to the pond, information boards provide an opportunity for educating the public with regards to the benefits that the pond provides. Whether all the potential hazards relating to health are listed as well or a general warning given against swimming and fishing, depends to some extent on the likely health risks and the community where the pond is located.

Pond management

Where there is the requirement for no swimming and fishing to take place, this needs to be backed up by a management plan. Once these practices develop, it is more difficult to prevent recurrence. Therefore sufficiently regular visits should be made to ensure that unsafe practices are not taking place.

Instances of drowning often relate to weather conditions, particularly hot weather. Where there is a possibility that a swim to cool down may seem attractive, particular vigilance is required, especially if consumption of alcohol might be associated with the location.

8.4.4 Detention basins

There is a difference of opinion as to whether detention basins are more or less of the risk than ponds. Clearly detention basins only retain water for a brief period of time over the year, and that the depth of retention for the majority of events will be shallow. Therefore if risk of drowning relates to the period when water is available to drown in and its depth, then detention basins can be regarded as a much lower risk than ponds. As detention basins take significantly less land than ponds their use would therefore seem to be attractive.

Apart from being intrinsically less attractive than ponds, the use of barrier planting to dissuade access into it is less easily addressed. The location in the basin as to where they should be grown and the additional maintenance implications created, makes barrier planting less desirable. It is therefore perceived by some authorities that detention basins provide no less a safety risk than ponds. This means that many of the issues regarding safety provision for ponds apply to the use of detention basins.

8.4.5 Filter trenches

Filter trenches with granular material on the side of the road is commonly used on major roads, but not in residential areas. If they were to be used the only particular risk related issue is the effects of stone scatter on the road. These risks are not new as these drainage systems have been used for many years.

8.5 LIABILITY

Liability related to drowning is a high priority for any owner of a site with hazards. Provision needs to be made such that in the unfortunate occurrence of a drowning taking place, that it can be shown that every reasonable effort had been made to prevent such an event happening. These provisions can include:

- Suitable (pond) design
- Consideration of distance and adjacent land use
- Educational warning signs
- Appropriate management
- Lifesaving equipment
- Appropriate fencing

In addition to these provisions, the responsibility in law for liability is affected by whether the property is private, or whether the public have a right of access. These various issues are briefly discussed below.

Legal disputes relating to personal injury and negligence are an important consideration for both the design of the pond and other safety provisions. The legal requirements relating to safety that are applicable to ponds are the Occupiers Liability Acts of 1957 and 1984 and the Countryside and Rights of Way Act 2000.

The law recognises that there is a difference in degree of liability between areas with a public right of access and private property. It also recognises that certain activities, such as fishing, implicitly accept the risks associated with open water. It is therefore likely that all such SUDS components will have to be located in public open space.

8.6 SUMMARY

Table 8.1 summaries the issues raised in this chapter. Items highlighted in red indicate a potentially contradictory requirement while those in yellow are less important issues for compromise. Green indicates areas where design criteria should not result in contradictory requirements.

Table 8.1 Summary of safety, amenity and environmental factors and issues requiring compromise in design

Pond Design	***Aesthetics***	***Safety***	***Environment***	***Hydraulic***	***Water Quality***
Location	Close- enhances property values	Distant	Near "natural" rural land	Backwater effects if close to river	-
Depth	Greater than 1m to maintain open water	Minimise	Extensive shallow zone with variations	-	Stratification, thermal warming
Vegetation	Variety limited to extent	Barrier planting	Natural local plants	Increased risk of blockage and reduction in volume	Enhanced treatment
Fences	Undesirable	Desirable	Undesirable	-	-
Signs	Negative effects of safety signs	Essential	Educational	-	-
Slopes	Gentle	Gentle	As flat as possible at normal depth margin	Steep and deep to minimise land use	Shallow for improved treatment
Maintenance/ Management	Regular	Regular	Minimal	Regular	Infrequent
Safety equipment	Negative impacts	Essential	-	-	-

9. Stormwater Ownership and Management

This chapter provides an overview of drainage roles and responsibilities and the current situation for SUDS ownership and management and its implications for developers.

This document is primarily a guide on how to use SUDS to ensure appropriate drainage is designed and built. However it is important to address the issue of ownership and management as the current division of responsibilities for drainage in the water industry make the issue of SUDS ownership a complex problem which is worth summarising. This chapter details the current situation, while acknowledging that parts of this section will rapidly become dated.

9.1 DRAINAGE RESPONSIBILITIES AND OWNERSHIP

Drainage responsibilities involve a number of different stakeholders including:

- local authorities
- the environmental regulator
- sewerage undertakers
- highways authorities
- private land-owners

Although good SUDS design can be achieved to meet the various needs of the community and environment, the ownership and maintenance of SUDS systems will influence the design. The following sections summarise the responsibilities of various stakeholder organisations, and this will inform the developer about the current SUDS ownership issues. It encourages an early consideration of ownership issues in the planning and design of the site.

9.2 LOCAL AUTHORITY DRAINAGE RESPONSIBILITIES

Local authorities act as planning and building control authorities and also have responsibilities for local roads and their drainage, public landscaping, and land drainage.

Planning authorities implement development policy and approve new development, including drainage. Their role is essential in ensuring that SUDS are incorporated into new developments.

In Scotland, the local authority also has the primary flood management responsibility. Local authority-led Flood Appraisal Groups co-ordinate actions where catchments cover several separate local authority areas.

Local authorities are responsible for administering the Building Regulations via their approved inspectors which includes drainage construction.

9.2.1 Ownership of SUDS

Public open space is normally the responsibility of the local authority. Recently, management companies have been created to manage public open space. It is therefore possible that the SUDS components, which are located in these areas, might also become the responsibility of these organisations. However the responsibilities of these organisations are effectively underwritten by the local authority if the company becomes insolvent.

The mechanism for managing SUDS by the local authority is currently quite difficult due to fiscal rules within which authorities must operate. A commuted sum is the normal method of addressing the liability for maintaining the adopted SUDS component(s).

Where land ownership, or maintenance responsibility is assumed by the local authority, it is taken under a Section 106 Town and Country Planning Act Agreement. Some SUDS, relating to Highways can be covered under the Highways Act 1980.

9.3 ENVIRONMENTAL REGULATORS DRAINAGE RESPONSIBILITY

In England and Wales, the Environment Agency is an executive agency of the Department of Environment, Food and Rural Affairs (Defra). It has wide-ranging responsibilities including the management of water resources, control of pollution in inland, estuarial and coastal waters, and flood defence. The principal duty of the Agency is "to contribute towards the achievement of sustainable development". In carrying out all its functions, the Agency is subject to general duties to protect and enhance the environment and promote recreation.

The Agency has general flood defence and land drainage powers, including a supervisory duty over all flooding (but primarily in respect of Main rivers). It is responsible for recommending planning conditions (discharge consents) relating to stormwater runoff. The Rivers Agency is the equivalent organisation responsible for watercourses in Northern Ireland. In Scotland, this is a local authority function. SEPA has equivalent powers for the control of pollution only.

To meet statutory duties related to securing the proper use of water resources and as part of its role as statutory consultee to the land-use planning process, the Agency provides guidance and recommendations on the potential for pollution within a catchment and on good practice to prevent water pollution. The Agency is the competent authority for implementation of the Water Framework Directive, which requires that all discharges obtain consents or authorisation from the relevant body. Moreover the Agency has powers to serve notices requiring works to be carried out to protect watercourses and groundwater quality. The Scottish Environmental Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Services (EHS) have similar powers.

All these regulators have policies that promote SUDS as the preferred solution for drainage of surface water runoff, including roof water, for all proposed developments. In general, they will not serve prohibition notices (and the associated requirement to apply for consent) in relation to the quality of stormwater discharges. However, conditional prohibition notices may be served prior to construction to ensure that the drainage system is constructed to the agreed design.

9.3.1 Ownership of SUDS

The Environment Agency will not take ownership of any drainage system, whether SUDS are involved or not.

9.4 SEWERAGE UNDERTAKERS

There are nine water and sewerage companies across England, with individual companies serving Scotland (Scottish Water), Wales (Welsh Water) and Northern Ireland (Northern Ireland Water Service). They are responsible for both water supply and sewerage. In addition, there are a number of 'water-only supply' companies who do not have sewerage responsibilities.

Figure 9.1 shows the locations of all the sewerage undertakers across the UK.

The main duty of a sewerage undertaker under the Water Industry Act, 1991 is to provide a public sewer connection to be used for drainage of domestic premises in its area (if served notice by the owner or the occupier of the premise, and/or the local planning authority, and/or a development board or corporation). This process is known as requisitioning. The Act also allows a highway authority to enter into an agreement with the sewerage undertaker to use its sewers for conveying surface water from roads repairable by the authority. Similarly, the sewerage undertaker can enter into an agreement with the highway authority to use the highway drainage to carry surface water from premises or streets. The Act prohibits either party from refusing to enter into or consent to such an agreement on unreasonable grounds.

In Scotland, the Water Environment and Water Services (Scotland) Act 2003 amended the Sewerage (Scotland) Act 1968 to include a definition of SUDS, thus giving public SUDS the same legal status as traditional sewers. The Act gives responsibility to Scottish Water for the adoption and maintenance of public SUDS in Scotland. The definition does not include private SUDS that are located entirely within the curtilage of a property, or SUDS that convey road drainage only.

Sewerage undertakers issue technical approval of the parts of the proposed sewerage infrastructure that they will 'adopt / vest' and assume maintenance responsibility from the developer.

Water companies have a wide range of environmental policies through which they seek to minimise the environmental impact and maximise the sustainability of their core activities. They have a statutory duty to promote the efficient use of water, environmental good practice and the use of cost-effective solutions.

9.4.1 Ownership of SUDS

Scottish Water will normally only vest Detention Ponds and Detention Basins. Other SUDS components are either deemed to be the domain of Highways (Filter trenches, Pervious pavements, Swales) as they are primarily associated with roads and parking. The revised version of Sewers for Scotland 2nd Edition (WRc, expected in 2005) does make an emphasis on a holistic drainage design, with an expectation that SUDS will be provided for private properties and highways and vested with the appropriate owner. In addition there is an emphasis on maintenance and rehabilitation of SUDS systems with vesting being implemented up to 12 months after completion of construction.

The situation in Northern Ireland is very similar to England and Wales in that there is no legal provision for Water Services to own such structures. However, an investigation is currently taking place to look into how SUDS can be adopted in Northern Ireland. It is being driven by the Northern Ireland Environment and Heritage Service and involves all relevant interested parties. Water Services is undergoing a major reorganisation with a change in its status. It can therefore be anticipated that, like Scotland, some progress can be expected to be made in 2005.

Figure 9.1 UK sewerage undertakers

In England and Wales the Sewerage Undertakers have taken slightly varying positions on adopting SUDS, but in general the consensus is that the Water Resources Act 1991 defines a sewer as being a pipe and that there are too many issues that need addressing for SUDS to be considered for adoption under the current drainage legislative framework. For example the "right to connect" is seen as an obstacle to the widespread adoption of SUDS. In principle, however, there is general agreement amongst all stakeholders that SUDS are best practice drainage and this is reflected in the Interim Code of practice document produced by the National Suds Working Group in 2004.

Undertakers have defined their position on SUDS in this document. A key component relating to potential acceptance of a SUDS component is that it should have an outfall or overflow pipe. This is summarised in Table 9.1.

UKWIR, their research organisation, is carrying out a number of research studies in anticipation of being required to adopt using SUDS systems.

9.5 HIGHWAY AUTHORITIES DRAINAGE RESPONSIBILITIES

Highway authorities (both local highway authorities and the Highways Agency) have the power to construct, adopt and maintain highway drainage infrastructure. Each authority sets down standards which developers must follow throughout the construction process to ensure that adoptable roads are of satisfactory construction, safe for the public to use and able to be easily maintained. Effective road drainage is fundamentally important to road safety and to the integrity and structural stability of the road, including its footways, verges and margins.

When considering construction consent applications, local authorities will want to be satisfied that SUDS employed in particular locations meet their road drainage requirements and will not require high levels of maintenance.

9.5.1 Ownership of SUDS

The Highways Agency is quite proactive in research and the use of SUDS systems, though there is an emphasis on these components being referred to as vegetated drainage systems and not sustainable drainage. This is due to the belief that the sediment is likely to be sufficiently contaminated that it will need to be treated as being special waste.

Local highways authorities do not seem to have taken a stand on using SUDS systems, but once the position of the Sewerage Undertakers is resolved, co-ordination with the local highways authority on drainage of developments will result in a more defined position having to be taken.

9.6 HOME OWNER / PRIVATE (IN-CURTILAGE) SUDS OWNERSHIP

Homeowners are generally responsible for drainage within the curtilage of their properties. Ownership of this land may change through the development process, with a landowner selling the land to a developer and this then being sold to the house owner. Each party must therefore be made aware of any drainage constraints in terms of land use restrictions or maintenance requirements and relevant drainage details should be included within house sale documentation.

Although there may be stipulations regarding the need to maintain aspects of the property to ensure the SUDS component(s) remain effective, in practice the risks related to change of use of some SUDS is high. Prevention and rectification of such changes may not be practical in that monitoring of all properties is virtually impossible.

9.7 CONSERVATION ORGANISATIONS DRAINAGE RESPONSIBILITIES

English Nature is the government body in England whose purpose is to promote the conservation of wildlife and natural features. Powers have been given to them via several Acts of Parliament, and their duties now include the following:

- advising government, organisations and individuals on nature conservation;

- designating the most important areas for wildlife and natural features, e.g. Sites of Special Scientific Interest (SSSI's), and securing management of these sites;
- implementing EC directives on nature conservation and biodiversity;
- supporting and undertaking research.

The Countryside Council for Wales (CCW), Scottish Natural Heritage (SNH), and the Environment and Heritage Service of Northern Ireland are the relevant bodies for other parts of the UK.

These organisations should be consulted during the planning process for any major development so that issues relating to wildlife and conservation can be addressed. This is likely to influence the design of SUDS systems.

9.8 SUMMARY OF SUDS ADOPTION BY DRAINAGE ORGANISATIONS

Table 9.1 summarises the current position of SUDS adoption by the various organisations with drainage responsibilities. The table should be read taking into account the following explanations.

Sewerage Undertakers: The adoption of SUDS is subject to resolution of what is seen as a number of legal constraints. In addition all the components are required to have outfalls to qualify as SUDS.

Scottish Water: Although all SUDS except two are defined as not being adoptable in accordance with Sewers for Scotland 2nd Edition (WRc, expected in 2005), negotiations with regard to sites which are deemed to have a high risk of pollution can result in other SUDS components being vested.

Highways Agency: Vegetated open channels, ponds and wetlands are being used. Swales are designed rather differently to SUDS manuals with a focus on safety taking into account the risks relating to fast moving traffic. They are officially not recognised as SUDS components.
Private owner: Theoretically private owners can be responsible for any form of SUDS component. However, in practice, there are a number of SUDS components that will not normally be used within the private curtilage due to the risk of change of use.

Table 9.1 SUDS ownership/maintenance by drainage organisation – status as of 2004/2005

SUDS component	Local authority	Highways Authorities	Scottish Water	Sewerage U'taker	NI Water Service	Private owner
Water Butts, stormwater use systems	✗	✗	✗	✗	✗	✓
Pervious pavement	✓	✓	✗	✗	✗	✓
Filter drains	✓	✓	✗	✓	✗	✓
Filter strips	✓	✓	✗	✗	✗	✓
Swales	✓	✓	✗	✓	✗	✓
Detention ponds	✓	✓	✓	✗	✗	✓
Retention ponds	✓	✓	✗	✗	✗	✓
Wetlands	✓	✓	✗	✗	✗	✓
Detention basins	✓	✓	✓	✗	✗	✓
Soakaways	✓	✓	✗	✓	✗	✓
Infiltration trenches	✓	✓	✗	✓	✗	✓
Infiltration basins	✓	✓	✗	✗	✗	✓
Green roofs	✗	✗	✗	✗	✗	✓
Bio-retention areas	✓	✓	✗	✓	✗	✓
Underground storage	✗	✓	✓	✓	✓	✓
Proprietary drainage units	✗	✓	✓	✓	✓	✓
Pipes	✓	✓	✓	✓	✓	✓

Can a component be adopted: ✓ yes ✗ no

10. References

British Council for Offices. (2003). Green roofs, research advice note, Corporation of London, London, UK

CIRIA and HR Wallingford, (to be published). SUDS – updated guidance on technical design and construction, Report RP697, CIRIA, London

CIRIA, (2004). Interim Code of Practice for Sustainable Drainage Systems, www.ciria.org.uk/suds/icop.htm, CIRIA, London

Countryside and Rights of Way Act, (2000). The Stationary Office, London

Defra, (2000). Flood and Coastal Defence Project Appraisal Guidance 3 – economic appraisal, Defra, London

Defra, (2004). PPS23, Planning and Pollution Control. Defra, London.

Department of the Environment and Department of Transport, (1992). Residential Roads and Footpaths, Design Bulletin 32, 2nd Edition, HMSO, London

Department of the Environment, Transport and the Regions, (2000). Housing, Planning Policy Guidance Note 3, Stationary Office, London

Department of the Environment, Transport and the Regions, (2001). Development and flood risk, Planning Policy Guidance Note 25, Stationary Office, London

DOE, (1981). The Wallingford Procedure, HR Wallingford

Department of the Environment, (Currently under public consultation stage, comments by 29 April 2005), Planning Policy Statement 15: Planning and Flood Risk PPS15, Belfast, Northern Ireland

DTLR, (2000). The Building Regulations, Part H: Drainage and Waste Disposal, The Stationary Office, 2002 Edition

DTLR, (2002). Planning for Open space, Sport and Recreation, Planning Policy Guidance Notes 17, The Stationary Office, London

Environment Agency, (2004). Preliminary rainfall runoff management for developments, R&D Technical Report W5-074/A, Environment Agency, UK

Environment Agency, (2003). UK Climate Impacts Programme 2002 Climate Change Scenarios: Implementation for Floods and Coastal Defence: Guidance for Users, R&D Technical Report W5B-029/TR, Environment Agency, UK

European Union, (2000). Directive 2000/60/EC of the European Parliament and the Council establishing a framework for the Community action in the field of water policy (Water Framework Directive)

Hall, M.J., Hockin, D.L. and Ellis, J.B., (1993). Design of Flood Storage Reservoirs, CIRIA, UK

Hewlett, H.W.M., Boorman, L.A. and Bramley, M.E., (1987). Design of reinforced grass waterways, CIRIA Report 116, CIRIA, London

Highways Act, (1980). HMSO, London

Highways Agency, (1998). Manual of contract documents for highway works - Volume 1: Specification for highway works, HMSO, UK

HR Wallingford, (2003). Maximising the Ecological Benefits of Sustainable Drainage Schemes, SR Report 625, HR Wallingford, Wallingford, UK

Institute of Highway Incorporated Engineers, (2002). Home Zone - design guidelines, 1st Edition, Institution of Highway Incorporated Engineers, UK

Institute of Hydrology, (1975). Flood Studies Report, Institute of Hydrology, Wallingford, UK

Institute of Hydrology, (1994). Flood Estimation for small catchments, Report 124, Institute of Hydrology, Wallingford, UK

Institute of Hydrology, (1999). Flood Estimation Handbook (FEH), 5 Volumes, Institute of Hydrology, Wallingford, UK

Kellagher, R.B.B., (2004). Drainage of Development Sites: A guide, CIRIA Report X108, CIRIA, London

MAFF, (2000). Flood and Coastal Defence Project Appraisal Guidance 4 – Approaches to Risk, MAFF, London

MAFF, (1981). The design of field drainage pipe systems, Report 345, MAFF, London

Martin, P, Turner, B, Dell, J, Payne, J, Elliot, C and Reed, B., (2001). Sustainable urban drainage systems – best practice manual, Report C523, CIRIA, London

Martin, P, Turner, B, Waddington, K, Dell, J, Pratt, C, Campbell, N, Payne, J and Reed, B (2000a). Sustainable urban drainage systems – design manual for England and Wales, Report C522, CIRIA, London

Martin, P, Turner, B, Waddington, K, Pratt, C, Campbell, N, Payne, J and Reed, B., (2000b). Sustainable urban drainage systems – design manual for Scotland and Northern Ireland, Report C521, CIRIA, London

Masters-Williams, H., Heap, A., Kitts, H., Greenshaw, L., Davies, S., Fisher, P., Hendrie, M., and Owens, D., (2001). Control of water pollution from construction sites, CIRIA Report C532, CIRIA, London

National Assembly for Wales, (2004). Development and Flood Risk, Planning Guidance (Wales), Technical Advice Note (Wales) 15, Cardiff, TSO, 7pp

National building specification landscape specification (www.thenbs.com)

National Playing Fields Association, (2001). The Six Acre Standard: Minimum standards for outdoor playing space, National Playing Fields Association

National SUDS Working Group, (2004). Interim Code of Practice for Sustainable Drainage Systems, National SUDS Working Group (www.ciria.org/suds/icop.htm)

National SUDS Working Group, (2003). Framework Document, National SUDS Working Group

NERC, (1977). The estimation of low return period flows FSSR 2, Flood Studies Supplementary Report, Institute of Hydrology

NERC, (1983). Review of regional growth curves FSSR 14, Flood Studies Supplementary Report, Institute of Hydrology

NERC, (1985). The FSR rainfall-runoff model parameter estimation equations updated FSSR 16, Flood Studies Supplementary Report, Institute of Hydrology

Occupiers Liability Act, (1957 and 1984). The Stationary Office, London

ODPM, (unknown). Assessing needs and opportunities: Planning Policy Guidance 17 companion document, ODPM, http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_plan_606788.hcsp

Oxford University Press, (1989). Oxford English Dictionary, 2nd Edition, Oxford University Press, Oxford, UK

Pratt, C, Wilson, S, Cooper, P., (2002). Source control using constructed pervious surfaces – Hydraulic, structural and water quality issues, C582, CIRIA, London

Scottish Executive, (2004). Planning and Flooding, National Planning Policy Guidance 7 NPPG7, Edinburgh, Scottish Office Development Department, 31pp

Scottish Executive, (2001). Planning and Sustainable Urban Drainage Systems, Planning Advice Note 61, Scottish Executive Development Department

Scottish Executive, (2003). Planning and Open Space, Planning Advice Note 65, Scottish Executive Development Department

Scottish Office, (1996). National Planning Policy Guidance 11: Sport, Physical Recreation and Open Space, Scottish Office

Town and Country Planning Act, (1990). The Stationary Office, London

UKWIR, (2004). Water for Scotland, WRc, UKWilson, S, Bray, R, Cooper, P., (2004). Sustainable drainage systems – Hydraulic, structural and water quality advice, Report C609, CIRIA, London

WRc, (2001). Sewers for adoption, 5th Edition, WRc, UK

WRc, (expected in 2005). Sewers for Scotland, 2nd Edition (Consultation Draft), WRc, UK

Additional references (not cited in text)

Abbott, C.L, Comino, L., (2001). In situ performance monitoring of an infiltration drainage system and field testing of current design procedures, Journal of Water and Environmental Management, Vol. 15, July/August, p198-202

Bettess, R., (1996). Infiltration drainage – manual of good practice, Report 156, CIRIA, London, pp107

BS EN 12256-3:2000 Gravity drainage systems outside buildings – Part 3, Roof drainage, layout and calculation, BSI

BS EN 752-2:1997 Drain and sewer systems outside buildings – part 2: Performance requirements, BSI

BS EN 752-4:1998 Drain and sewer systems outside building - Part 4: Hydraulic design and environmental considerations, BSI

Building Research Establishment, (1986). Soakaway design, Digest 365, Building Research Establishment, Garston, UK

CIRIA, (1994). Control of pollution from highway drainage discharges, Report 142, reprint 1997, CIRIA, London, pp152

Comino, L., (2000). InfoWorks CS – Modelling a permeable pavement as an infiltration system, Report IT 488, HR Wallingford, Wallingford, UK

DETR, (undated). Better places to live by design: a companion guide to PPG3, http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_plan_605963.pdf

Dublin Drainage, (2004) Greater Dublin Strategic Drainage Study: Regional Policies – Volume 2 New development, Dublin Drainage, Dublin, Ireland

Environment Agency, (2003). Guidance manual for constructed wetlands, R&D Technical Report P2-159/TR2, Environment Agency, UK

Hall, M. J, Hockin, D.L, Ellis, J.B., (1993). Design of flood storage reservoirs, Book 14, CIRIA, London

Leggett, D, Brown, R, Brewer, D, Stanfield, G and Holliday, E., (2001). Rainwater and greywater use in buildings – best practice guidance, Report C539, CIRIA, London

Shaffer, P, Elliot, C, Reed, J, Holmes, J and Ward, M., (2004). Model agreements for sustainable drainage systems, Report C625, CIRIA, London

UKWIR, (1998). Civil Engineering Specification for the Water Industry, 5th Edition, WRc, UK

WRc, (2001) Sewers for Scotland, 1st Edition, WRc, UK

Appendices

Appendix 1 Greenfield runoff estimation

Appendix 1 provides information with regards to runoff estimation from greenfield areas. It also provides all the relevant values and the background to the use of the formulae.

A1.1. Greenfield peak rate of runoff estimation

The Institute of Hydrology Report No. 124 was published in 1994 and describes research on flood estimation for small catchments. The research was based on 71 small rural catchments (<25 km^2), some of which were additional to the original 1975 FSR catchment data set. A new regression equation was produced to calculate $QBAR_{rural}$, the mean annual flood. $QBAR_{rural}$ is estimated from the equation:

$$QBAR_{rural} = 0.00108 AREA^{0.89} SAAR^{1.17} SPR^{2.17} \quad (A1.1)$$

Where:

$QBAR_{rural}$	= the mean annual flood flow from a rural catchment in m^3/s
AREA	= the area of the catchment in km^2.
SAAR	= the standard average annual rainfall (for the period 1941 to 1970) in mm. This map is available with the Flood Studies Report or with the Wallingford Procedure.
SPR	= SPR value of the SOIL class, which is a composite index determined from soil survey maps that accompany the Flood Studies Report and the WRAP map of the Wallingford Procedure.

$QBAR_{rural}$ can be factored by the regional growth curve to produce peak flood flows for other return periods. The mean annual flood approximates to a return period of around 2.3 years.

The Flood Estimation Handbook (FEH), which was brought out in 1999, uses a revised soil index called HOST. These soil classification also have an SPR value. This means that the peak flow rate estimation formula can be applied using either HOST or SOIL classes. Purists would probably expressed concern as the correlation basis for the formula was carried out against the SOIL classes, and because of the HOST SPR values were not derived in the same way. The 5 SOIL classes and their respective SPR values are detailed in Table A1.1.

Table A1.1 Soil classes SPR values

SOIL class	1	2	3	4	5
SPR value	0.1	0.3	0.37	0.47	0.53

The soil map of the Wallingford Procedure was based on FSR and was produced as an A0 plan. It has been reduced to A4 for inclusion in this appendix. It should be noted that the Wallingford Procedure values for SPR were the original values from FSR which are slightly different to the values in Table A1.1 which were produced as a revision after the Wallingford Procedure was issued. The use of the SOIL class for any site must be treated with caution and only used for initial assessment of the catchment runoff characteristics. A soil survey is strongly recommended to confirm the mapping information. This is important because the soil class is the most significant parameter for this formula. Figure A1.1 is the SOIL (WRAP) map for UK from the Wallingford procedure.

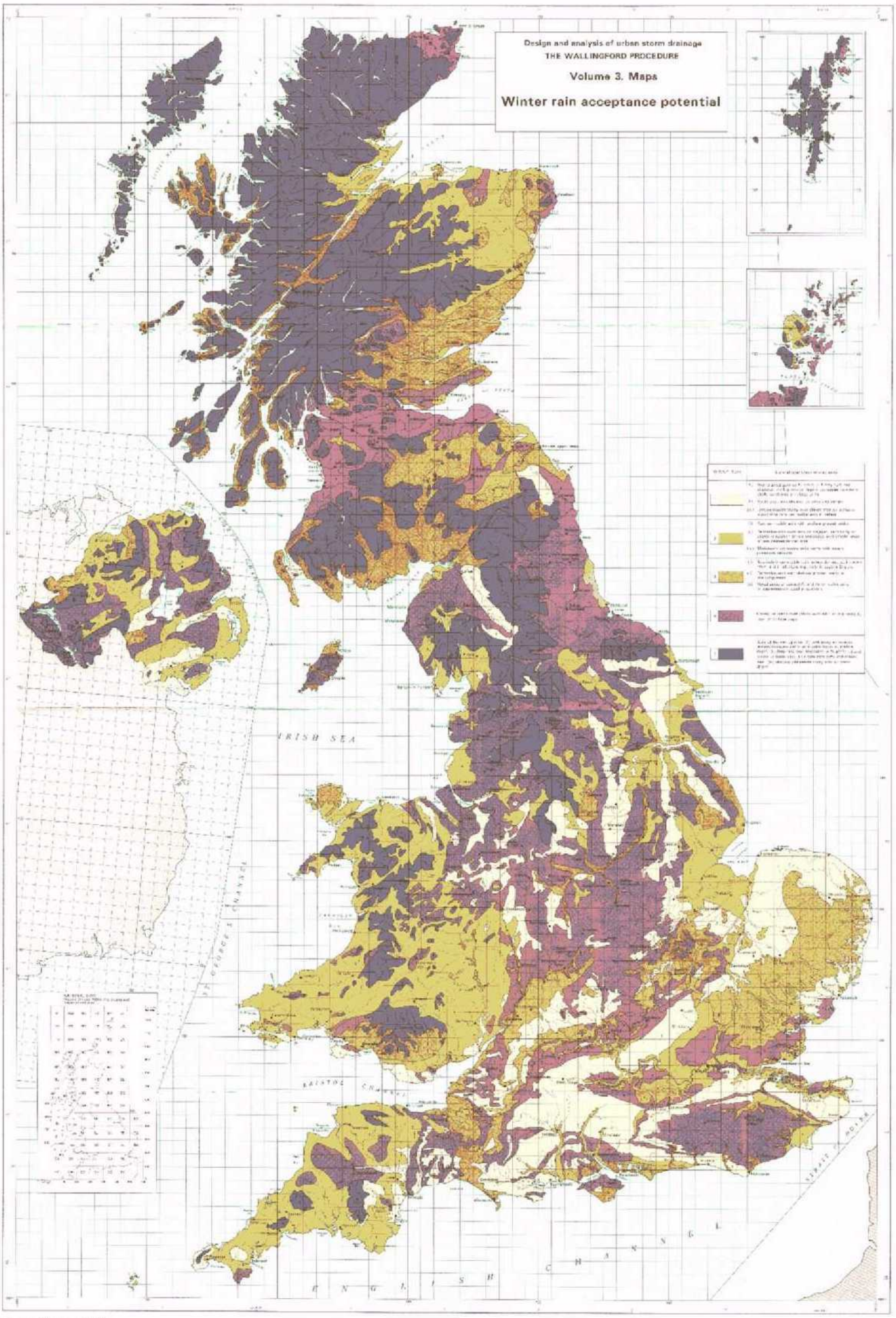


Figure A1.1 SOIL classes map of UK

A1.2. FSSR 14 growth curves

There are 10 growth curves for regions in UK and these are given in FSSR 14 (1986). Figure A1.2 provides the UK regions which relate to the UK individual curves which are shown in Figure A1.3. To obtain an approximate estimate of the 1 year return period flow factor, a figure in the region of 0.8 is used. FSSR 2 provides these factors based on hydrological region, which range from 0.8 to 0.9. Table A1.2 provides all the growth curve regional factors for return periods between one year and 100 years.

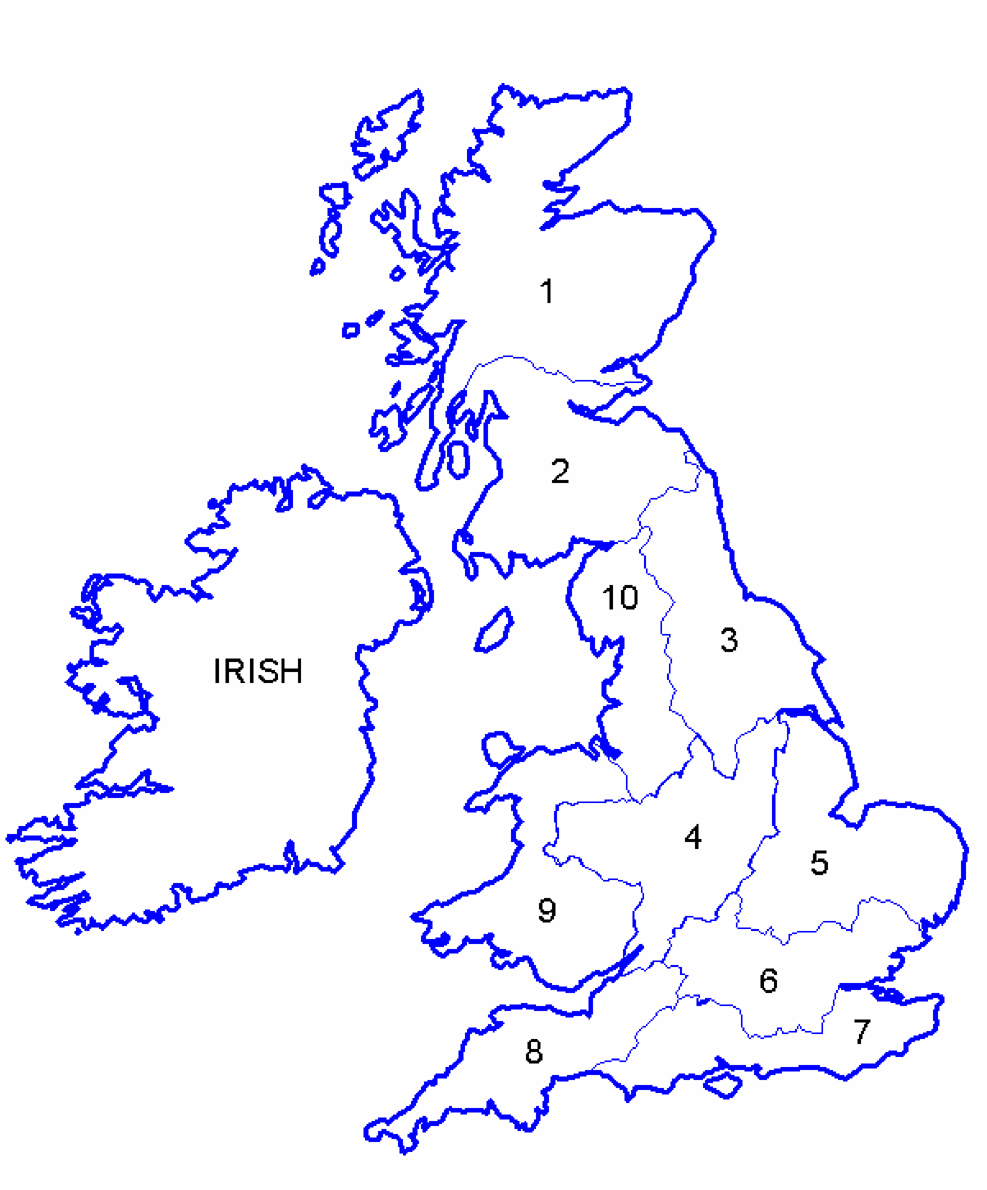


Figure A1.2 UK Hydrological Growth Curve Regions

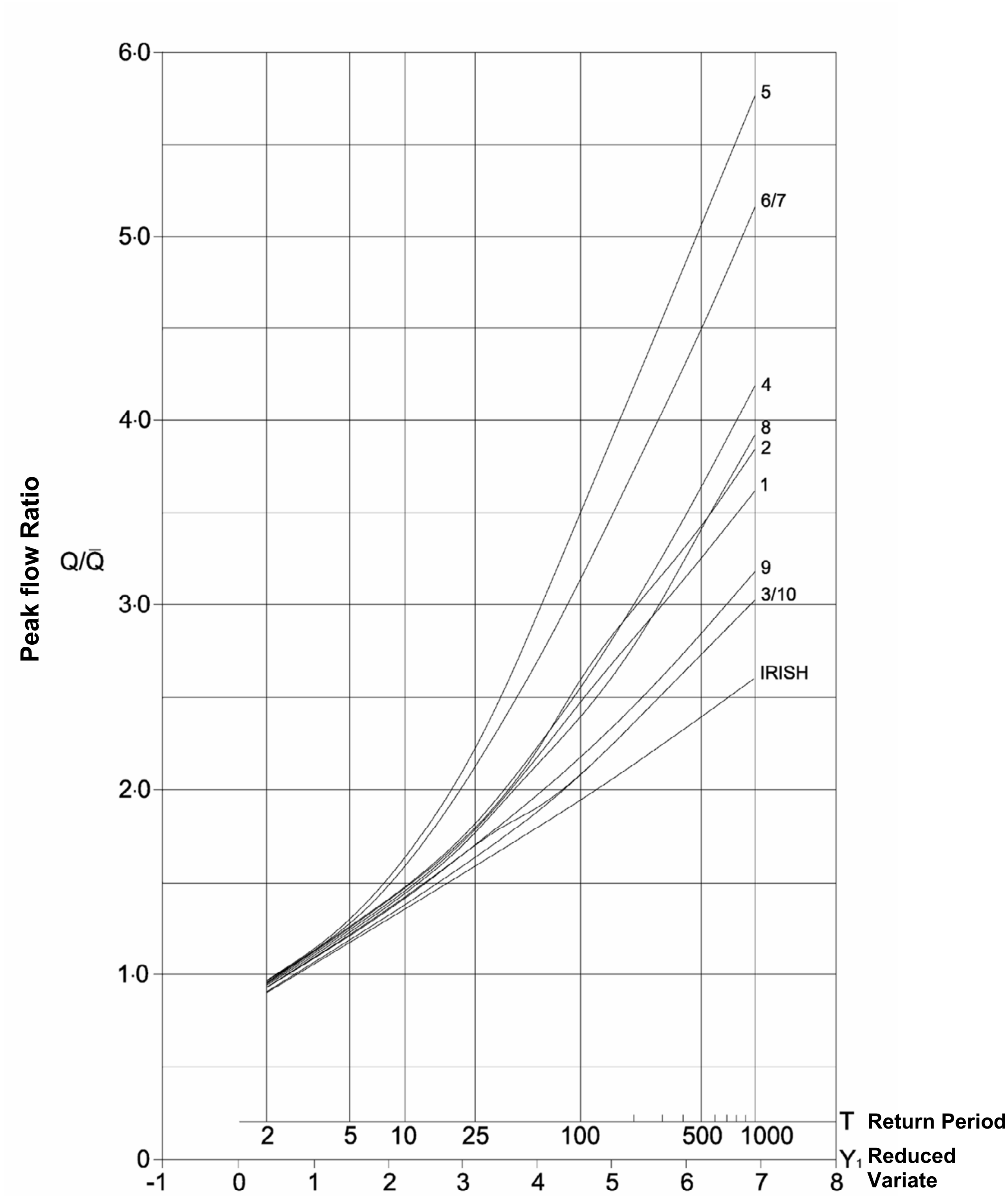


Figure A1.3 FSR Regional Growth Curves

Table A1.2 Regional growth curve factors

Region	1 years	5 years	10 years	30 years	50 years	100 years
1	0.85	1.24	1.48	1.80	2.15	2.47
2	0.87	1.21	1.48	1.90	2.20	2.61
3	0.86	1.27	1.38	1.70	1.80	2.10
4	0.83	1.27	1.45	1.85	2.20	2.60
5	0.87	1.34	1.65	1.85	2.85	3.50
6	0.85	1.33	1.60	2.20	2.65	3.16
7	0.85	1.33	1.60	2.20	2.65	3.16
8	0.78	1.27	1.40	1.80	2.10	2.38
9	0.88	1.24	1.40	1.70	1.90	2.20
10	0.87	1.22	1.38	1.60	1.80	2.10

A1.3. Greenfield runoff volume estimation

For assessing long term storage needs, the simple assumption can be made that the runoff from a greenfield site is equal to the SPR value for the SOIL type. There are a number of other methods for deriving volumes of runoff, but the formula in FSSR 16 is both easy to use and is the most recent output in the FSSR series addressing this issue. It should be noted that this formula is only suitable for estimating volumes for extreme events.

The FSSR 16 formula is:

$$PR_{RURAL} = SPR + DPR_{CWI} + DPR_{RAIN} \quad \text{(A1.2)}$$

Where:

PR_{RURAL} = the proportion of runoff from a rural catchment

SPR = the standard percentage runoff which is a function of the five SOIL classes S_1 to S_5

$$= 10S_1 + 30S_2 + 37S_3 + 47S_4 + 53S_5 \quad \text{(A1.3)}$$

DPR_{CWI} = a dynamic component of the percentage runoff. This parameter reflects the increase in percentage runoff with catchment wetness. The catchment wetness index (CWI) is a function of the average annual rainfall. The relationship is shown in Figure A1.4.

$$DPR_{CWI} = 0.25\ (CWI - 125) \quad \text{(A1.4)}$$

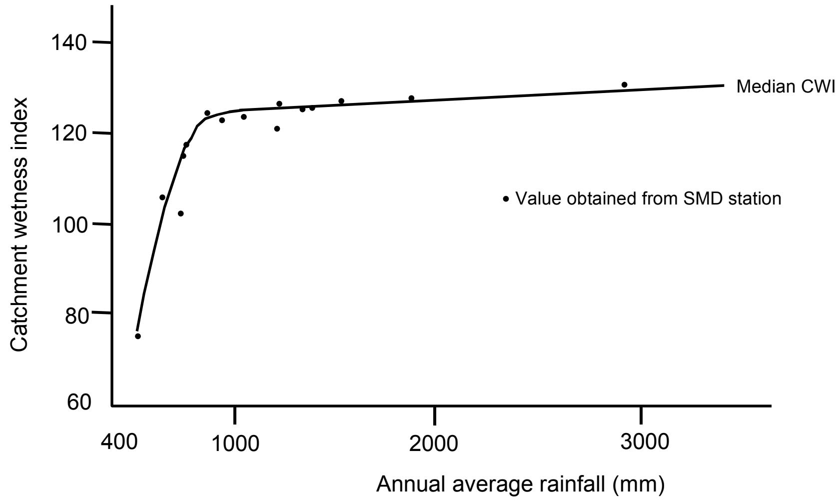


Figure A1.4 CWI vs SAAR – Flood Studies Report

The DPR_{RAIN} is the second dynamic component that increases the percentage runoff from large rainfall events.

$DPR_{RAIN} = 0.45(P - 40)^{0.7}$ for $P > 40$ mm (A1.5)
$DPR_{RAIN} = 0$ for $P \leq 40$ mm (A1.6)

Where
P = the rainfall depth

It can be seen from the formula for DPR_{RAIN} that the runoff proportion is generally slightly greater than the value of SPR for all areas where the SAAR value is greater than 800mm. In addition rainfall depths for the 100 year 6 hour event for any location in UK is greater than 40mm, and this results in an additional slight increase in the rainfall-runoff fraction.

The derivation of this equation is for extreme events and for catchments which are significantly larger than those of development sites. Its accuracy therefore is to be treated with caution. However if account is to be taken of the volumetric effects of development, this is a simple and consistent method for assessing greenfield runoff volumes.

The key feature of this formula is the important influence of soil type. In practice it indicates that developments on sandy soils create massive additional runoff compared to the pre-development condition, but development on clays do not. This is obvious, but it has very significant implications for the cost of developments in terms of the storage provision. Other parameters have little influence.

Tests of the local soil permeability and relating it to SOIL class is therefore important to carry out at an early stage.

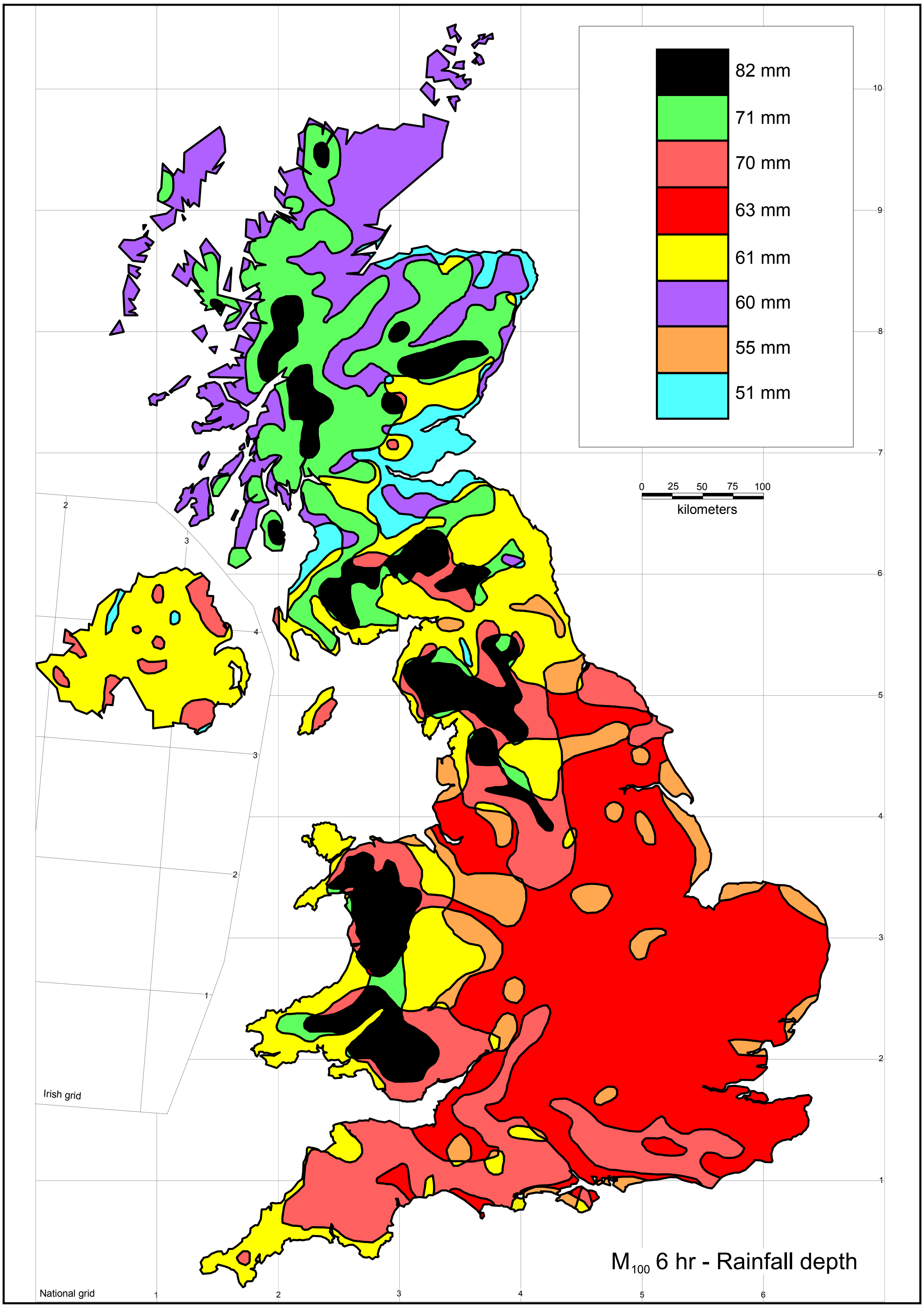


Figure A1.5 100 year 6 hour rainfall depths (based on FSR parameters)

Appendix 2 Example of initial assessment of stormwater storage volumes

A2.1. Design of Stormwater Storage

This procedure contains an illustration of the drainage requirements for a site in UK.

This method provides a quick and easy method to find the storage needed for a development site. It is anticipated that most sites would require detailed modelling of the proposed drainage systems to be carried out in order to demonstrate the effectiveness of the drainage proposals at the detailed design stage.

A2.1.1 Drainage design process flow chart

Figure A2.1 summarises the main drainage design stages as a graphical flow chart. Figures A2.2 to A2.6 illustrate in more detail the analytical process that needs to be carried out to implement the design criteria in Chapters 3 and 7 of the guide.

The 4 main hydraulic criteria are:

- River water quality protection
  - Interception
  - Treatment volume

- River regime protection
  - Limit of discharge to receiving water, at the 1 and 100 year greenfield runoff rates

- Level of service
  - Flooding on the site
    - protection against internal flooding of property
    - Temporary local flooding from rare events, short intense storms
    - Flow depths from long duration storms

- River flood protection
  - long term flood storage.

Runoff models that are suggested for analysis of these various criteria are summarised in Table A2.1

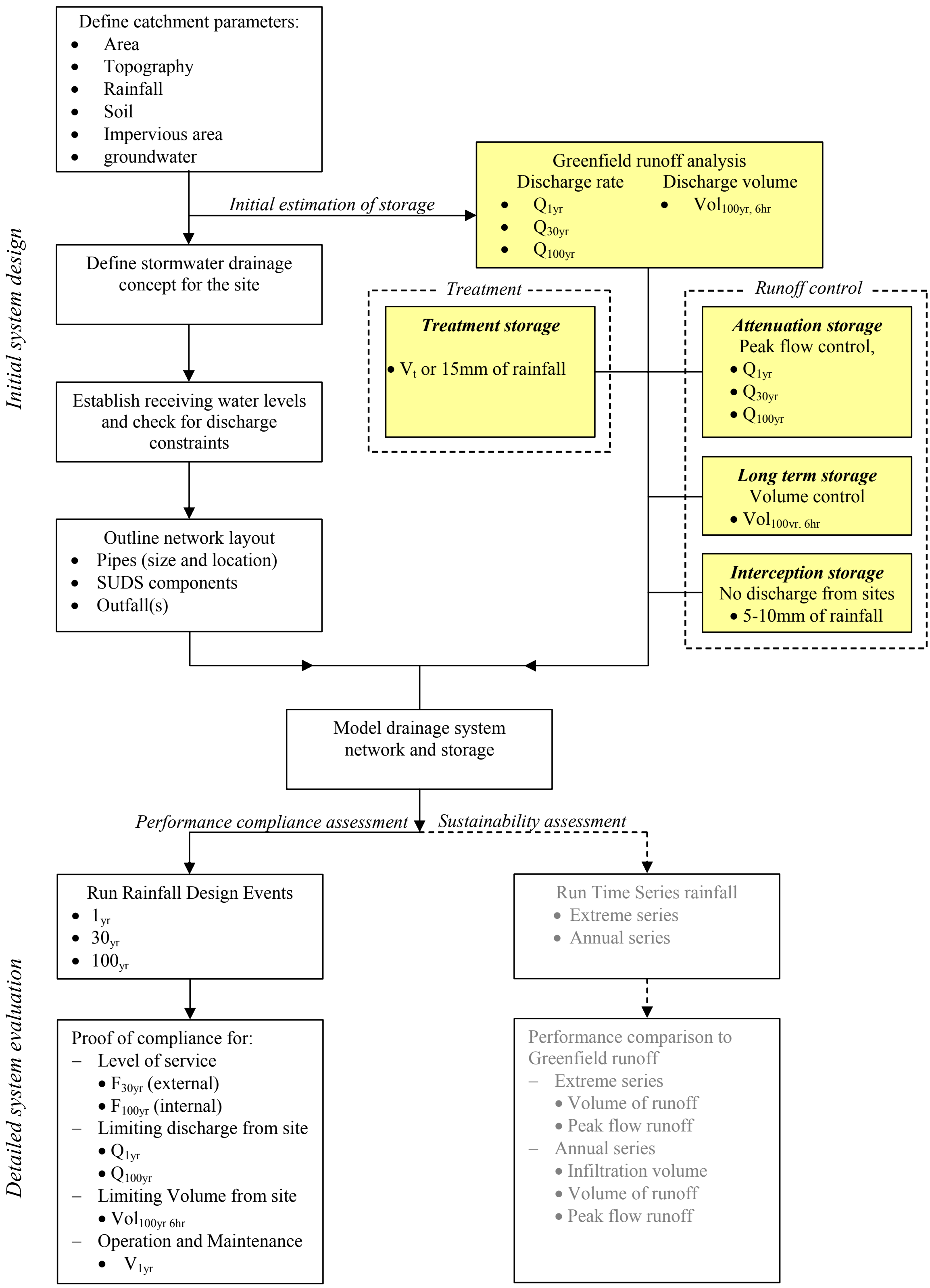
Table A2.1 Runoff models for storage analysis

Criteria	Storage type assessment	Runoff model (percentage rainfall-runoff)
River water quality	Interception and Treatment volumes	60% to 80% paved, 0% permeable surfaces
River regime	Attenuation storage volume	80% for paved + 0% for permeable surfaces for 1yr event 80% paved + SPR factor for permeable surfaces for 100yr event, or Variable UK PR equation
Level of service	Temporary flooding and routing	Variable UK PR equation (detailed network model)
River flood protection	Long term storage volume	80% for paved and SPR factor for permeable surfaces positively draining to the stormwater system, or Variable UK PR equation

It should be noted that:

- these volumes are not cumulative.
- the provision of Interception storage also constitutes provision of (part of) the long term storage.
- long term storage reduces the Attenuation storage volume by approximately an equal amount.
- Treatment storage is not storage for attenuation of rainfall runoff. It is normally provided as the volume of the permanent pool in a pond.
- Treatment storage can be reduced proportionally for any paved area that is served by infiltration systems, or pervious pavements. This is because neither contributes any significant pollutants, particularly sediments. However as sedimentation is the key factor to address, short circuiting and pond jetting are at least as important an issue to consider as the calculated value of the treatment volume.
- Detailed simulation of the network and storage system is advised at detailed design to check that all elements of the drainage system perform as expected.

Figure A2.3 suggests the alternative of using either 15mm or the formula for V_t to calculate the treatment storage volume.



Q_{1yr} *Peak discharge rate for 1 year return period*
F_{30yr} *Flooding volume (and location) for 30 year return period*
Vol_{100yr} *The volume of storage for 100 year return period*
V_{1yr} *Velocity of conveyance systems for 1 year return period*

Figure A2.1 Design elements of stormwater drainage for new developments

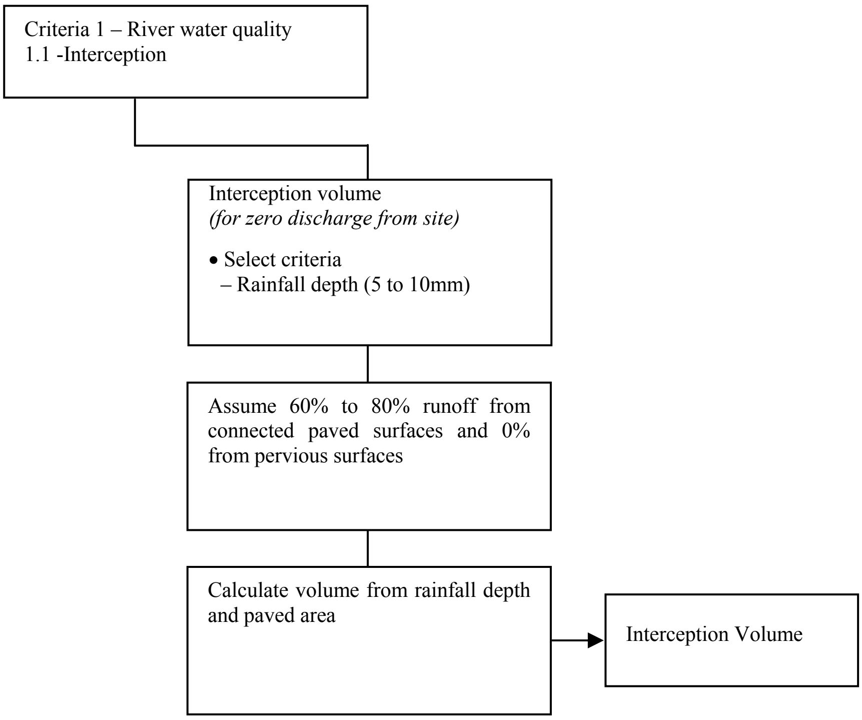


Figure A2.2 River water quality – Criterion 1.1; Interception storage

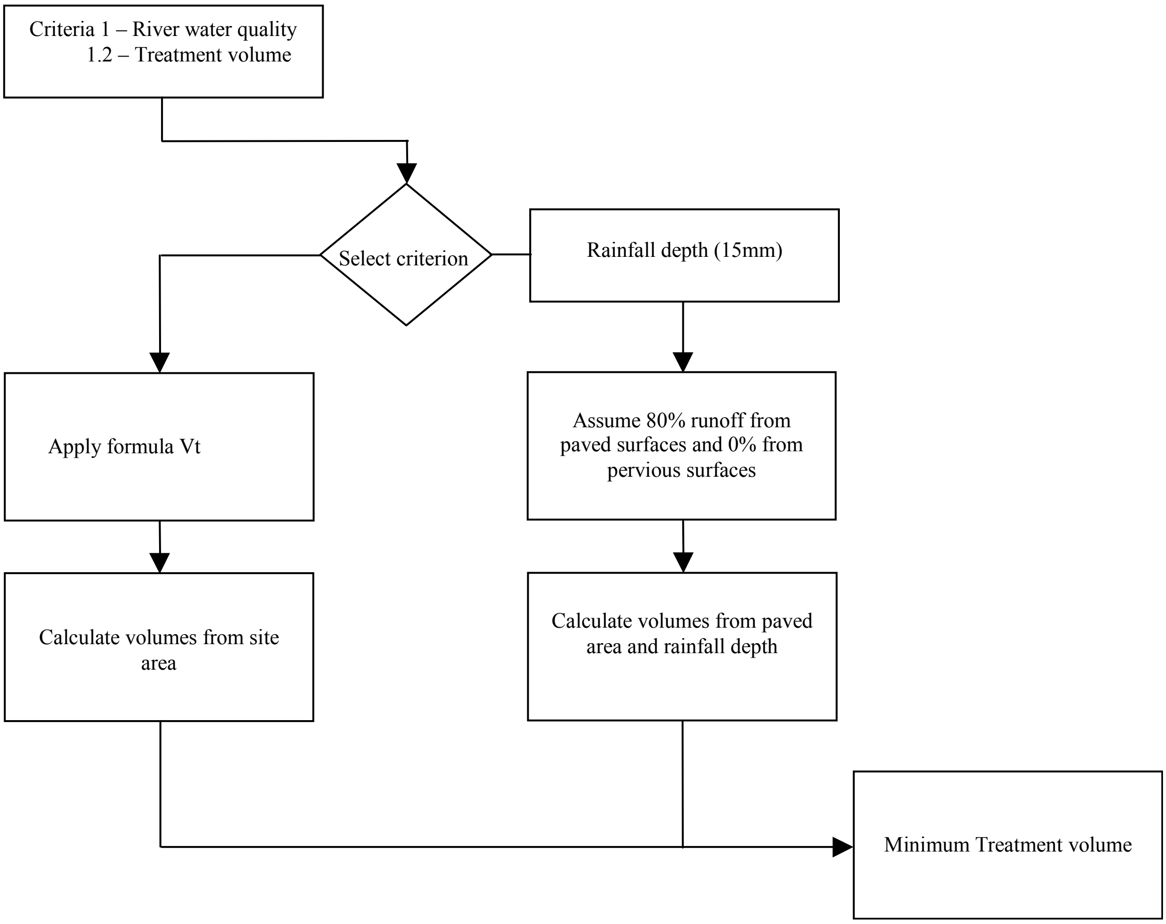


Figure A2.3 River water quality – Criterion 1.2; Treatment (wet pond) volume

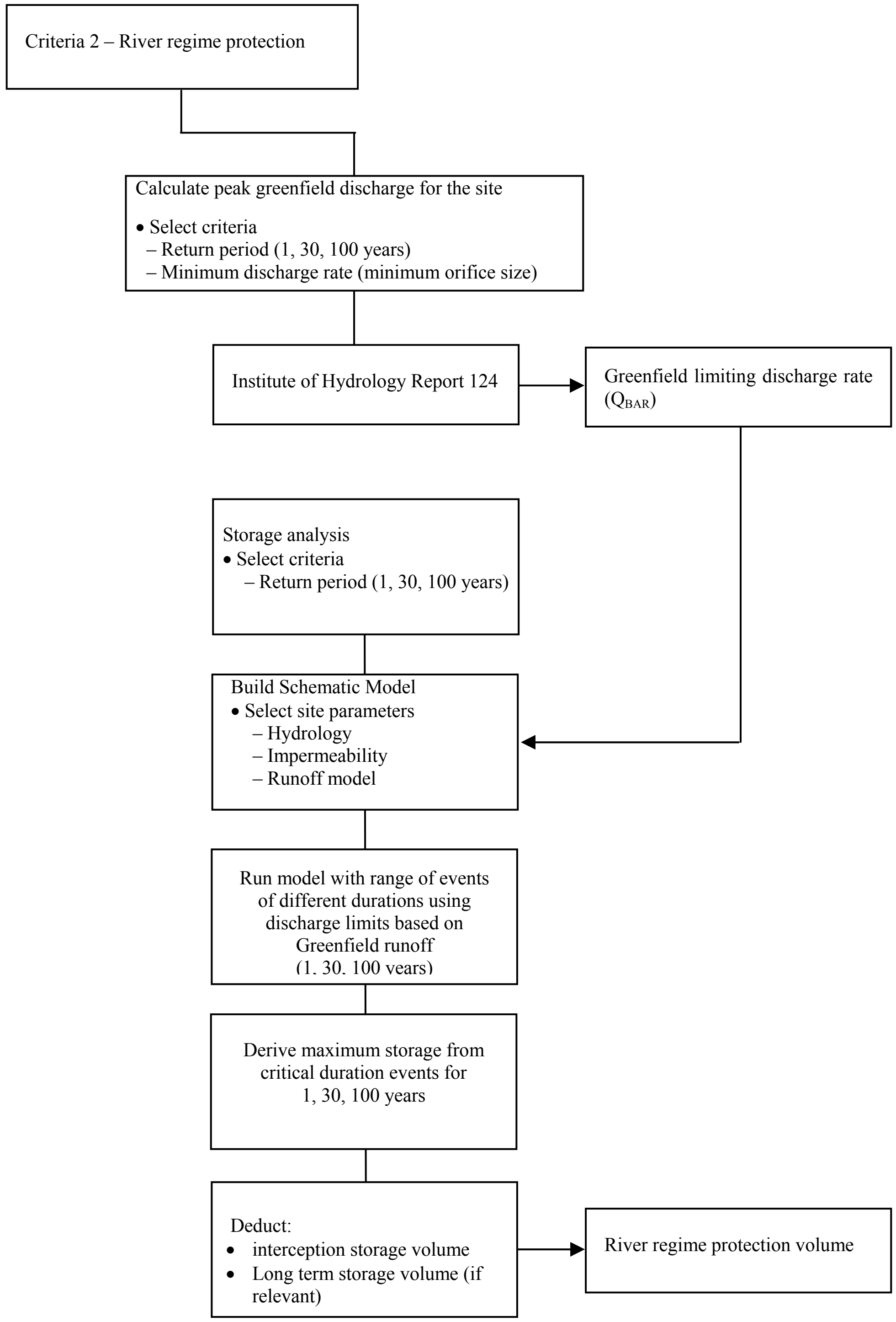


Figure A2.4 River regime protection – Criterion 2; Attenuation storage

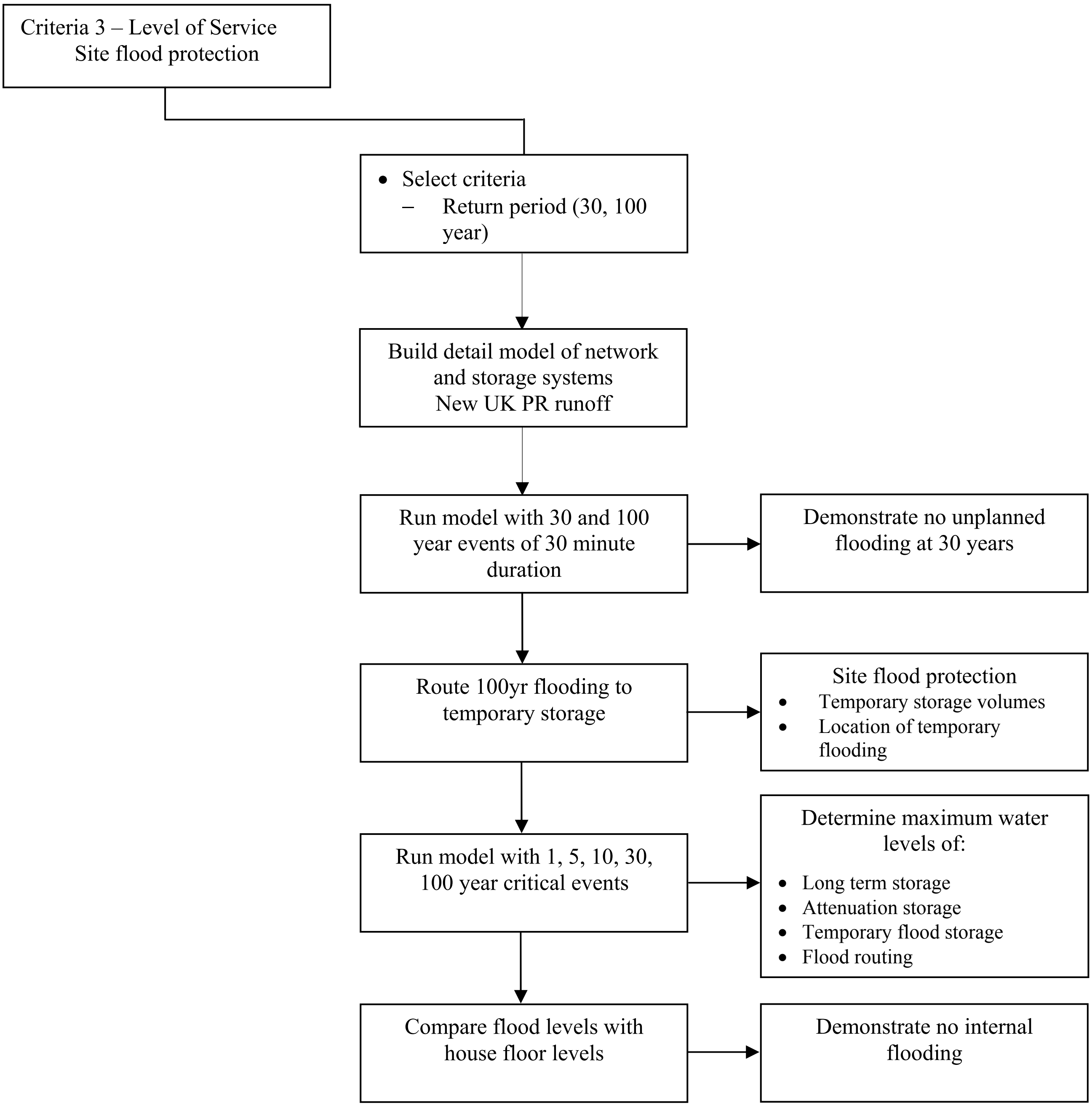


Figure A2.5 Levels of service – Criterion 3; flood depths, flood routing and temporary storage operation

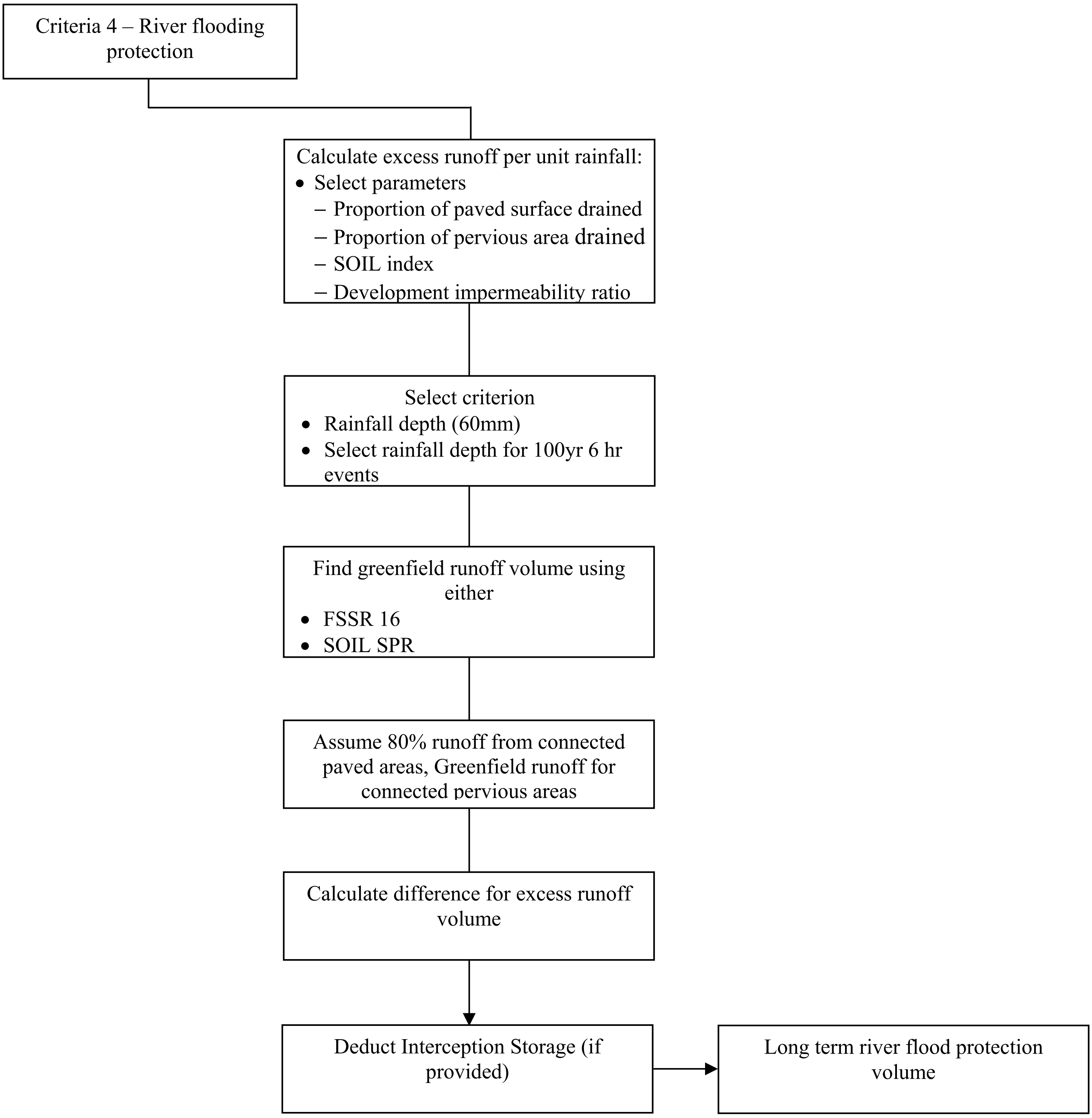


Figure A2.6 Storage design – Criterion 4; River flood protection

A2.2. Worked Example

The following example is an illustration of the process of applying the design criteria for estimating stormwater storage for discharge attenuation and volume reduction. The example does not illustrate design of pipe systems nor does it look into the process of ensuring an effective SUDS system is provided in protecting the environment from the impact of urban pollution washoff.

Catchment Characteristics

Site Area	= 70ha
SAAR	= 750mm
SOIL class	= 3
M5-60	= 17mm
r	= 0.30
PIMP	= 65%
Hydrological region	= 4

In addition it is assumed that:

- climate change factor for rainfall is 1.1 (10% increase)
- 25% of the paved surface drains to infiltration, and
- 60% of the pervious area is positively drained by the drainage system
- runoff from the remaining 40% of the pervious area does not enter the drainage system.

A2.2.1 River water quality protection – Criterion 1

Water quality protection (Figures A2.2 and A2.3) is the provision of either interception and/or treatment volume. Both are calculated below.

A2.2.1.1 Interception – Criterion 1.1

Assume 80% runoff from paved surfaces and 0% from pervious surfaces for the first 5mm of rainfall. The paved runoff proportion is actually likely to be around 60% for most small events with at least the first 0.5mm of rainfall being lost in depression storage and evaporation before any runoff takes place. The interception volume is calculated in Table A2.2.

Table A2.2 Calculation of Interception volume

Item	Measurement/ calculation	Comment / clarification
Paved surfaces connected to the drainage system	0.75 x 0.65 x 700,000 = 341250 m^2	75% of the paved area is connected 65% of the site is paved 70ha development in m^2
Volume of interception storage	341250 x 0.005 x 0.8 = 1365m^3	Paved area directly drained 5mm rainfall depth 80% paved runoff factor 0mm depression storage assumed

Infiltration using infiltration trenches for roof runoff and filter trenches or swales for road runoff is probably the most effective way of meeting this criterion. Direct runoff from roads into soakaways is generally not regarded as sustainable without the provision of high levels of maintenance to prevent blinding of the soil. However soil type needs to be considered and in this example SOIL type 3 may be considered to be unsuitable for infiltration. Field tests should always be carried out to establish whether the use of infiltration is possible.

The top water level design of a pond may also be a useful way of addressing part or all of this volume. The period when water quality is a particular issue is in summer when dry periods between events are measured in days or even weeks and river levels are low. If a pond liner (if needed) is finished 150mm below the outfall invert, and the pond perimeter can be designed to maximise infiltration, water levels will drop below the outlet and therefore provide some storage without discharge taking place for small events. It thus provides some interception storage.

Different surface types have different pollution characteristics. Paved surfaces served by SUDS (such as swales and pervious pavements) may be considered to have relatively clean runoff compared to runoff from roads served only by pipes. Interception volume should be focused on serving those areas which are likely to be more of a pollution problem.

A2.2.2 Treatment volume – Criterion 1.2

For events larger than 5mm, and in situations where "Interception storage" can not be provided, surface water runoff treatment is provided using a retention pond or wetland in accordance with the CIRIA design manual C521. This storage volume is the permanent pool of the retention pond.

Figure A2.3 suggests that either 15mm rainfall depth, or the formula for V_t from CIRIA report 521 can be used.

Table A2.3 Calculation of Treatment volume

Item	Measurement/ calculation	Comment / clarification
Paved surfaces draining to river	0.75 x 0.65 x 700,000 = 341250 m^2	75% of the paved area is connected 65% of the site is paved 70ha development in m^2
Volume of treatment storage	341250 x 0.015 x 0.8 = 4095m^3	Paved area directly drained 15mm rainfall depth 80% runoff from paved surfaces

If the use of V_t is preferred:

V_t (m^3/ha) = 9 x D(SPR/2 + (1 - SPR/2) x I)

V_t = 9 x 17 (0.4 /2 + (1 – 0.4 /2) x 0.65 x0.75)

V_t = 90m^3/ha

Therefore V_t for a 70ha site is 6300 m^3

The use of V_t is therefore effectively asking for around 20mm of rainfall as the treatment volume. CIRIA manual 521 suggests $4V_t$ for retention ponds is required to ensure a good level of treatment is achieved. This would amount to over 25,000m^3 being required for this 70ha site, equivalent to nearly 80mm of rain. There is little evidence at present that such a large storage provision is cost effective. It is currently recommended that the normal treatment storage requirement should be based on 15mm or 1 times V_t.

A2.2.3 River regime protection – Criterion 2

River regime protection is achieved by limiting the discharge to greenfield runoff rates for return periods of 1 and 100 years which therefore requires attenuation storage to enable stormwater discharges to meet this criterion. Sometimes 30 years is included as this is the design standard applied by Sewerage undertakers for protection against flooding. This is best evaluated using a simulation model to calculate the storage volume by using the estimated greenfield runoff rates as fixed throttle rates for these three return periods.

Before carrying out the calculations, a few notes on using simulation models are given.

A2.2.3.1 General comments on the use of computer drainage models

The Variable UK PR Equation
It is normal to use the Variable PR equation (often referred to as the New UK PR equation) when doing detailed modelling. However much of this analysis is more easily carried out using fixed percentage runoff assumptions and detailed modelling is only normally applied when the actual performance of the system needs to be established in detail. The variable UK PR model allows for some contribution from pervious areas which increases with event size. As storms become larger, this is a reasonable premise to make. This pervious term is controlled by the parameter NAPI (Net Antecedent Precipitation Index).

NAPI increases with rainfall depth during the event and therefore PR also increases. Design values for NAPI are a function of SOIL class and selected (usually) on the basis of the mean winter value from analysis of a rainfall time series. Values are commonly assumed to be:

SOIL class 1	1mm
SOIL class 2	5mm
SOIL class 3	10mm
SOIL class 4	25mm
SOIL class 5	40mm

The moisture depth parameter (PF) has a standard default value of 200mm.

Use of Hydrodynamic Models
When modelling to determine the approximate storage required, the pipe system is often modelled with a limiting discharge throttle and an overflow. The volume passing over the overflow is the storage needed for that specific event and throttle. A range of different storm durations is used to determine the maximum spill volume. This is done three times; each time the storage for the lower return period is included as storage in the node from which the overflow takes place.

This method under-predicts the volume of storage needed as the head-discharge relationship of the hydraulic control(s) is not being represented. An additional allowance of 25% should therefore be applied to this first estimate of storage to allow for this approximation. Detailed design, using the actual head-discharge relationship, will be needed to check whether the storage provision has been estimated correctly.

A2.2.3.2 Greenfield runoff rate analysis

The formula from report IOH 124 is:

$$QBAR_{rural} = 0.00108 AREA^{0.89} SAAR^{1.17} SPR^{2.17} \quad (A2.1)$$

The site is greater than 50ha, therefore apply the formula for the actual site area.

$QBAR_{rural} = 0.00108 \text{ x } 0.7^{0.89} \text{ x } 750^{1.17} \text{ x } 0.37^{2.17}$

$QBAR_{rural} = 0.00108 \text{ x } 0.728 \text{ x } 2311 \text{ x } 0.116$

$QBAR_{rural} = 211\text{l/s}$

Therefore $QBAR_{rural}$ / ha is 3.0l/s/ha

Note that the FSR SPR value for SOIL class 3 is 0.37.

To get the 1, 30 and 100 year throttle rates the growth curve advised for use for developments which is shown in Appendix 2 is needed. Growth curve values for hydrological region 4 are:

1 year factor	0.85
30 year factor	2.00
100 year factor	2.60

Therefore greenfield limiting discharge rates are:

1 year throttle	2.55 l/s/ha (178l/s)
30 year throttle	6.00 l/s/ha (420l/s)
100 year throttle	7.80 l/s/ha (546l/s)

A2.2.3.3 Attenuation storage analysis using a computer model

Assuming 25% of the paved surface drained to infiltration components does not contribute direct runoff even in the 100 year event, a simple model of 70ha with an impervious connected area of 48.8% (0.65 x 0.75) is built. As the variable UK PR equation is statistically based, the whole pervious area would be modelled except for the areas of large open green space. For the purpose of this example the remaining area is treated as contributing pervious area, although this is clearly a conservative position to take.

Figure A2.7 illustrates the modelling process.

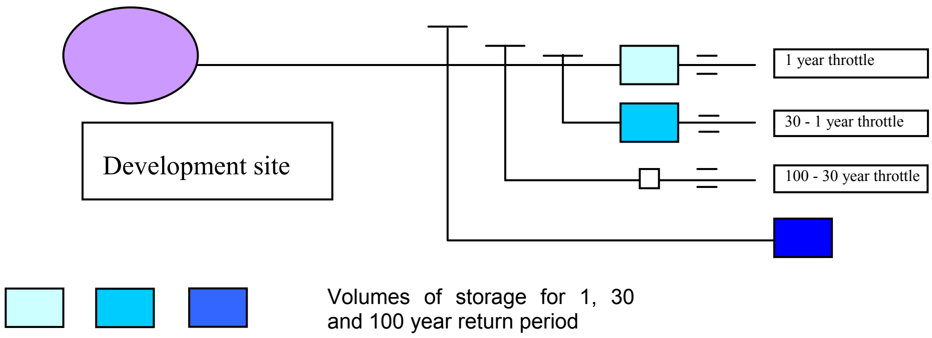


Figure A2.7 Modelling for river regime protection

Figure A2.7 illustrates the nodes, links, throttles and overflow structures that are represented in the model. The process of the model construction and analysis is discussed below.

1. Create rainfall files for range of durations (6, 12, 18, 24, 36 hours) for 1, 30, and 100 year events.
2. Factor all hyetograph (rainfall intensity) values by 1.1 to allow for climate change.
3. Use fixed discharge rates as calculated for greenfield runoff rates for 1, 30 and 100 year events.

Run 1
Run model for 1 year event with storage node set with a nominal volume ($1m^3$) with 1 year throttle of 178l/s.

Spill volume = $5250m^3$

Run 2
Alter 1st storage node in model to provide $5250m^3$ before spill occurs from overflow. Run model for 30 year event with 2nd storage node set at nominal volume ($1m^3$) with outflow rate equal to 242l/s (420 – 178). This is the 30 year throttle minus the 1 year throttle rate.

Spill volume = $5820m^3$ from second overflow

Run 3
Alter 2nd storage node in model to provide $5820m^3$ before spill occurs from overflow. Run model for 100 year event with 3rd storage node volume of $1m^3$ with outflow rate equal to 304l/s (546 - 420). This is the 100 year throttle minus the 30 year throttle rate.

Spill volume = $2990m^3$

Therefore the total storage volume is approximately equal to:

1 year	$5250m^3$
30 year	$5820m^3$
100 year	$2990m^3$
Total	$14060m^3$

An allowance to account for the simplifying assumption of head–discharge relationship of 1.25 may then be needed depending on the design of the storage outlet structure. This is because the model assumes the maximum flow rate can be mobilised immediately for each design return period.

Therefore an estimate of the attenuation storage of (14060 x 1.25) = 17575m^3 is required. This figure would be checked and refined at detailed design.

Analysis then needs to be undertaken to evaluate the impact of high river levels on the discharge arrangements for the attenuation storage. This is not detailed here. An initial worse case scenario of the maximum 100 year water should be used to assess the degree of impact. If the analysis seriously affects the storage volume results, a more detailed analysis should be carried out using a joint probability approach.

This attenuation storage volume would be reduced if provision is made for interception and long term storage volume.

A2.2.4 Levels of Service – Criterion 3

There are four criteria for levels of service. These are:

Criterion 3.1 - No external flooding except where specifically planned. (30 year high intensity rainfall event).
Criterion 3.2 - No internal flooding from site drainage system. (100 year high intensity rainfall event).
Criterion 3.3 - No internal flooding from rivers – hinterland runoff and site attenuation storage systems. (100 year long duration events)
Criterion 3.4 - No flood routing off site except where specifically planned. (100 year high intensity rainfall event)

These criteria can only be analysed using a detailed drainage model of the proposed system.

Assessment of river levels requires either good knowledge of local flood levels or the use of a suitable hydrodynamic river model to predict them. On site retention storage levels can only be defined at detailed design stage when ground levels and storage component arrangements have been defined in detail.

A2.2.5 River Flood Protection – Criterion 4

The volumetric analysis for "River Flood Protection" is purely a comparison of pre- and post-development runoff volumes and can be described as "long term" storage volume. The objective is to limit the runoff discharged to the river after development to the same as that which occurred prior to development.

There are three ways of ensuring that this volume is prevented from passing to the river.

The first assumes that this volume can be designed to come into effect during extreme events only. This requires very careful modelling and analysis. Although design storm events can be used to evaluate the design proposals to check that long term storage is mobilised effectively and does not come into operation too frequently, it should be recognised that real rainfall is only being approximated by these rainfall profiles. Theoretically a check should be carried out using a time series rainfall which is sufficiently long that suitable extreme events are represented. However as high resolution recorded data does not extend for more than a few decades, even if there are suitable gauges locally, there are unlikely to be sufficient extreme events to carry out a comprehensive check. New stochastic rainfall tools are being developed which will enable this type of testing of proposed solutions to be carried out more easily.

The second approach assumes that long term storage volume is provided in the form of infiltration volume which provides sufficient storage at the time of an extreme event occurring. In the case of this example of a site with SOIL type 3, it is probable that much of the infiltration volume provided might only have a small proportion of the volume available if such an event took place in a wet period. Although both approaches have difficulties to overcome, it does not alter the need to try and address the requirement to provide long term storage.

However if it is considered that neither approach is possible, a third approach allows for long term storage to be ignored, but that all runoff should be limited to QBAR (approximately 2 year return period), or 2 l/s/ha which ever is the greater. This should ensure sufficient stormwater runoff retention is achieved to protect the river during extreme events. In this case QBAR which is 211l/s and would be used rather than 2l/s/ha (140l/s).

The formula for long term storage is:

$$Vol_{xs} = RD.A.10\left[\frac{PIMP}{100}(\alpha 0.8) + \left(1 - \frac{PIMP}{100}\right)(\beta.SPR) - SPR\right] \quad \text{(A2.2)}$$

where:
Vol_{XS} = the extra runoff volume (m^3) of development runoff over Greenfield runoff
RD = the rainfall depth for the 100 year, 6 hour event (mm)
PIMP = the impermeable area as a percentage of the total area (values from 0 to100)
A = the area of the site (ha)
SPR = the “SPR” index for the FSR SOIL type
α = the proportion of paved area draining to the network or directly to the river (values from 0 to1) with 80 percent runoff
β = the proportion of pervious area draining to the network or directly to the river (values from 0 to1)

If it is assumed that 60% of the pervious area can be positively drained:

Vol_{xs} = 60 x 70 x 10 [(0.65 x 0.75 x 0.8) + (1 – 0.65) x 0.6 x 0.37 – 0.37]

Vol_{xs} = 42000 [0.39 + 0.078 - 0.37]

$Vol_{xs} = 4116m^3$

This volume is not additional to the attenuation storage volume, but it is effectively an element of it. This point is discussed further below.

It should be noted that this calculation assumes that the 25% of paved area is drained by infiltration and is not contributing any direct runoff. It can be seen by inspection that SOIL type 2 (with an SPR value of 0.3 rather than 0.37) would have significantly more volume to be stored while SOIL type 4 (SPR of 0.47) would need none.

If the long term storage is not provided, then the attenuation volume increases from 14060m^3 to 20450m^3 (calculated using the 1 year and QBAR throttle rates for the 100 year event in accordance with third criterion described above. The storage volumes are respectively 5250m^3 and15200m^3, a total of 20450 m^3). This is assessed using the same approach described in A2.3.3. As before, this volume may need to be increased by 25% to take account of the head-discharge curve. This therefore could increase the total attenuation storage volume up to 25562 m^3 (20450 x 1.25).

A2.2.6 Storage solutions for the site

Having calculated all the elements of storage needed to comply with the various stormwater control criteria, the actual drainage solution needs to be developed. From the points made earlier as to difficulties that can exist in providing various forms of storage, 2 options are described below which illustrate two sets of drainage solutions for this example situation.

A2.2.6.1 Option 1

Assume that Interception storage (criterion 1.1) and long term storage can be provided and that the long term storage is in the form of flooding from the attenuation pond during extreme events.

Criterion 1 – River water quality protection

1. Interception storage = 1365 m^3 from Table 2.1

2. Treatment volume = 4095 –1365 = 2730 m^3 from Table 2.2

Treatment storage is reduced by 1365 m^3 as Interception storage has been provided.

Criterion 2 – River regime protection

3. Attenuation storage (5250 x 1.25) + 5820 + 2990 – 4116 = 11256m^3 from Section A2.3.3. The following explains the volumes calculated above.

It has been assumed that the additional provision of 25% due to head-discharge assumptions in the model is only needed for the 1 year event and that the design of the pond inlet structure mobilises the 30 year discharge rate immediately once the 1 year storage volume has been exceeded. Similarly the same assumption is made when the water level in the pond rises above the 30 year level. Figure A2.8 illustrates this head-discharge assumption.

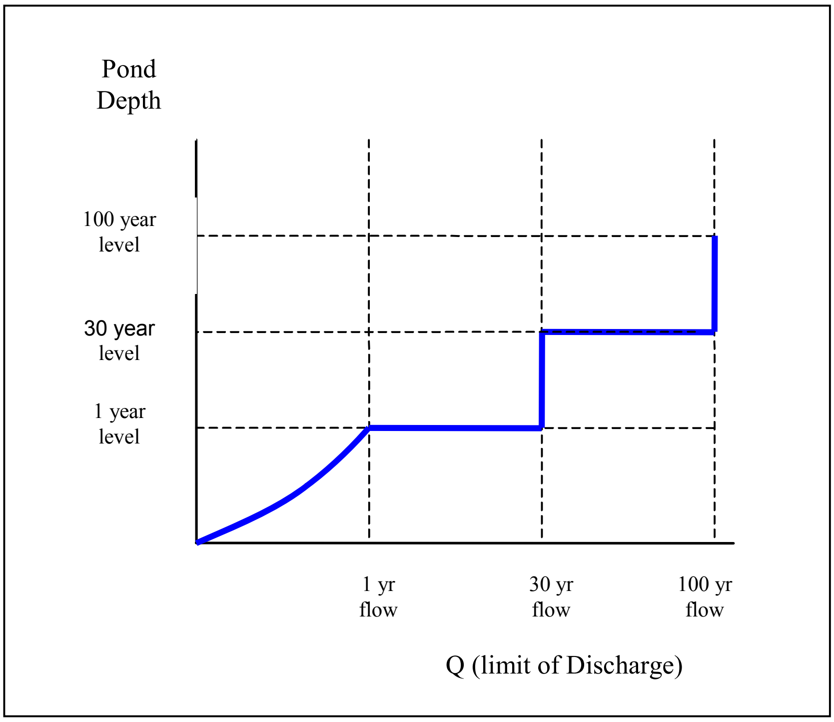


Figure A2.8 Head-discharge assumptions – mobilising 30 and 100 year discharge rates immediately on exceeding the 1 year and 30 year water levels

In addition, a reduction in the attenuation storage volume can be made equal to the long term storage volume of 4116 m^3 as this volume of water is being stored elsewhere. At the detailed design stage these estimates would be checked using the actual head-discharge and depth-storage relationships.

The assumption that the attenuation storage above the 1-year event can avoid the variable head-discharge due to storage depth presumes that:

1. The authority allows the discharge to increase to the 30 year rate immediately after the 1 year storage volume has been mobilised
2. The water levels in the pond and receiving water allow for a hydraulic design that enables this to be achieved.

In the case of the first assumption, it is reasonable to discharge the 30 year flow rate once the storage has filled above the 1 year storage volume. The river flows are likely to be fairly high by this stage and the important morphological protection would have been provided for 99 percent of events. Many events of greater magnitude than the 1 year event will also be controlled to the 1 year criterion where the duration of the event is significantly different to the critical duration used for determining the 1 year storage. Thus a significant step in runoff (around 2.5 times) does not contravene the principle of protecting the river.

The second assumption is needed because the design approach to achieve this step change in discharge could require a flow control arrangement which involves a headloss to mobilise the additional flow effectively.

Criterion 4 – River flood protection
4. Long term storage 4116 – 1365 = 2751 m^3 from Section A2.5

Long term storage is reduced by 1365 m^3 as Interception storage has been provided.

It can be seen by inspection from the figures for River Regime Protection, that to mobilise 2751 m^3 for long term storage, the flooding will have to start coming into effect at about the 30 year return period. This is because the volume needed for attenuation storage between the 30 and 100 year events is only slightly larger at 2990 m^3. If interception storage is not provided and all the long term storage (of 4116 m^3) is to be mobilised from flooding from the attenuation storage structure, it will start coming into effect for events which are significantly less than a 30 year return period.

Although the long term flood volume is calculated using a 100 year 6 hour event, if it is provided as extreme event flooding from the attenuation structure, it will probably only be mobilised fully for the critical duration event, which may be nearer 24 hours. This may or may not be particularly appropriate for protecting the receiving river, but unless real time control systems are proposed, it is unlikely that a better structure can be found. However if it is provided as infiltration which comes with affect for all events, the river is protected from all extreme rainfall.

A2.2.6.2 Option 2

The drainage assumptions (interception and long term storage) made in the first option may not be possible. This second option looks at providing a drainage solution which does not utilise interception storage and that long term storage cannot be provided as either infiltration or extreme event flood storage.

Volumes to be provided would then be:

Criterion 1 – River water quality protection
Treatment storage = 4095m^3 from Table 2.2

Criterion 2 and 4 – River regime and flood protection
Attenuation storage (5250 x 1.25) + 15200 = 20,662m^3 from Section 2.5

Attenuation storage is based on using Qbar for the throttle rate for events greater than 1 year.

This example and the 2 solution options demonstrate the importance of using the greenfield runoff rates of 30 and 100 years to minimise storage volumes.

A2.2.6.3 Options 1 and 2 storage summary

To assist in illustrating the differences between the two drainage solution options, Table A2.4 has been produced which provides the information more succinctly.

Table A2.4 Storage requirements summary for options 1 and 2

Criterion	Calculated storage for each criterion	Storage for Option 1	Storage for Option 2
1. River Water Quality Protection			
Criterion 1.1 "Interception storage"	5mm – 1365 m^3	1365 m^3	-
Criterion 1.2 "Treatment" Storage	15mm – 4095m^3 (Vt – 6300 m^3)	4095 – 1365 = 2730 m^3	4095m^3
2. River Regime Protection			
Criteria 2.1 and 2.2 "Attenuation" Storage	1year – 5250 m^3 30year – 5820 m^3 100year – 2990m^3	5250x1.25 + 5820 + 2990 – 4116 = 11256 m^3	See River Flood protection
3. Level of Service for the Site *			
Criteria 3.1 to 3.4	-	defined at detailed design	defined at detailed design
4. River Flood Protection			
Criterion 4.1 "long term" Storage	100yr, 6hr = 4116 m^3	4116 - 1365 m^3 = 2751 m^3	-
Criterion 4.3 "Attenuation and long term" Storage	1year – 5250 m^3 Qbar – 15200m^3	-	5250x1.25 + 15200 = 20,662 m^3

** Detailed modelling is needed to determine level of service network performance, flood routing, temporary storage volumes and locations and operational characteristics of long term flood storage.*

Appendix 3 Attenuation storage volumes

Figure A3.1 to A3.4 provide an indication of the 100 year return period attenuation storage requirements per hectare for a 100 ha development site. The large number of variables involved with estimating attenuation volumes would require a large number of figures to provide a set of look-up graphs. The assumptions made here are fairly representative of many sites and provide a useful indication of attenuation volume requirements. It can be seen how sensitive storage volume is to PIMP and soil class.

The figures have been developed from the Environment Agency tool from the "Preliminary Rainfall Runoff Management for Developments" report.

The parameters assumed are:

PIMP = 50% and 70%
Climate change factor = 1.1
FSR/FEH factor = 0.9

All paved areas are positively drained.

Runoff model* = 100% runoff from paved areas
= 0% runoff from pervious areas
Hydrological zones M_560 = 20, r = 0.4 (South and East)
M_560 = 17, r = 0.3 (North and West)

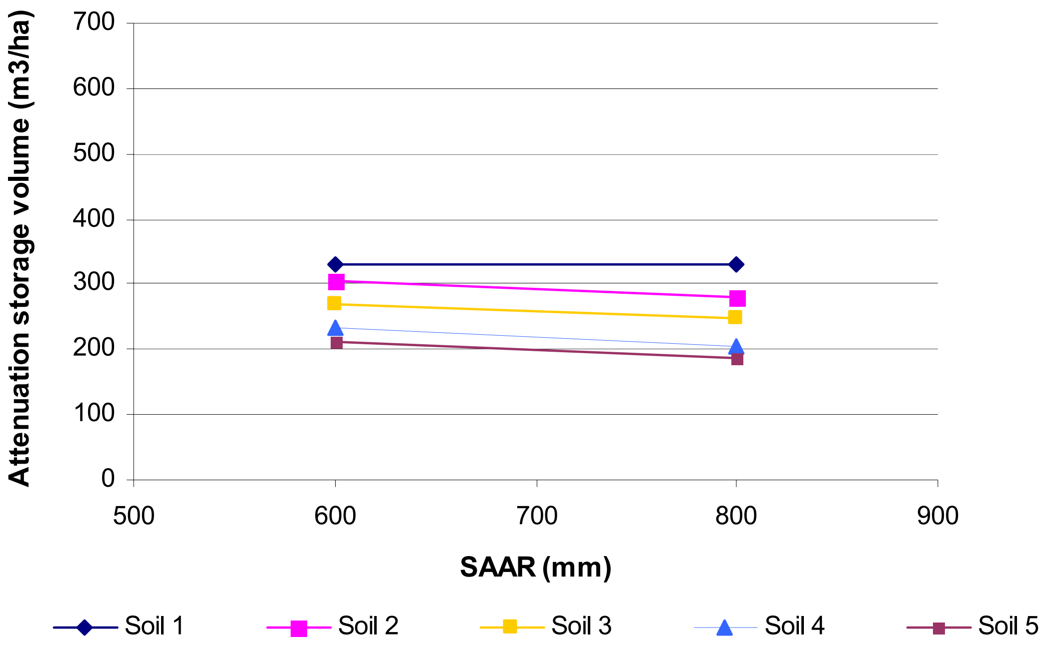


Figure A3.1 Attenuation storage volume – South and East (PIMP = 50%)

* The runoff model for 100% paved runoff and 0% from pervious areas, although not conforming to suggested criteria in Appendix 2 or Chapters 3 and 7, will produce similar results to the use of 80% and SPR respectively, depending on the area of pervious contribution.

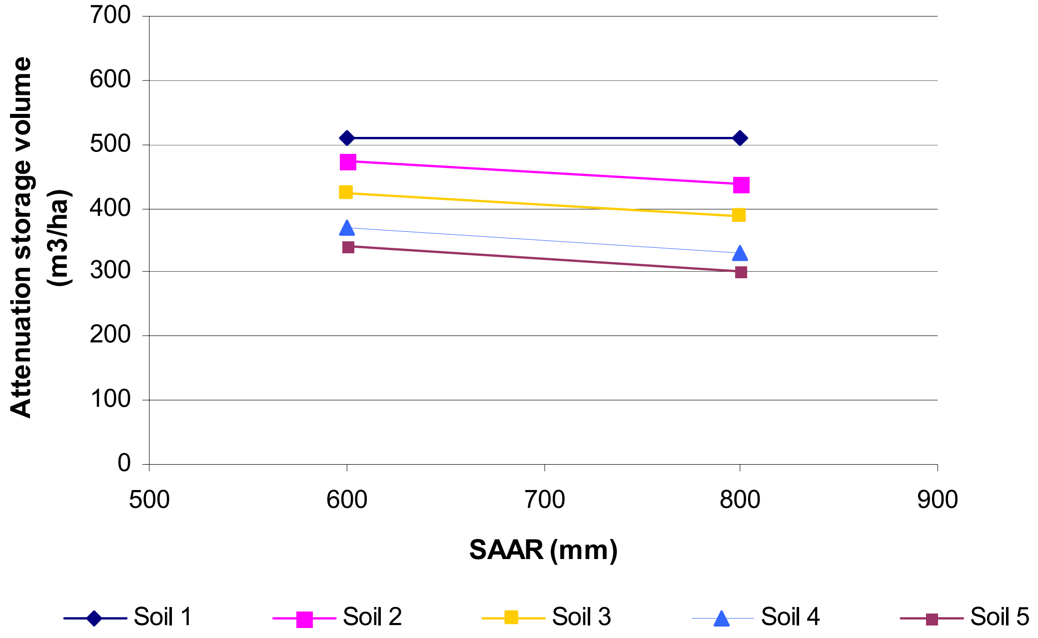


Figure A3.2 Attenuation storage volume – South and East (PIMP = 70%)

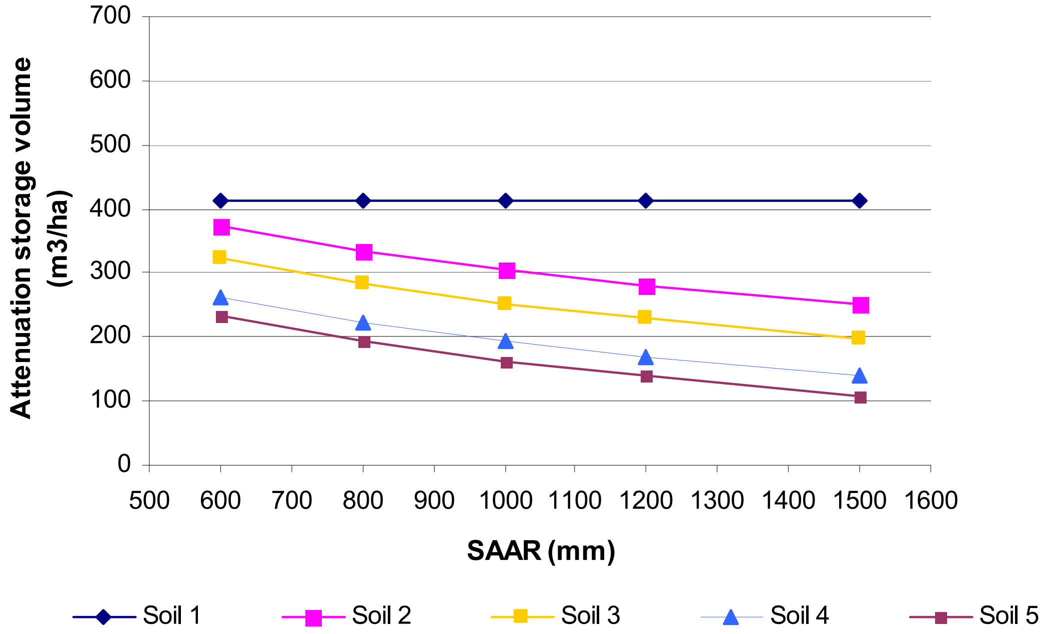


Figure A3.3 Attenuation storage volume – North and West (PIMP = 50%)

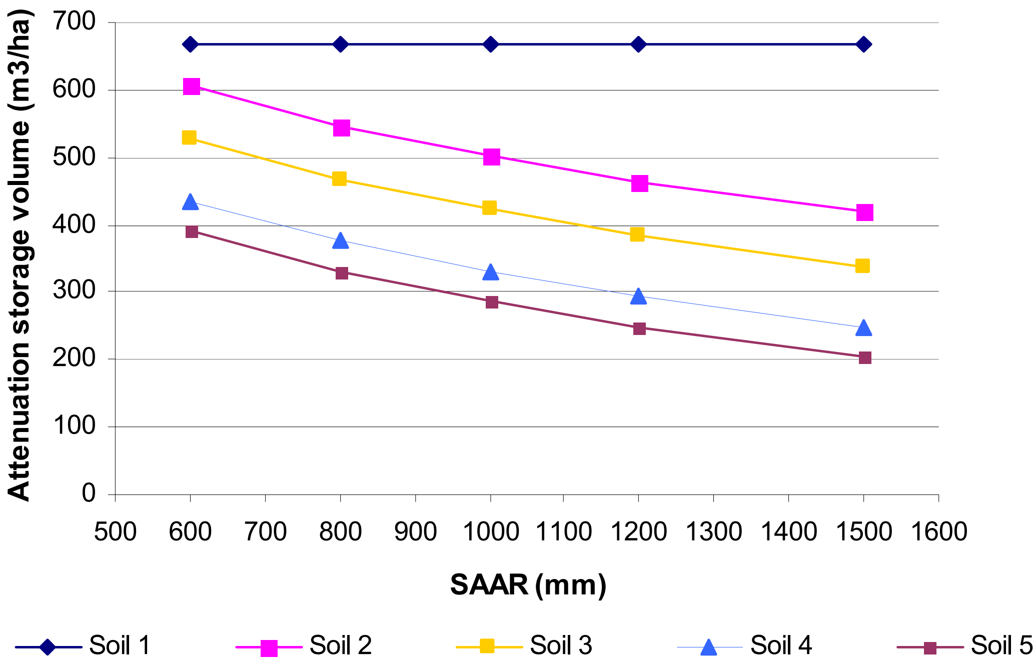


Figure A3.4 Attenuation storage volume – North and West (PIMP = 70%)

Appendix 4 Long term storage volumes

Long term storage volume estimates can be seen in Tables A4.1 to A4.3.

Assume PIMP = 70%
Assume all paved areas are positively drained.
Assume 0%, 50% and 100% of the pervious areas are positively drained in Tables A4.1 to A4.3 respectively

Runoff model = 80% runoff from paved areas
= SPR runoff from pervious areas

Table A4.1 Estimates of long term storage volumes – 0% pervious area runoff

Rainfall depth	Soil Class	1	2	3	4	5
(mm)	SPR	0.1	0.3	0.37	0.47	0.53
51		234.6	132.6	96.9	45.9	15.3
55		253	143	104.5	49.5	16.5
60		276	156	114	54	18
61		280.6	158.6	115.9	54.9	18.3
63		289.8	163.8	119.7	56.7	18.9
70		322	182	133	63	21
71		326.6	184.6	134.9	63.9	21.3
82		377.2	213.2	155.8	73.8	24.6

Table A4.2 Estimates of long term storage volumes – 50% pervious area runoff

Rainfall depth	Soil Class	1	2	3	4	5
(mm)	SPR	0.1	0.3	0.37	0.47	0.53
51		277.95	262.65	257.295	249.645	245.055
55		299.75	283.25	277.475	269.225	264.275
60		327	309	302.7	293.7	288.3
61		332.45	314.15	307.745	298.595	293.105
63		343.35	324.45	317.835	308.385	302.715
70		381.5	360.5	353.15	342.65	336.35
71		386.95	365.65	358.195	347.545	341.155
82		446.9	422.3	413.69	401.39	394.01

Table A4.3 Estimates of long term storage volumes – 100% pervious area runoff

Rainfall depth	Soil Class	1	2	3	4	5
(mm)	SPR	0.1	0.3	0.37	0.47	0.53
51		249.9	178.5	153.51	117.81	96.39
55		269.5	192.5	165.55	127.05	103.95
60		294	210	180.6	138.6	113.4
61		298.9	213.5	183.61	140.91	115.29
63		308.7	220.5	189.63	145.53	119.07
70		343	245	210.7	161.7	132.3
71		347.9	248.5	213.71	164.01	134.19
82		401.8	287	246.82	189.42	154.98

Appendix 5 Flood Risk Assessments to accompany planning applications (England and Wales)

This appendix provides an overview of the requirement to carry out a flood risk assessment to accompany a planning application for new development. For further information, reference should be made to the relevant planning policies provided at the national and regional levels and by the Local Planning Authority (LPA) that will determine the application.

A5.1 Introduction

A5.1.1 Planning policy

Flood risk is a material consideration to be taken into account by LPAs when determining planning applications. The planning process requires an assessment to be made of any flood risks related to proposed developments. Separate planning policy guidance or statements are provided for each country in the UK, as listed in the table below.

Table A5.1 National planning policies on development and flooding

UK Country	National planning policy on development and flooding
England	Planning Policy Guidance 25: Development and Flood Risk (PPG25), DTLR July 2001 (currently under review by the Office of the Deputy Prime Minister)
Wales	Technical Advice Note 15: Development and Flood Risk (TAN15), National Assembly for Wales July 2004.
Scotland	Scottish Planning Policy 7: Planning and Flooding (SPP7), Scottish Executive, February 2004.
Northern Ireland	Planning Policy Statement 15: Planning and Flood Risk (PPS15), Department of the Environment, (currently at public consultation stage, comments by 29 April 2005).

A5.1.2 Definition

These assessments are usually referred to as site-specific Flood Risk Assessments (FRAs). These assessments have the purpose of determining the following:

- Whether the development itself will be subject to a flood risk, and
- Whether the development will increase the flood risk elsewhere.

This includes demonstrating how the flood risk can be managed or mitigated.

A FRA should assess risks associated with all types of flooding. These being:

- Fluvial flooding
- Coastal and tidal flooding
- Estuarial flooding and watercourses affected by tide-locking
- Groundwater flooding
- Flooding from overland flow

- Flooding from artificial drainage systems
- Flooding from infrastructure failure

The results of the FRA will depend on a variety of factors, including the location of the development, its proposed nature and its usage. In general, as the complexity of the site and the level of risk increases, the detail of the assessment should increase. Further details of this are provided in Section A3.1.

The assessment should consider the flood risk for the life-time of the development. Therefore, issues such as climate change, long term sea level changes, deterioration in defence condition, etc. need to be taken into consideration.

A5.1.3 Context for SUDS

As stated earlier in this manual, the purpose of SUDS is to minimise the impact of the development on the environment. This includes flooding. Therefore, SUDS can act as a means to mitigate the effects of the development on the surrounding area.

It is increasingly common for LPAs to specify the use of SUDS as a planning requirement for all new developments, whether in an area prone to flooding or not. This approach is strongly supported by the Environment Agency and other national regulators.

A5.2 Roles and Responsibilities

It is the responsibility of those choosing to develop a site and, therefore, generating the risk (either for the site itself or for the surrounding area) to demonstrate how the risk will be managed.

There are three main parties involved in FRAs (although other stakeholders should be consulted as appropriate). These are:

- The Developer
- The Local Planning Authority
- The Environment Agency

The primary roles and responsibilities of the three main parties are summarised below.

A5.2.1 The Developer

- Consult with the LPA and EA to obtain advice/guidance and information.
- Carry out the FRA in order to:
- Determine/understand the extent of the flood risk posed at the site and elsewhere.
- Demonstrate how the flood risk associated with a proposed development will be mitigated or managed.
- Submit the FRA alongside the planning application.
- Employ a suitably qualified professional to carry out these tasks.

A5.2.2 The Local Planning Authority

- Provide advice to the Developer regarding the requirements for a FRA.
- Provide information to the Developer regarding planning policy.
- Seek advice from the EA, which is subsequently treated as a material planning consideration.
- Review the FRA, if using the EA’s Standing Advice (see Section 3.2)

- Decide whether the flood risk will be at an acceptable level.
- Take into account all material planning considerations, flood risk being one of these.
- Decide whether the development can take place, imposing conditions if necessary.

A5.2.3 The Environment Agency

- Encourage best practices to be adopted for assessing the risk, managing the risk and deciding the risk is acceptable.
- Provide advice to the Developer regarding how to carry out an appropriate FRA.
- Provide data and information to the Developer, if available, regarding the local conditions.
- Provide information to the Developer regarding relevant flood risk management and environmental objectives/plans.
- Review FRAs at the request of the LPA.
- Choose to object to the planning application, if it considers that the FRA has not been carried out appropriately.
- Choose to object to the planning application, if it considers that the residual flood risk is not acceptable.

The Developer should involve both the LPA and EA as early as possible in the assessment process. Early consultation should help to prevent unnecessary cost for the Developer where an application is turned down. If the FRA is carried out appropriately, it should also reduce (but not eliminate) the likelihood that the EA will object to the application.

A5.3. The FRA Process

A5.3.1 Best practice guidance

The CIRIA guidance C624 "Development and flood risk – guidance for the construction industry"[1] provides best practice guidance for carrying out FRAs to accompany planning applications. It is recommended that reference is made to this document, rather than relying on the information contained in this manual, which only provides an overview of the requirements.

Box A5.1 A Summary of CIRIA guidance C624

- A description of the different types of flooding
- A description of the potential impacts of flooding on development vice versa
- A description of the requirements for FRAs within the planning process (as of 2003-04)
- The best practice approach for FRAs
- A tool-kit, consisting of a series of flow charts and check-lists to enable users to complete an appropriate FRA
- Examples of FRAs for sites with different flooding problems
- Descriptions of mitigation measures to manage flood risk at or caused by a development (including management of development runoff using SUDS)

The FRA carried out should be proportionate with regard to the individual characteristics of the site. All sites should carry out a Level 1 assessment. The results

[1] Lancaster, J, Preene, M and Marshall, C (2004) *C624 Development and Flood Risk – Guidance for the Construction Industry*, CIRIA, London.

of this assessment will determine whether a more detailed assessment is required. The nature of the flood hazard, the sensitivity of the proposed development, the potential impact it may have elsewhere and the amount of existing information available will influence the level of assessment to be undertaken.

Table A5.2 Levels of FRA (courtesy of CIRIA)

FRA Level	Description
1	**Screening study** to identify whether there are any flooding issues related to the development site that may warrant further consideration.
2	**Scoping study** to be undertaken if the Level 1 study indicates that the site may lie within an areas that is at risk of flooding or that the site may increase flood risk due to increased runoff, to confirm the possible sources of flooding that may affect the site. The study should include the following objectives: • Assessment of the availability and adequacy of existing information; • Qualitative assessment of the flood risk to the site, and the impact of the site on flood risk elsewhere; • Assessment of the possible scope for appropriate development design and to scope additional work required.
3	**Detailed study** to be undertaken if the Level 2 study concludes that quantitative analysis is required to assess flood risk issues related to the development site. The study should include: • Quantitative assessment of the potential flood risk to the development; • Quantitative assessment of the potential impact of the development on flood risk elsewhere; • Quantitative demonstration of the effectiveness of any proposed mitigation measures.

It is recommended that at least a Level 1 FRA is carried out as soon as a site is considered for development. As development proposals progress, additional FRAs can be undertaken to inform the master planning and outline design process. These will be at increasing levels of detail, as appropriate.

A5.3.2 Standing advice

The EA has produced Standing Advice[2] for England to enable LPAs to make decisions on low risk planning applications where flood risk is an issue without directly consulting the EA for an individual response. It also identifies those higher risk development situations where case by case consultation with the EA should be sought. The Standing Advice can be treated as if it were EA advice via a direct consultation response and a material planning consideration in determining the application. It remains a matter for the LPA to decide what weight it attaches to this Standing Advice having regard to this and all the other material considerations involved.

This Standing Advice includes reference to the use of SUDS. Comments on appropriate design are limited and users are referred to other documents for further information. These being:

[2] Environment Agency (2003) *National Standing Advice to Local Planning Authorities for Planning Applications - Development and Flood Risk*, Environment Agency.

- Approved Document Part H of the Building Regulations 2000
- Building Research Establishment (BRE) Digest 365
- PPG25 Appendix E
- CIRIA C522 document, Sustainable Urban Drainage Systems – Design Manual

A5.4. Audit and control

As described in Box A5.2, it is essential that a suitably qualified professional is employed to carry out the assessment. The assessment approach adopted, in combination with suitably precautionary solutions, needs to be robust enough to stand up to scrutiny at a public inquiry.

Box A5.2 Use of Professional Services according to PPG25

Paragraph 72 of PPG25 states:

The assessment of the significance of flooding issues requires careful professional judgement. The developer is responsible for ensuring the safe development and secure future occupancy of his site and should ensure that appropriate expertise is available to carry out any necessary investigations and to design and execute any necessary flood alleviation works. While the local planning authority will need to consider flooding issues in the public interest, it is entitled to require the developer to provide at application stage suitable expert advice from an appropriately qualified competent person on such matters. To inform a developers assessment, the Environment Agency should make available any relevant flood-risk information subject to their normal charging policy. The Agency should also be aware of the reliance that developers and their experts may place on the information provided in terms of local flooding conditions and flood risk. A local planning authority is not required to carry out its own assessment of flood risk but may rely on the developers information, subject to any views expressed by consultees, particularly those of the Environment Agency, in determining the application and any necessary conditions. Those providing such expert advice should be aware of the reliance that may be placed on it.

Appendix 6 Review of relevant policy and guidance for SUDS

Contents

Tables

1. Introduction

Due to pressure for new development and the demand for housing, particularly in the south of England, a guidance note was issued by the DLTR (PPG3) which emphasises the need for the foot-print of developments to be minimised. The housing density suggested by PPG3 will create urban areas that have a high proportion of impervious surface and therefore potentially restrict the opportunity to use certain SUDS components.

SUDS are now considered to be extremely important for minimising the impact of urbanisation. The Environment Agency, SEPA and DLTR/DTI (through PPG25) are making concerted efforts to implement Sustainable Drainage Systems in all proposed developments.

It can be seen that there is potential conflict between PPG3 and PPG25 and this may cause difficulties for Planners and Developers and their supporting expert engineering service providers.

This appendix references specific requirements for both PPG3 and PPG25 together with other relevant guidance and legislated material and summarises the various development policy requirements, which effect the nature of modern developments.

Firstly the relevant policy frameworks for England and Wales, Scotland, and Northern Ireland are outlined. In each region there is a different mechanism for setting out policies related to development and the focus of the policies can also vary.

Secondly, the key policies and guidance documents are identified according to their main focus. Short descriptions of their aims are provided. A more detailed review of both the key and other relevant references is provided in Chapter 4 of Appendix 6.

A summary of the main factors in planning new developments that affect the provision of SUDS is given in Section 3.2. This synthesises the information provided throughout the document. This is followed by a brief section about the legal requirements relating to adoption and maintenance of SUDS for new developments, recognising that this aspect is not a focal point of this project.

As mentioned, Section 4 provides a detailed review of the various policy and guidance documents relating to or with potential impacts upon the use of SUDS.

2. Planning information framework

Planning policy in the UK is set separately by the governing bodies of England, Scotland, Wales and North Ireland. Table A6.1 outlines the different types of policy statements associated with each area.

Table A6.1 Planning information framework in the UK

Country	Organisation	Guidance
England	Office of the Deputy Prime Minister (ODPM) DLTR (formerly DETR and DoE)	**Planning Policy Guidance Notes (PPGs)** set out the Government's national policy on different aspects of planning. **Circulars** are statements of national planning policy and contain guidance on policy implementation through legislation or procedural change
	ODPM	Relevant accompanying guidance material is also available from the ODPM (formerly DETR) in the form of **Good Practice Guidance** and other planning documents, including accompanying reports for different PPGs.
	Environment Agency (EA)	The environmental regulator (EA) also releases **PPGs**, which are **Pollution Prevention Guidance** documents. The EA also releases various **Policy** documents.
Northern Ireland	Department of the Environment	**Planning Policy Statements (PPS)** set out policies on particular aspects of land-use planning and apply to the whole of Northern Ireland. **Development Control Advice Notes (DCANs)** represent non-statutory planning guidance, which are intended to supplement, and expand upon policy documents.
	Environment and Heritage Service (EHS)	The environmental regulator (EHS) also releases **PPGs**, which are **Pollution Prevention Guidance** documents. The EHS also releases various **Policy** documents.
Scotland	Scottish Executive	**Scottish Planning Policies (SPP's)** are statements of Scottish Executive policy on nationally important land use and other planning matters. Previously, **National Planning Policy Guidelines (NPPG's)** were issued and these remain relevant until replaced by a **SPP**. **Circulars** provide statements of Scottish Executive policy, contain guidance on policy implementation through legislation or procedural change. **Planning Advice Notes (PANS)** provide advice on good practice and other relevant information.
	Scottish Environment Protection Agency (SEPA)	The environmental regulator (SEPA) also releases **PPGs**, which are **Pollution Prevention Guidance** documents. SEPA also releases various **Policy** documents.
Wales	Welsh Assembly Government	**Planning Policy Wales (PPW)** sets out the land use planning policies of the Welsh Assembly Government. **Technical Advice Notes (TANs)** provide additional guidance on implementing planning policy. Welsh Office **Circulars** provide procedural guidance on national planning policy.
	Environment Agency (Wales)	The Environment Agency (Wales) also produces **PPGs**, which **are Pollution Prevention Guidance**

Policy statements issued at regional and local level can also address the issues related to the incorporation of SUDS in new developments. However, regional and local planning policy and guidance is beyond the scope of the present review.

Other organisations such as CIRIA also provide supporting technical information in the form of good practise guides and design guides.

3. Summary of guidance and conclusions

This chapter provides a summary of the information on planning guidance and conclusion with regard to their impact on the use of SUDS in new developments.

3.1 REFERENCES

3.1.1 References directly relating to stormwater runoff designs of new developments

In this section the key references relating to stormwater runoff design of new developments are outlined. The references are grouped according to their key focus and a brief description of the overall aim of the documents is provided.

Focus: Flooding

The two key references relating drainage design for new developments and flood risk are noted below.

- DLTR, 2001. Planning Policy Guidance 25 (PPG 25): Development and Flood Risk, London, The Stationary Office
- National Assembly for Wales, 1998. Technical Advice Note (Wales) 15: Development and Flood Risk, www.wales.gov.uk/subiplanning/content/tans/tan15/tan_15_infor_e.htm

Both these references focus on the issue of development and flooding, with the minimisation of flood risk being the driving theme. It is expected that runoff from new developments should remain the same as for the predevelopment situation. For new developments the use of SUDS systems is promoted as the most effective method of minimising discharges from the site and also for addressing existing or potential changes to the flood risk. Also the impact of changes caused by new development should be considered at a catchment wide level.

Focus: Provision of drainage

The key regulations and policy statements below deal specifically with the provision of drainage to new developments and in particular they emphasise the benefits of SUDS systems over conventional drainage systems. The Building Regulations specifically promote infiltration and similar systems ahead of conventional piped drainage design.

- DTLR, The Building Regulations 2000, Part H: Drainage and Waste Disposal, The Stationary Office, 2002 edition
- Scottish Executive, the Building Standards Amendment (Scotland) Regulations 2001, 6th Amendment, Part M: Drainage and Sanitary Facilities

- National Assembly for Wales, 2002. Planning Policy Wales, www.wales.gov.uk/subiplanning/content/planningpolicy/final/intro_e.htm
- Scottish Executive, 2001. Planning Advice Note 61: Planning and Sustainable Urban Drainage Systems, Scottish Executive Development Department
- National SUDS Working Group, 2003. Framework for Sustainable Drainage Systems (SUDS) in England and Wales, Draft document for consultation.
- National SUDS Working Group, 2004, Interim Code of Practice, CIRIA.

The Interim Code of Practice was produced by the National SUDS working Group to give guidance on all SUDS issues. It is a holding document stating the position of all drainage stakeholders in England and Wales on SUDS and it will largely be superseded by activities resulting from Making Space for Water, Defra, 2005.

Focus: Groundwater protection and pollution control

- SEPA, 1997. Groundwater Protection Policy for Scotland, Policy No. 19, Scottish Environment Protection Agency
- SEPA, Environment Agency, Environment and Heritage Service, Pollution Prevention Guidelines, General Guide to the Prevention of Pollution PPG1, Scottish Environment Protection Agency
- ODPM, 2004. *Planning and Pollution Control*. Planning Policy Statement 23 (PPS23), www.odpm.gov.uk

The potential for the pollution of groundwater is an important issue for many SUDS systems, particularly those involving infiltration methods. The above documents deal with the protection of groundwater by limiting discharges in and around sources of water supply and also within particular 'zones'. PPS23 also covers the general control of pollution and emphasises the use of SUDS. It sets out the relevant mechanisms for pollution control planning, clearly identifying the level of responsibility for the various planning bodies.

3.1.2 References for guidance affecting design layout of new developments

The following references relate to different aspects that will affect the design of new developments. They are grouped according to the main focus of the document and a brief overview of their aims is provided.

Focus: Housing and Design

The following documents provide comprehensive policy and advice on the design of housing environments. They deal with issues such as site layout, house types, parking and transportation, along with the provision of green spaces. The companion guide to PPG3 also provides a series of case studies to illustrate how the policies and guidance can be applied in practice. Drainage design and the incorporation of SUDS systems are not explicitly addressed.

- DLTR, 2000. Planning Policy Guidance Note 3 (PPG3): Housing, London, The Stationary Office
- ODPM, 2001. Better Places to Live by design: a companion guide to PPG3, http://www.planning.odpm.gov.uk/betrplac/index.htm
- The Planning Service, 2001. Planning Policy Statement PPS 7 – Quality Residential Environments, Department of the Environment, Northern Ireland

- The Planning Service, 2000, Creating Places – achieving quality in residential developments, Department of the Environment, Northern Ireland, http://www.doeni.gov.uk/planning/Guidance/Creating_Places/Creating_Places.pdf
- Scottish Executive, 2003. Scottish Planning Policy 3 (SPP 3): Planning for Housing, Scottish Executive Development Department
- National Assembly for Wales, 2002. Planning Policy Wales, www.wales.gov.uk/subiplanning/content/planningpolicy/final/intro_e.htm
- Welsh Assembly Government, 2002, Technical Advice Note (TAN 12): Design, The Welsh Assembly Government, http://www.wales.gov.uk/subiplanning/content/tans/tan12/design-e.pdf

Focus: Transport and Roads

The main document covering transport policy is PPG13. The key focus is on an integrated transport strategy whereby the use of land determines the transport requirements, with an emphasis on reducing the need to travel and the length of journeys. Cycle and pedestrian transport are encouraged, along with improved provision for public transport.

- DoE, 1994a. Policy Planning Guidance Note 13 (PPG13): Transport, London, HMSO
- Highways Agency 2001. Vegetative treatment systems for highway runoff, Advice Note HA 103/01, The Stationary Office, London

Advice from the Highways Agency is included because of issues related to adoption of SUDS by highway authorities and discharge of SUDS into the highway drainage.

Focus: Open space

In new developments the requirement for green space provision and nature conservation are important concerns for developing a sustainable urban environment. The following documents provide policy guidance in these areas. The requirements for green space provide a possible mechanism for incorporating SUDS systems into high-density developments.

- DTLR, 2002. Planning Policy Guidance 17 (PPG17): Planning for Open Space, Sport and Recreation, London, The Stationary Office
- Scottish Executive, National Planning Policy Guideline 11 (NPPG 11): Sport, Physical Recreation and Open Space, www.scotland.gov.uk/about/Planning/nppg_11_sportphysica.aspx
- Scottish Executive, Planning Advice Notice 60 (PAN 60): Planning for Natural Heritage, Scottish Executive Development Department

3.2 SUMMARY ON REFERENCES

From the information outlined in the preceding section and the detailed policy statements given in Chapter 4, various conclusions can be drawn that have implications for the use of SUDS in new developments.

- The re-use of previously developed land is promoted ahead of greenfield sites. For example, both England and Northern Ireland have a target that 60% of any additional housing must be provided on previously developed land.

Any SUDS system needs to consider any previous site drainage. In many instances the use of SUDS will be able to improve the runoff characteristics of any previously developed land.
Any SUDS system must consider the pollution risk relating to the actions of previous owner occupiers of these sites.

- In England, in particular, the policy for new developments is to provide higher density housing, with a range of housing types within the development.
  This means that some garden space will be available for certain types of houses, but unavailable for others. The density of housing developments is set to increase.

- In future vehicular transport should give way to various forms of public transport. Within developments the emphasis is on pedestrian and cycle methods of transport i.e. 'home zone' roads, which means lower speed, lower use roads. There should also be increased provision of cycle ways and pedestrian paths through a site.
  Sites with slow traffic movement (especially pedestrian and cycle ways) represent possible locations for the use of permeable pavements and similar types SUDS systems.

- Provision of car parking space is no longer a requirement for developers and the use of on-street, and communal parking areas will increase. The allocation of land for parking as part of individual properties will decrease.
  The decrease in available parking areas has two impacts. Firstly, this reduces the area of impermeable surface created. Communal, parking areas are slow traffic movement locations and therefore amenable to the use of permeable pavements and similar SUDS systems.

- Energy conservation and minimisation principles are promoted and the layout and style of buildings and developments should take these concepts into consideration.
  These principles will affect the siting and orientation of buildings. The constraint this makes to the use of SUDS is likely to be limited, but remains to be quantified.

- Safety policy for new developments requires visibility and openness within the urban environment.
  Openness and visibility require space within a development which is potentially in conflict with the increased housing density and on-road parking recommendations of policies such as PPG3. Different layout and house styles can be used to address this issue. Public open space adjacent to roads meets this requirement and provides opportunities to use SUDS.

- Sustainable residential environments and the 'greening' of residential environments are promoted. The provision of green space and recreational areas is sought for a number of reasons, from increasing biodiversity and wildlife in an area, allowing space for children to play, to provide general areas for recreation and sport. This means that green spaces must be incorporated into any new development.
  Green space requirements represent a possible mechanism for incorporating SUDS in a new development. The actual needs of the community in terms of usable space must however be met and consideration must be given to related safety issues.

- Any new development should not add to the flood risk of an area or create additional pollution discharges from the site. It is recognised that new

developments create impervious areas and therefore there is a potential increased flood risk to the catchment. Consideration must also be given to the impact of the SUDS system on any groundwater resources.
New development must be limited to the same runoff from the site as for the predevelopment condition. SUDS are promoted as the preferred method of providing compliance with this requirement. Issues such as attenuation and pollution prevention are as important as flood risk and must also be addressed. For infiltration systems the impact upon groundwater levels and quality is the limiting condition for their application to particular locations.

3.3 OWNERSHIP AND ADOPTION ISSUES

In addition to planning requirements for SUDS in new developments there are also issues relating to the ownership and adoption of such systems for new developments that will affect their uptake and the types of SUDS chosen.

Within the curtilage of private properties, surface drainage is the responsibility of the owner. Outside the property, (unless the drain is privately owned) statutory responsibility of surface water drainage is split between various authorities.

England and Wales

The issues relating to adoption of SUDS systems are addressed in detail in the SUDS Interim Code of Practice (2004). The main stakeholders involved are local authorities, Sewerage Undertakers and the Highway Agency.

Section 106 of the Town and Country Planning Act 1990 is a suitable mechanism by which a SUDS system can be transferred into the management and maintenance of a local authority.

The highway authorities also have powers to adopt and maintain SUDS within the highway authorities drainage system.

Adoption of SUDS systems by Sewerage undertakers has a number of difficulties relating to the type of SUDS technique used, and in particular how the system discharges to the existing sewer or receiving waters. These issues are discussed in detail in the Framework document.

In July 2003 the Department for Environment Food and Rural Affairs (DEFRA) issued a consultation document called "Review of existing private sewers and drains England and Wales. This document sets out the present situation regarding the ownership and adoption of private sewers in England and Wales. This potentially has implications for the ownership and/or adoption of SUDS systems.

- Department for Environment, Food and Rural Affairs and the Welsh Assembly Government, 2003. Review of existing private sewers and drains in England and Wales – Consultation paper, www.defra.gov.uk/corportate/consult/sewers/index.htm

Scotland

The relevant document outlining the responsibilities of the various Statutory bodies in relation to drainage provision for new developments is outlined in:

Scottish Executive, 2001. Planning Advice Note 61: Planning and Sustainable Urban Drainage Systems, Scottish Executive Development Department.

"Section 7 of the Sewerage (Scotland) Act 1968 provides for local authorities (roads authorities) and water authorities to enter into agreements for shared drainage. Some agreements provide for a single shared drainage system to drain water from properties and from roads. While generally considered to apply to piped sewerage systems, it has been used as the basis for an agreement for maintenance of public above ground SUDS being the responsibility of the local authority, whilst below ground SUDS will be the responsibility of the water authority."

The guidance also suggests that as road authorities, water authorities and SEPA are statutory consultees for new development, including drainage, then the planning process should be used to co-ordinate the provision of SUDS.

4. Detailed references on new development requirements

4.1 GUIDANCE DIRECTLY RELATING TO STORMWATER RUNOFF DESIGNS OF NEW DEVELOPMENTS

Listed here are general policies and guidance statements that relate to stormwater runoff design of new developments.

DLTR, 2001. Planning Policy Guidance 25 (PPG 25): Development and Flood Risk, London, The Stationary Office

Paragraph 14
"…While there remain uncertainties, the importance of acting on a precautionary basis in relation to development and flood risk has increased in recent years by:…
more sustainable alternatives to conventional drainage systems, which can assist in reducing downstream flooding;…"

Paragraph 15
"…Individual property owners are also responsible for managing the drainage of their land in such a way as to prevent, as far as it reasonable practicable, adverse impacts on neighbouring land."

Paragraph 26
"…local authorities and developers should recognise that intense rainfall may still cause localised flooding almost anywhere due to surface flow exceeding the capacity of the existing drainage system."

Paragraph 30
"…Locally in all zones (zones refer to Table 1, PPG25), an assessment may be needed of the risk of groundwater flooding or local flooding due to overland sheet flow or runoff exceeding the capacity of drainage systems during prolonged or intense rainfall….The run-off implications of development should also be assessed for all zones and controlled, where possible, through the use of sustainable drainage systems."

Paragraph 38 (Canals and other artificial water bodies)
"… where developments propose to drain into a canal, due consideration should be given to the level and impact this drainage would have on the canal's ability to store water. The use of sustainable drainage systems is one way of overcoming concerns about the impact of developments on the canal's ability to handle flood water…"

Paragraph 41
"The restriction and reduction of surface water run-off from new developments can be encouraged by the provision of surface water storage areas, flow limiting devices in conjunction with surface or sub-surface storage or, where ground conditions permit, the use of infiltration areas and soakaways. Recently, there has been growing interest in the use of 'soft' sustainable drainage systems to mimic natural drainage. As well as reducing total and peak flows of run-off, these systems can contribute substantially to good design in improving the amenity and wildlife interest of developments, as well as encouraging natural groundwater recharge…."

Paragraph 56
"Recognising that flood risk should be an integral part of all land-use decisions, local plans should include policies which promote the use of appropriate areas of more sustainable drainage systems to control the water as near its source as possible. Since development in one part of a catchment may increase run-off and hence flood risk elsewhere, the aim should be for new development not to increase run-off from the undeveloped situation and for redevelopment to reduce run-off…."

Environment Agency, 1997. Policy and Practice for the Protection of Floodplains, the Environment Agency,
www.environment-agency.gov.uk/commondata/105385/126710.pdf

Section 2.4 Sustainable Development
The principles of sustainability in relation to the Agency's flood defence function include:
"Inappropriate development within floodplains should be resisted where such development would itself be at risk from flooding or may cause flooding elsewhere…"
"To minimise any increased surface water run-off, new development must be carefully located and designed. Where appropriate, run-off source control measures which may also improve water quality should be incorporated into the development proposal"

Policy FD-P5
"The Environment Agency will use its limited powers under the flood defence legislation to regulate development which might adversely affect floodplain and flood risk issues."
In this policy statement the term 'adversely affect' relates to the flood defences and the land drainage system.

Environment Agency, Policy EAS/0102/1/1: Sustainable Drainage Systems (SUDS)

"The Environment Agency will promote Sustainable Drainage Systems (SUDS) as a technique to manage surface and groundwater regimes sustainably."

Environment Agency, Sustainable Drainage Systems (SUDS) – AMP4 guidance for Agency Staff, Environment Agency Guidance

> The Environment Agency has adopted a policy to promote the use of SUDS (EAS/0102/1/1). The guidance therefore explains how "Environment Agency staff should approach the issue of SUDS within the context of the 2004 periodic review of the water industry and the development of the water industry asset management plans for 2005-2010 (AMP4)."

SEPA, 2001, Regulation of Urban Drainage, Policy No. 15, Scottish Environment Protection Agency

> Section 2.2
> "Sustainable Urban Drainage Systems (SUDS) allow water to be treated prior to release into Scotland's rivers, lochs, estuaries and coastal waters. SUDS also allow water to soak away into soil. SUDS are regarded by SEPA as the best practical means of protecting water quality from pollution by surface water run off. SEPA is therefore revising its approach to discharges of surface water runoff, in order to encourage the wider application of SUDS…"
>
> Section 5.1
> "…It is SEPA policy to promote sustainable urban drainage systems as the preferred solution for drainage of surface water runoff, including roof water, for all proposed developments."

Scottish Executive, 2001. Planning Advice Note 61: Planning and Sustainable Urban Drainage Systems, Scottish Executive Development Department

> Paragraph 5
> "…All proposals for development should therefore take account of the effects of potentially increased surface water run-off… This is particularly so for development on greenfield sites but the downstream impacts can also be significant for brownfield development where the existing drainage system may not have the capacity or be in a fit condition to carry the additional drainage without substantial reconstruction. For brownfield development, therefore, sustainable urban drainage also contributes to more efficient use of existing conventional systems."
>
> Paragraph 8
> "…It is SEPA policy to promote SUDS as the preferred solution for drainage of surface water run-off, including roof water, for all proposed development, greenfield and brownfield."
>
> Paragraph 17
> "Local plans should indicate the basis on which SUDS will influence the overall design of a major development or regeneration project. They should take into consideration the land requirement needed for SUDS when specifying housing density, and the opportunity that certain SUDS may contribute to satisfying a development's open space requirement…"

SEPA, 1997. Groundwater Protection Policy for Scotland, Policy No. 19, Scottish Environment Protection Agency

Section 5.38
Paragraph 2
"This typically involves small-scale discharges from septic tanks and sewage treatment plants serving individual properties, small housing estates and commercial developments. Such discharges normally pass to a constructed 'soakaway', where the effluent is distributed by a system of pipes within the lower soil horizon and soaks away to the underlying strata. Passage through the soil provides for the retention and degradation of the organic matter; the adsorption/absorption of nutrients: and the filtering of micro-organisms. Correctly constructed soakaways have the potential of providing an environmentally safe disposal route with minimal maintenance costs. The effectiveness of the system is however dependent upon the type of substrate and over time, leakage of nutrients is reported. In addition, the concentration of large numbers of soakaways over a shallow aquifer or their construction close to an abstraction source has been shown to affect groundwater quality."

Paragraph 6
"Runoff from urban areas such as roads, car parks and industrial yards has been demonstrated to be chronically polluted…SEPA advocated source control as the most effective means of minimising the pollution threat posed to Scotland's rivers by urban runoff. A combination of permeable surfaces, infiltration structures and soakaways avoids the concentration of flow and contaminants within a drainage system which then required treatment prior to discharge."

Paragraph 7
"…The bulk of the contaminants associated with urban runoff are strongly bound to particles and will be retained within the soil surface layers and will not normally pose a risk of groundwater contamination. However, it is important to identify those types of discharges and forms of drainage structures which may have the potential to threaten groundwater resources. Clearly, the risks associated with drainage from industrial and commercial properties may preclude the discharge of surface water to soakaway. Diversion to foul sewer, or pretreatment and monitoring may be required. The absorptive capacity of the substrate has the potential to retain and/or break down the contaminants associated with road and car park drainage. However, the concentration of flow to large deep soakaways poses a greater risk to groundwater than widespread permeable surfaces which avoid overwhelming the adsorption capacity of the substrate. Guidance from SEPA should be sought on the design of permeable systems within Source Protection Zones."

This policy is currently under review and will be updated to reflect the introduction of new and relevant legislation. A new policy is expected to be available in July 2003.

Scottish Executive, *Planning and Flooding – Consultation Draft*, Scottish Planning Policy 7 (SPP7), Scottish Executive Development Department.

Paragraph 15
"…The possibility of rainfall causing flooding from other sources is not restricted to the flood plain and coastal areas. If it is an issue, any drainage measures proposed as part of a planning application should have a neutral or better effect on the risk of flooding both on and off site."

Paragraph 20
"Sustainable drainage systems (SuDS) are a means of managing the flow of rain water run-off from a site by treating it on site and so reducing the loading on conventional piped drainage systems. Some SuDS such as detention ponds slow the rate of run-off by temporarily storing the water and this can help to mitigate peak flows on watercourses. SuDS can therefore make an important contribution to limiting off site flood risk and managing the water environment generally. They are not however a flood prevention measure for on-site flooding. Development proposals which would increase surface water run-off should incorporate a full or partially sustainable drainage system. In areas where the probability of flooding is high, SuDS should be designed so that they function soon after a flood subsides. If that is not possible they are unlikely to be acceptable and if conventional drainage is constrained this may amount to a reason for refusal."

National Assembly for Wales, 1998. Technical Advice Note (Wales) 15: Development and Flood Risk,
www.wales.gov.uk/subiplanning/content/tans/tan15/tan_15_infor_e.htm

Paragraph 14
The policy suggests that the "local planning authorities should discuss with the Environment Agency proposed developments on land which is: …iii. of such a size or nature relative to the receiving watercourse that there could be a significant increase in surface water run off from the area;…vi. situated in any area where the Environment Agency has indicated that there may be drainage problems;…"

Paragraph 18
"New developments may increase the quantity of and the rate at which run-off reaches watercourses because impermeable surfaces such as paved areas and roofs reduce the ground area capable of absorbing rainfall, as do some mining, land drainage and forestry developments. The effect maybe to cause an increase in run-off which may, in turn, mean that the capacity of the watercourse could be exceeded at times of flood risk, particularly where there are culverts, bridges or other artificial of natural restrictions. Similarly, canals may be more likely to flood if increased run-off causes the design capacity of culverts and weirs to be exceeded, or if their ability to provide buffer storage for watercourses downstream is overloaded. These potential effects should be taken into account by local planning authorities. Where the planning authority considers that, if it were not for this factor, planning permission should be given, it should advise the applicant accordingly, after consultation with the Environment Agency. The onus is then on the applicant to investigate and submit amendments to the planning application to show how sustainable water management techniques can alleviate or mitigate unacceptable flood risk arising from the development proposed."

Paragraph 19
"Works to limit surface water run-off from new developments can include the provision of surface water storage areas, flow limiting devices in conjunction with surface or subsurface storage or, where ground conditions permit and acceptable measures to avoid groundwater pollution can be achieved, the use of infiltration areas or soakaways. Ponds berms can enhance nature conservation interests, aid in the prevention of pollution and prove effective in delaying the discharge of water to natural watercourses. Where control devices are involved it will be particularly important to ensure that the developer enters into a legal agreement that ensures long term maintenance and renewal."

TAN 15 is currently being revised and a draft consultation document was released for consultation in July 2003.

National Assembly for Wales, 2003. Development and Flood Risk. Technical Advice Note (Wales) 15 – Consultation Draft,
www.wales.gov.uk/subiplanning/content/consultationpapers/tan15-cons-let-e.htm

Paragraph 10.1
"All types of land use change will impact on the natural hydrological cycle in one way or another. In all zones (referring to flood risk zones), development should not increase the risk of flooding elsewhere."

Paragraph 10.2
"Built developments, such as roads, pavements, and roofing, tends to increase the surface area of impermeable ground, thus reducing infiltration and increasing rapid surface run-off. This has the effect of reducing the time it takes for precipitation to enter the watercourse and increasing the peak discharge. Changes in vegetation cover associated with agricultural and forestry practises can, in some cases, exacerbate these effects. Therefore sustainable drainage systems (SuDS) should be implemented, wherever they will be effective, in all new development proposals, irrespective of the zone in which they are located."

Paragraph 10.3
"SuDS offer a variety of engineering solutions, both soft and hard, that can be employed to manage surface water run-off. It should be noted, however, that options which involve increasing infiltration will have limited effectiveness on sites underlain by high groundwater tables and/or very low permeability terrain. Consideration must also be given to maintaining the effectiveness of any artificial drainage system. Where artificial drainage systems are utilised it will be important to ensure provision for long term maintenance and renewal. Where necessary, conditions attached to permissions and/or agreements can be used to secure these objectives…"

Paragraph 16.8
"….Development in one part of a catchment may increase run-off and hence flood risk elsewhere, therefore, the aim should be for new development not to create additional run-off when compared with the undeveloped situation, and for redevelopment to reduce run-off where possible. It is accepted that there may be practical difficulties in achieving this aim. Systems that involve infiltration of all surface waters within the site will achieve this, however, balancing ponds and Suds techniques will not, as they work by reducing and delaying the peak discharge rather than preventing it altogether…"

Appendix 4 Sustainable drainage systems
This appendix contains more detailed supporting information to the document on SuDS techniques, their benefits and constraints, and their implementation.

European Union, Water Framework Directive, Directive 2000/60/EC, Official Journal of the European Communities.

The Directive requires member states to "decide on measures to limit pollution from storm water overflows". At present a large number of overflows require attention and improvement. The UK government has asked to Environment Agency to ensure that 85 percent of the overflows are brought up to standard by 2025.

Scottish Executive, the Building Standards Amendment (Scotland) Regulations 2001, 6th Amendment, Part M: Drainage and Sanitary Facilities.

Paragraph 3
"Conventional piped surface water drainage systems can cause flooding and pollution and disrupt the water cycle to the detriment of water resources and the natural environment. An alternative approach is needed to reach a more sustainable solution. Sustainable urban drainage is a concept that focuses decisions about drainage on the environment and people. The concept takes account of the quantity and quality of surface water run-off and the amenity value of surface water in the urban environment. Sustainable Urban Drainage Systems (SUDS) are physical structures that are designed to store, treat and control surface water run-off making provision for the concept for sustainable urban drainage…"

For surface water drainage the discharge options in order of priority are:
"a. drainage to suitable SUDS techniques; or
b. a surface water drainage system…"

Scottish Executive, National Planning Policy Guidelines 14 (NPPG 14): Natural Heritage, www.scotland.gov.uk/about/Planning/nppg_14_naturalherit.aspx

Paragraph 56
"Developers should be encouraged to incorporate existing ponds, watercourse or wetlands as positive environmental features in development schemes, and to identify suitable opportunities for creating new water or wetland features. They should generally be encouraged to seek alternatives to extensive culverting or canalisation, as these greatly reduce the ecological and amenity value of watercourses and culverting can also increase the risk of flooding…"

The Planning Service, 2001. Planning Policy Statement PPS 7 – Quality Residential Environments, Department of the Environment, Northern Ireland

Paragraph 4.24
"While the Department considers it important to ensure that all new development fits in well with its surroundings this will not preclude quality contemporary design using modern materials. Innovative design and layouts can achieve greater energy efficiency through the orientation of buildings to maximise passive solar gain and the use of renewable energy technologies and sustainable construction techniques. Greater consideration should also be given to the use of sustainable urban drainage systems (SUDS) and more environmentally sound methods of disposing of effluent."

Environment and Heritage Service, EHS Policy on Water Quality, Northern Ireland, www.ehsni.gov.uk/environment/waterManage/policy/policy.shtml and
Environment and Heritage Service, Sustainable drainage systems, Northern Ireland, www.ehsni.gov.uk/environment/waterManage/advice/suds.shtml

"SUDS systems can provide treatment of surface water and remove runoff from developments without causing flooding, pollution or a reduction in the amenity value or local biodiversity of a site".

SEPA, Environment Agency and Environment and Heritage Service, Pollution Prevention Guidelines, General Guide to the Prevention of Pollution PPG1, Scottish Environmental Protection Agency

> Section 4.a
> "…Where significant work is being undertaken on an existing site or new development, the Agencies (SEPA, the Environment Agency, Environment and Heritage Service) encourage the consideration of an alternative approach for surface drainage, which uses a combination of techniques known collectively as Sustainable Drainage Systems (SUDS)…"
>
> SUDS are also mentioned for surface water treatment in Section 4b.

National Assembly for Wales, 2002. Planning Policy Wales,
www.wales.gov.uk/subiplanning/content/planningpolicy/final/intro_e.htm

> Chapter 12 Infrastructure and Services
> Paragraph 12.4.2
> "Development proposing the use of non-mains drainage schemes will only be considered acceptable where connection to the mains sewer is not feasible. Non-mains sewage proposals, such as septic tanks and surface water drainage schemes, included in development applications should be the subject of an assessment of their effects on the environment, amenity and public health in the locality, in accordance with the criteria set out in Circular 10/99, prior to the determination of the planning application. A catchment wide perspective should be adopted, including the use of Sustainable Urban Drainage Systems where appropriate."
>
> Chapter 13 Minimising and Managing Environmental Risks and Pollution
> Paragraph 13.4.2
> "In determining applications for development, local planning authorities should work closely with the Environment Agency, drainage bodies, sewage undertakers, prospective developers and other relevant authorities to ensure that surface water run-off is to be controlled as near to the source as possible by the use of sustainable urban drainage systems…"

Scottish Executive, National Planning Policy Guideline 7 (NPPG 7) – Planning and Flooding, www.scotland.gov.uk/about/Planning/nppg_7_planningflood.aspx

> Paragraph 25
> "Road construction, including on-line improvements, can lead to changes in the run off characteristics of a watercourse's catchment area and hence the local drainage regime. Run off treatment and drainage design should be undertaken so that possible impacts on areas where there is a risk of flooding are reduced…"

Scottish Executive, 2003. Scottish Planning Policy 3 (SPP 3): Planning for Housing, Scottish Executive Development Department

> Paragraph 17
> “New developments should respect and where appropriate enhance existing vegetation and other natural features…Developments can enhance a site’s wildlife value through retention, creation or management of natural features and wildlife habitats. Well-designed sustainable urban drainage-systems (SUDS) can also add to the amenity, character and natural heritage interest of housing.

The Planning Service, 1997. Planning Policy Statement 2 (PPS2): Planning and Nature Conservation, http://www.doeni.gov.uk/planning/Planning_Policy_Statements/Planning_Policy_Statement_2/PPS2.pdf

> Paragraph 56
> “Development outside, but close to, the defined boundaries of a protected site may have serious repercussions within it, even to the point of destroying its scientific value. Wetlands (including marshes and estuaries, as well as rivers and lakes) are particularly vulnerable to the effects of drainage, alterations to the water table, water-borne pollution and other developments within catchment areas…”

DoE (Welsh Office), 1990. Planning Policy Guidance 14 (PPG14): Development on unstable land, http://www.planning.odpm.gov.uk/ppg/ppg14/pdf/ppg14.pdf

> Paragraph A46
> “…Increases in water content due to heavy rainfall or alteration of drainage may increase water pressures and thus decrease the resistance to ground movement.”
>
> Paragraph A52
> “…A rising groundwater table or increased water infiltration may cause collapse settlement of loose fills…”

Environment and Heritage Service, 2001. Policy and practice for the protection of groundwater in Northern Ireland, http://www.ehsni.gov.uk/pubs/publications/Policy_and_Practice_for_the_Protection_of_Groundwater_in_Northern_Ireland.pdf

> Groundwater protection policy statement 19
> “Disposal of surface drainage water to underground strata should have due regard to the contamination risk posed to groundwater.”

CIRIA, 1996. Infiltration drainage – Manual of good practice, Report 156, CIRIA, London, pp107

> Section 3.8.1, p33
> "If the discharge from the infiltration system is of a polluting nature a Consent to Discharge must be obtained. If it incorporates an overflow to a watercourse then, in addition, it will require Land Drainage Consent"
>
> Section 3.8.3, p34
> "There is no direct guidance on how the planning authority should determine an application for planning permission. Past experience shows, however, that the authority will need evidence of the adequacy of the system to provide drainage and the likelihood of any flooding occurring."

CIRIA, 2003. Sustainable drainage systems (SUDS) techniques: hydraulic, structural and water quality issues (PSG2), CIRIA project RP 663, (draft, March 2003)

> Pg 33
> "Some SUDS techniques require more land space than others. An easily recognisable example of this is the space required to construct a pond. Although a technique may require a large amount of space this is not necessarily a barrier to its use, even on high density urban developments. Planning Policy Guidance PPG3 requires developments to provide sufficient provision for open space and playing fields where such spaces are not already adequately provided within easy access of the new housing. A pond could be included in this area or it could be designed to flood on rare occasions and for a short time during and after extreme storm events..."
>
> Pg 36
> "There are several factors that may be considered when first developing the site design to help incorporate SUDS." (it contains a list of them)
>
> Section 3.2, pg 52
> "…The Building Regulations, Approved Document H lists the discharge options in order of priority:
>
> 1. Infiltration to the ground via a soakaway or other system.
> 2. Discharge to a watercourse or other surface water.
> 3. Discharge to a sewer…"

In the British Standard BS 752-4: 1998, Drain and sewer systems outside buildings, Part 4: Hydraulic design and environmental considerations information is provided on the design of flow detention facilities in the National Annex NF. This includes detention tanks and tank sewers, flood storage ponds, and soakaways. In Part 2 of the standard the performance requirements of drain and sewer systems are detailed.

The Highways Agency, together with other national highway administrations, have issued advice on the selection, design, construction and maintenance of vegetative treatment systems suitable for the control and treatment of runoff from major highways, including trunk roads and motorways. The vegetative treatment systems described are suitable for use on all types of road.

Other guidance documents include:

- CIRIA, 2000, Sustainable urban drainage systems – design manual for Scotland and Northern Ireland, C521, CIRIA, London, pp114
- CIRIA, 2000, Sustainable urban drainage systems – design manual for England and Wales, C522, CIRIA, London
- CIRIA, 1997. Review of the design and management of constructed wetlands. Report 180, CIRA, London, pp267
- CIRIA, 1999, Sustainable urban drainage systems – best practice guide. Publication C523, CIRIA, London, pp112
- CIRIA, 2000, Sustainable urban drainage systems – design manual for Scotland and Northern Ireland, C521, CIRIA, London, pp114
- CIRIA, 2000, Sustainable urban drainage systems – design manual for England and Wales, C522, CIRIA, London
- DTLR, The Building Regulations 2000, Part H: Drainage and Waste Disposal, The Stationary Office, 2002 edition
- DLTR, Circular 03/2001 for the Building and AI Amendment Regulations 2001, http://www.safety.odpm.gov.uk/bregs/brpub/brcircs/2001/01.tml
- National SUDS Working Group, 2003. Framework for Sustainable Drainage Systems (SUDS) in England and Wales, Draft framework for consultation, May 2003

4.2 GUIDANCE AFFECTING DESIGN LAYOUT OF NEW DEVELOPMENTS

DLTR, 2000. Planning Policy Guidance Note 3 (PPG3): Housing, London, The Stationary Office

Paragraph 22
"The Government is committed to maximising the re-use of previously developed land and empty properties and the conversion of non-residential buildings for housing, in order to both promote regeneration and minimise the amount of greenfield land being taken for development."

Paragraph 23
"The national target is that by 2008, 60% of additional housing should be provided on previously-developed land and through conversions of existing buildings."

Paragraph 31
"In deciding which sites to allocate for housing in local plans and UDPs, local planning authorities should assess potential and sustainability for development against each of the following criteria:…

- the capacity of existing and potential infrastructure; …
- the physical and environmental constraints on development of land."

Paragraph 38
"…Where a proposed housing development involves the use of a previously-developed site or the conversion of existing buildings, the proposal may need to be amended in accordance with this guidance, for example, in relation to design, layout, density and parking."

Paragraph 46
"To promote more sustainable residential environments, both within and outside

existing urban areas, local planning authorities should promote:….

- a greener residential environment;…"

Paragraph 52
"The Government attaches particular importance to the 'greening' of residential environments. Greening initiatives can enhance quality, assist the permeability of land for storm drainage and contribute to biodiversity…."

Paragraph 53
"Local planning authorities should have clear policies for the protection and creation of open space and playing fields, and new housing developments should incorporate sufficient provision where such spaces are not already adequately provided within easy access of the new housing…"

Paragraph 58
"Local planning authorities should therefore:

- avoid developments which make inefficient use of land (those of less than 30 dwellings per hectare net;
- encourage housing development which makes more efficient use of land (between 30 and 50 dwellings per hectare net); …."

Annex C - Paragraph 8.19
"A 'net site density' is a more refined estimate than the gross site density and includes only those areas which will be developed for housing and directly associated uses. This will include:

- access roads within the site;
- private garden space;
- car parking areas;
- incidental open space and landscaping; and
- children's play areas where these are to be provided."

Annex C - Paragraph 8.20
"It therefore excludes:

- major distributor roads;
- primary schools;
- open spaces serving a wider areas; and
- significant landscape buffer strips.

Paragraph 51
"…Local planning authorities should allow housing developments with limited or no off-street car parking in areas with good public transport accessibility and where effective on-street parking control is present or can be secured."

Paragraph 56
"…Local planning authorities should adopt policies which ….focus on the quality if the places and living environments being created and give priority to the needs of pedestrians rather than the movement and parking of vehicles…"

Paragraph 57
"…Local planning authorities should therefore examine critically the standards they apply to new development, particularly with regard to roads, layouts and car parking, to avoid the profligate use of land."

Paragraph 60
"Car parking standards for housing have become increasingly demanding and have been applied to rigidly, often as minimum standards. Developer should not be required to provide more car parking than they or potential occupiers might want, nor to provide off-street parking where there is no need, particularly in urban areas where public transport is available or where there is a demand for car-free housing. Parking policies should be framed with good design in mind, recognising that car ownership varies with income, age, household type, and type of housing and its location. They should not be expressed as minimum standards."

Paragraph 62
"Car parking standards that result, on average, in development with more than 1.5 off-street car parking spaces per dwelling are unlikely to reflect the Government's emphasis on securing sustainable residential environments. Policies which would result in higher levels of off-street parking, especially in urban areas, should not be adopted."

DLTR, 2001. Planning Policy Guidance 25 (PPG 25): Development and Flood Risk, London, The Stationary Office

Paragraph 11
"…Soft engineering techniques such as creating, preserving and enhancing natural flood meadows and washlands or salt marshes can mud flats can be of great value in attenuating flooding as well as contributing to biodiversity…"

Paragraph 20
"… those proposing particular developments are responsible for:…satisfying the local authority that any flood risk to the development or additional risk arising from the proposal will be successfully managed with the minimum environmental effect, to ensure that the site can be developed and occupied safely."

DTLR, 2002. Planning Policy Guidance 17 (PPG17): Planning for Open Space, Sport and Recreation, London, The Stationary Office

Planning Objectives
5 planning objectives are included for planning policy for open space, sport and recreation including:
"promoting more sustainable development – by ensuring that open space, sports and recreational facilities (particularly in urban areas) are easily accessible by walking and cycling and that more heavily used or intensive sports and recreational facilities are planned for locations well served by public transport."

Paragraph 11
"Open space and sports and recreational facilities that are of high quality or of particular value to a local community, should be recognised and given protection by local authorities through appropriate policies in plans. Areas of particular quality may include:
i. small areas of open space in urban areas that provide an important local amenity and offer recreational and play opportunities;…
iii. areas of open space that particularly benefit wildlife and biodiversity."

Paragraph 23
"Local authorities should ensure that provision is made for local sports and recreational facilities (either through an increase in the number of facilities or through improvements

to existing facilities) where planning permission is granted for new developments (especially housing)…"

Paragraph 24
"In planning for new open spaces and in assessing applications for development, local authorities should seek opportunities to improve the local open space network, to create public open space from vacant land, and to incorporate open space within new developments on previously-used land…"

Annex: Definitions
2. Typology illustrating the range of open spaces that may be of public value:
iii. "green corridors – including river and canal banks, cycleways, and rights of way;
amenity greenspace (most commonly, but not exclusively in housing areas) – including informal recreation spaces, greenspaces in and around housing, domestic gardens and village greens;"

3. Local authorities should also recognise that most areas of open space can perform multiple functions…These include:
ii. urban quality: helping to support regeneration and improving quality of life for communities by providing visually attractive green spaces close to where people live;
iii. promoting health and well-being: providing opportunities to people of all ages for informal recreation, …
iv. havens and habitats for flora and fauna: sites may also have potential benefit to be corridors or stepping stones from one habitat to another and may contribute towards achieving objectives set out in local biodiversity plans;
vi. as a visual amenity: even without public access, people enjoy having open space near to them to provide an outlook, variety in the urban scene, or as a positive element in the landscape…."

DoE, 1997. Planning Policy Guidance 23 (PPG23): Planning and Pollution Control, www.planning.odpm.gov.uk/ppg/ppg23/pdf/ppg23.pdf

Section 3.3
"- the impact of any discharge of effluent or leachates, which may pose a threat to current and future surface or underground water resources or to adjacent areas"

The Planning Service, 2001. Planning Policy Statement PPS 7 – Quality Residential Environments, Department of the Environment, Northern Ireland

Section 1.5
"This statement seeks to achieve residential developments, on both brownfield and greenfield sites, which promote quality and sustainability in their design and layout, are more in harmony with their townscape or landscape setting and which ultimately will make a positive contribution to the character and appearance of our settlements…"
Paragraph 1.7
"…new housing layouts should incorporate formal open space, walks and cycleways and promote public transport provision. There should be more tree planting and a return to tree-lined avenues…"

Paragraph 1.11
"The (Regional Development) Strategy will promote the use of medium to high density housing schemes appropriate to their location which incorporate a mix of housing designs and sizes, while avoiding town cramming."

Paragraph 2
The main objectives of the Statement include:
"creates places for people which are attractive, locally distinctive and appropriate to their surroundings, safe convenient, adaptable and easy to maintain; reduces reliance on the private car, supports movement by pedestrians and cyclists, provides adequate and convenient access to public transport and connects well with the wider locality…"

Paragraph 4.16
"In future the Department will place more emphasis on the layout of houses and other buildings than on road layout in order to achieve an improved design quality and promote a sense of community, while continuing to ensure that standards of road safety are not compromised. All buildings should be located and orientated to front onto existing and proposed roads to present an attractive outlook. The Department will also expect to see greater variety introduced into schemes so that the spaces between houses include tree-lined avenues, crescents, mews, courtyards, lanes and greens. Particular care will be required in the treatment of corner sites within layouts and these should contain specifically designed buildings…"

Paragraph 4.26
"On greenfield sites innovative layouts and higher density schemes will be encouraged…On larger sites a range of densities, building forms and a mix of house types will be required to help enhance quality and sustainability…"

Paragraph 4.31
"….Developers should make adequate provision for private open space in the form of gardens, patios, balconies or terraces…All houses will need to provide some in-curtilage open space…For apartment developments private open space may be provided in the form of communal gardens…"

Paragraph 4.33
"…Residential developments will be required to incorporate traffic calming measures to keep traffic speeds low, improve safety and help create a better environment. The Department will therefore generally wish to see all access roads within a development designed to a 20mph maximum speed. On minor access roads favourable consideration will be given to the use of sub 10mph 'Home Zones'."

Section 4.36
"…All car parking should be well designed, convenient and located to allow for informal surveillance. It should not, however, dominate the residential environment created…"

Section 4.37
"Developers will also need to indicate what arrangements have been made within the development for secure bicycle parking. For apartment developments communal bicycle stands will often be required."

Section 4.38
"The protection of the privacy of the occupants of residential properties is an important element of the quality of a residential environment. It is a particularly important consideration where new development is adjacent to existing properties. Proposals should therefore seek to provide reasonable space between buildings in order to minimise overlooking. This will also assist in providing acceptable levels of daylight to properties."

Section 4.39
"…To enhance security from crime, the back gardens of dwellings should be enclosed and back onto each other. Public areas such as open spaces, pedestrian routes and cycle linkages should be overlooked by the fronts of dwellings and other buildings to provide maximum surveillance. Narrow, potentially unfrequented or unsupervised routes for pedestrians and cyclists will not be acceptable."

The Planning Service, 2002. Development Control Advice Note 8 (DCAN 8) – Housing in Existing Urban Areas, Department of the Environment, Northern Ireland.

Paragraph 1
"… The Regional development Strategy (RDS) has set an ambitious target which aims to achieve 60% of housing in Northern Ireland on land within existing urban areas…"

Paragraph 3.19
"The safety of residents as they move about the development is important and has been recognised by the 'Home Zones' concept. This is an idea promoted by Children's Play Council (1999), and aims to restore streets to pedestrians and make them more sociable places to live, by removing vehicle priority, and parking, and replacing them with enhanced landscaping, street furniture and public spaces…"

Paragraph 3.20
"Housing layouts should seek to maintain a clear definition between the public or civic realm of a street and private space allocated with the dwelling. Front gardens, or other forms of defensible space, of even a modest size, can provide an effective buffer to the street…"

Paragraph 3.22
"Distance separation, screening, window size and style, orientation and location of rooms and circulation space are some of the factors to consider in relation to ensuring adequate privacy and daylight."

Paragraph 3.23
"The protection of neighbouring properties from unreasonable loss of light is a well established planning consideration, and it is also important that layouts and dwellings are planned to provide acceptable levels of daylight to interiors."

Paragraph 3.42
"Provision of car parking should be broken up into a number of smaller areas, instead of one large car park, and it should be well integrated into the landscape strategy for the development."

Paragraph 3.46
"In new developments, on-street parking bays can be incorporated into the overall width of the street, and can be demarcated with paving, trees and planting."

National Assembly for Wales, 2002. Planning Policy Wales,
www.wales.gov.uk/subiplanning/content/planningpolicy/final/intro_e.htm

Chapter 2 Planning for sustainability
Paragraph 2.3.2
"Promote resource-efficient settlement patterns that minimise land-take (and especially extensions to the areas of impermeable surfaces) and urban sprawl, especially through preference for the re-use of suitable previously developed land and buildings…"

Paragraph 2.9.3
"The design process should promote the efficient use of resources, including land. It should seek to maximise energy efficiency and minimise the use of non renewable resources and the generation of waste and pollution. Ways to achieve this include, for example, site selection and treatment."

Chapter 5: Conserving and improving natural heritage and coast
Paragraph 5.1.3
"…new development on previously developed land provides opportunities to restore and enhance the natural heritage through land rehabilitation, landscape management and the creation of new or improved habitats."

Paragraph 5.5.1
"Biodiversity and landscape considerations must be taken into account in determining individual applications and contributing to the implementation of specific projects…"
Chapter 8 Transport
Paragraph 8.4.1
"…in areas of new development traffic calming measures should be incorporated…"

Chapter 8 Transport
Paragraph 8.4.2
"Car parking provision is a major influence on the choice and means of transport and pattern of development. Local authorities should ensure that new developments provide lower levels of parking than have generally been achieved in the past. Minimum parking standards are no longer appropriate…"

Chapter 9 Housing
Paragraph 9.1.1
"…new housing and residential environments (need to be) well designed, environmentally sound (especially energy efficient) and make a significant contribution to promoting community regeneration and improving the quality of life…"
"…the overall result of new housing developments in villages, towns or edge of settlement (needs to be) a mix of social and market housing that retains and, where practical, enhances important landscape and wildlife features in the development…"

Paragraph 9.1.2
Local planning authorities should promote:
"…attractive landscapes around dwellings, with usable open space and regard for biodiversity and nature conservation;…(and) well designed living environments, where appropriate at increased densities…"

Paragraph 9.2.11
"Policies will be needed to cover the physical scale and design of new buildings, access, density, and off-street parking, taking account of particular residential areas and of

changing needs. Strong pressure for development may give rise to inappropriate high densities if not carefully controlled. Higher densities should be encouraged on easily accessible sites, where appropriate, but these will need to be carefully designed to ensure a high quality environment…"

DETR, Planning for Sustainable Development: Towards Better Practise, www.planning.detr.gov.uk/susdev/index.htm

Chapter 3 – Growing new urban areas
"…New settlements will enjoy a high quality of urban and landscape design. As well as integrated open space, there should be habitat areas, and environmental gains such as energy efficiency measures introduced in layouts and individual buildings."
Chapter 5 – Incorporating other sustainability issues
"Local authorities should identify positive opportunities for improvements to the nature conservation of an area or site…"

Chapter 5
"Changes in site layout (orientation, location on slope, landscaping) can reduce the energy requirements of a typical dwelling by 20%, through the 'free' ambient sources created by passive solar gain, and microclimate improvements.

Scottish Executive, 2003. Scottish Planning Policy 3 (SPP 3): Planning for Housing, Scottish Executive Development Department

Paragraph 4
"…The planning system should encourage the creation of attractive, sustainable residential environments. New residential development must make efficient use of resources, reusing previously developed land wherever possible, supporting the aim of reducing energy consumption, and being accessible by forms of transport other than the private car."

Paragraph 14
"Good layout is at the heart of making residential environments safe and welcoming, and in helping people find their way around. Pedestrian activity in a residential area adds vitality and increases the feeling of personal safety…"

Paragraph 53
"…Proposals for sustainable residential developments using innovative, energy efficient technologies with particularly low impacts on the environment may be acceptable at locations where more conventional buildings would not…"

Scottish Executive, *Planning and Flooding*, National Planning Policy Guideline 7 (NPPG7), www.scotland.gov.uk/about/Planning/nppg_7_planningflood.aspx

Paragraph 52
"…all significant land allocations including housing land supply should now take into account the risk of flooding…"

NPPG7 is to be replaced by Scottish Planning Policy SPP7 Planning and Flooding. SPP7 is currently available in draft form for consultation.

Scottish Executive, *Planning and Flooding – Consultation Draft*, Scottish Planning Policy 7 (SPP7), Scottish Executive Development Department.

Summary, Paragraph 4
"Where built up areas already benefit from flood defences which reduce the probability of flooding, redevelopment of brownfield sites should be acceptable. Further greenfield development should be justified through the development plan process. Flood resistant materials and forms of construction may be required. Generally drainage will be a material consideration. Sustainable drainage will be required and watercourses should not be culverted…"

DoE, 1994a. Policy Planning Guidance Note 13 (PPG13): Transport, London, HMSO

Paragraph 49
"…Reducing the amount of parking in a new development (and in the expansion and change of use of an existing development) is essential, as part of a package of planning and transport measures, to promote sustainable travel choices…"

Paragraph 77 item 1
"Provision of wider pavements, including the reallocation of road space to pedestrians,…"

Scottish Executive, National Planning Policy Guideline 11 (NPPG 11): Sport, Physical Recreation and Open Space,
www.scotland.gov.uk/about/Planning/nppg_11_sportphysica.aspx

Paragraph 8
"Providing opportunities for sport and recreation near to where people live can make an important contribution to sustainable development…"

Paragraph 15
"…residential developments of 300 dwellings or more are likely to generate a need for new recreational provision…"

Paragraph 27
"In most residential areas the streets are not designed for play but children may still find them attractive and convenient. Traffic calming measures which remind drivers that they are sharing the environment with pedestrians and children at play can help to make the environment safer, but they do not override the need for formal play areas."

Paragraph 29
"…Provision for children's play should be made in planning consents for new housing and in development control generally…"

Paragraph 34
Illustrative Example 2
"The National Playing Fields Association recommends a minimum standard for outdoor playing space of 2.34 hectares per 1000 population…"

Paragraph 40
"Substantial new developments, particularly for housing or business should require the creation of additional open space to meet local needs…"

Scottish Executive, Planning Advice Notice 60 (PAN 60): Planning for Natural Heritage, Scottish Executive Development Department

Paragraph 23
"Safeguarding and enhancing landscape character is an important planning objective. Planning authorities can contribute to the protection and enhancement of landscape by:…setting clear policy objectives in relation to landscapes distinctive to the development plan area; and promoting high standards of siting and design and the use of appropriate materials."

Paragraph 45
" 'Greenspace' is an important component of open space. It can be defined as any vegetated land or water in or around the urban environment which has existing or potential natural heritage, amenity or recreational value. It can therefore encompass a wide range of different types of public and private open space including woodlands, parks, designed landscapes, wildlife sites, ponds and watercourses, areas of soft landscaping, open-air recreational facilities, play areas, and footpaths and cycleways. Research has demonstrated that diverse habitats in larger, consolidated, connected blocks offer greatest benefits to wildlife, but all greenspace can enhance the quality of urban life."

SEPA, 1997. Groundwater Protection Policy for Scotland, Policy No. 19, Scottish Environment Protection Agency

Preface
"The groundwater protection policy is aimed at providing a sustainable future for Scotland's groundwater resources by:…protecting groundwater quality through minimising the risks posed by point and diffuse sources of pollution;…"

Paragraph 5.8
"The presence of sewage works and the associated sewerage system present a risk of both bacteriological and chemical contamination to groundwater sources."

Paragraph 5.9
"Surface runoff from roads and railways is subject to chronic contamination with hydrocarbons and some heavy metals…"

Additional relevant references:

- DLTR, Green Spaces, Better Places, Report of the Urban Green Spaces Taskforce, www.urban.odpm.gov.uk/greenspace/taskforce/final. This report looks at the issues surrounding the provision of public green space in urban areas. There is a focus on quality and quantity of existing green space areas and also for the inclusion of sufficient green space in any new developments or redevelopment.

5. Bibliography

BS EN 752-4: 1998, Drain and sewer systems outside buildings – hydraulic design and environmental considerations, BSI

BS EN 752-2: 1997, Drain and sewer systems outside buildings – performance requirements, BSI

CIRIA, 1994. Control of pollution from highway drainage discharges, Report 142, reprint 1997, CIRIA, London, pp152

CIRIA, 1996. Infiltration drainage – Manuel of good practice, Report 156, CIRIA, London, pp107

CIRIA, 1997. Review of the design and management of constructed wetlands. Report 180, CIRA, London, pp267

CIRIA, 1999, Sustainable urban drainage systems – best practice guide. Publication C523, CIRIA, London, pp112

CIRIA, 2000, Sustainable urban drainage systems – design manual for Scotland and Northern Ireland, C521, CIRIA, London, pp114

CIRIA, 2000, Sustainable urban drainage systems – design manual for England and Wales, C522, CIRIA, London

CIRIA, 2003 Sustainable Drainage Systems (SUDS) Techniques: Hydraulic, Structural and Water Quality Issues, CIRIA Project RP 663, March, Draft for PSG2

DEFRA and the Welsh Assembly Government, 2003. Review of existing private sewers and drains in England and Wales – Consultation paper, www.defra.gov.uk/corportate/consult/sewers/index.htm

DETR, Planning for Sustainable Development: Towards Better Practise, www.planning.detr.gov.uk/susdev/index.htm

DETR (1999d) *Revision to Planning Policy Guidance Note (PPG) 13 Transport, Public Consultation Draft*, London, DETR

DETR, 1999. *Development Plans.* Planning Policy Guidance Note 12, London, TSO

DETR, 2000. *Regional Planning*. Planning Policy Guidance Note 11, London, The Stationary Office

DETR, Better places to live by design: a companion guide to PPG3

DLTR, Circular 03/2001 for the Building and AI Amendment Regulations 2001, http://www.safety.odpm.gov.uk/bregs/brpub/brcircs/2001/01.tml

DLTR, Green Spaces, Better Places, Report of the Urban Green Spaces Taskforce, www.urban.odpm.gov.uk/greenspace/taskforce/final

DoE, 1994a. *Transport.* Planning Policy Guidance 13, London, HMSO

DoE, 1996, *Town Centres and Retail Developments*. Planning Policy Guidance Note 6, London, The Stationary Office

DoE, 1997. *General Policy and Principles.* Planning Policy Guidance 1, London, The Stationery Office

DoE, 1997. *Planning and Pollution Control*. Planning Policy Guidance 23 (PPG23), www.planning.odpm.gov.uk/ppg/ppg23/pdf/ppg23.pdf

DTLR, 2000. *Housing*. Planning Policy Guidance Note 3, London, The Stationary Office

DTLR, 2001. *Development and Flood Risk*. Planning Policy Guidance Note 25, London, The Stationary Office

DTLR, 2002. *Planning for Open Space, Sport and Recreation*. Planning Policy Guidance Note 17, London, The Stationary Office

ODPM, 2002, Assessing Needs and Opportunities: A companion guide to PPG17, http://www.planning.odpm.gov.uk/anocg/index.htm

DTLR, The Building Regulations 2000, Part H: Drainage and Waste Disposal, The Stationary Office, 2002 edition

Environment Agency Guidance: Sustainable Drainage Systems (SUDS) – AMP4 guidance for Agency Staff
Environment Agency Policy EAS/0102/1/1: Sustainable Drainage Systems (SUDS)
Environment Agency, 1997, Policy and Practice for the Protection of Floodplains, The Environment Agency, www.environment-agency.gov.uk/commondata/105385/126710.pdf
European Union, Water Framework Directive, Directive 2000/60/EC, Official Journal of the European Communities.
Highways Agency et al.[1] 1996. Surface and sub-surface drainage systems for highways, Advice Note HD 33/96, The Stationary Office, London
Highways Agency et al.[1] 1998. Manual of contract documents for highway works, Volume 2, The Stationary Office, London
Highways Agency et al.[1] 1999. Safety aspects of road edge drainage features, Advice Note HA 83/99, The Stationary Office, London
Highways Agency et al.[1] 2001. Vegetative treatment systems for highway runoff, Advice Note HA 103/01, The Stationary Office, London
National SUDS Working Group, 2003. Framework for Sustainable Drainage Systems (SUDS) in England and Wales, draft for consultation, May 2003
National SUDS Working Group, 2004. Interim Code for Sustainable Drainage Systems, CIRIA publication

[1]Published jointly by the Highways Agency, Scottish Executive Development Department, National Assembly for Wales and Department for Regional Development, Northern Ireland in the Design manual for roads and bridges

Scotland

Scottish Executive, 2001. Planning and Sustainable Urban Drainage Systems, Planning Advice Note 61. Scottish Executive Development Department
Scottish Executive, 2003, Housing Land, Planning Advice Note 38, Scottish Executive Development Department
Scottish Executive, 2003. *Planning for Housing*, Scottish Planning Policy 3, Scottish Executive Development Department
Scottish Executive, *Natural Heritage*, National Planning Policy Guidelines 14, www.scotland.gov.uk/about/Planning/nppg_14_naturalherit.aspx
Scottish Executive, *Planning and Flooding*, National Planning Policy Guideline 7, www.scotland.gov.uk/about/Planning/nppg_7_planningflood.aspx
Scottish Executive, *Planning for Natural Heritage*, Planning Advice Notice 60, Scottish Executive
Scottish Executive, *Sport, Physical Recreation and Open Space*, National Planning Policy Guideline 11, www.scotland.gov.uk/about/Planning/nppg_11_sportphysica.aspx
Scottish Executive, *Planning and Flooding – Consultation Draft*, Scottish Planning Policy 7 (SPP7), Scottish Executive Development Department.
Scottish Executive, the Building Standards Amendment (Scotland) Regulations 2001, 6th Amendment, Part M: Drainage and Sanitary Facilities
SEPA and the Environment Agency, Works in, Near or Liable to Affect Watercourses, Pollution Prevention Guidelines PPG5
SEPA, 2001, Regulation of Urban Drainage, Policy No. 15, Scottish Environment Protection Agency
SEPA, 1997. Groundwater Protection Policy for Scotland, Policy No. 19, Scottish Environment Protection Agency

SEPA, 1996. Environment Agency and Environment and Heritage Service, General Guide to the Prevention of Pollution, Pollution Prevention Guidelines PPG1
SEPA, Environment Agency and Environment and Heritage Service, Disposal of sewage where no mains drainage is available, Pollution Prevention Guidelines PPG4
SEPA, 2000. Development at Risk of Flooding: Advice and Consultation, Policy No. 41, Scottish Environment Protection Agency

Northern Ireland

Environment and Heritage Service, EHS Policy on Water Quality, Northern Ireland, www.ehsni.gov.uk/environment/waterManage/policy/policy.shtml
Environment and Heritage Service, Sustainable Drainage Systems, Northern Ireland, www.ehsni.gov.uk/environment/waterManage/advice/suds.shtml
Environment and Heritage Service, 2001. Policy and practice for the protection of groundwater in Northern Ireland, http://www.ehsni.gov.uk/pubs/publications/Policy_and_Practice_for_the_Protection_of_Groundwater_in_Northern_Ireland.pdf
The Planning Service, (1996). *Roads Consideration*, Planning Policy Statement 3, Department of the Environment, Northern Ireland.
The Planning Service, (2002). *Access, Movement and Parking*, Draft Planning Policy Statement 3, Department of the Environment, Northern Ireland. (this will replace former PPS3: Roads)
The Planning Service, 2000. Creating Places – achieving quality in residential developments. Department of the Environment, Northern Ireland, www.doeni.gov.uk/planning/Guidance/Creating_Places/Creating_places.pdf
The Planning Service, 2000. Improving the Quality of Housing Layouts in Northern Ireland, Department of the Environment, Northern Ireland, www.doeni.gov.uk/planning/Guidance/Improving_the_Quality_of_Housing_Layouts.pdf
The Planning Service, 2001. *Quality Residential Environments*, Planning Policy Statement 7, Department of the Environment, Northern Ireland
The Planning Service, 2002. *Housing in Existing Urban Areas*, Development Control Advice Note 8 (DCAN8), Department of the Environment, Northern Ireland
The Planning Service, Planning Policy Statement 2 (PPS2): Planning and Nature Conservation

Wales

DoE (Welsh Office), 1990. Planning Policy Guidance 14 (PPG14): Development on unstable land, http://www.planning.odpm.gov.uk/ppg/ppg14/pdf/ppg14.pdf
National Assembly for Wales, Planning Policy Wales, 2002. http://www.wales.gov.uk/subiplanning/content/planningpolicy/final/intro-e.htm
National Assembly for Wales, 1996. Planning and Affordable Housing, Technical Advice Note 2, www.wales.gov.uk/subplanning/content/tans/tans02/tan2_intro-e.htm
National Assembly for Wales, 1998. Development and Flood Risk, Technical Advice Note 15, www.wales.gov.uk/subiplanning/content/tans/tan15/tan_15_infor_e.htm
National Assembly for Wales, 2002. Design, Technical Advice Note 12, http://www.wales.gov.uk/subiplanning/content/tans/tan12/design-e.pdf
National Assembly for Wales, 2003. Development and Flood Risk. Technical Advice Note (Wales) 15 – Consultation Draft,

www.wales.gov.uk/subiplanning/content/consultationpapers/tan15-cons-let-e.htm

References not sourced:

DETR, 1998d. Places, Streets and Movement: A Companion Guide to Design Bulletin 32, Residential Roads and Footpaths, London, DETR

DLTR, 1999. Planning requirements in respect of the use of non-mains sewerage incorporating septic tanks in new development, Circular C03/99, www.databases.dtlr.gov.uk/planning/npp/PubDetails.asp?thisPub=03/99

Appendix 7 Research reports produced during this project

A list of project outputs is included here. The reports listed are interim project reports only.

Kellagher, R.B.B. and Lauchlan, C.S., (2003). Use of SUDS in High Density Developments: Review of policy and guidance, SR Report 638, Rev 0.0, HR Wallingford, Wallingford, UK

Kellagher, R.B.B. and Lauchlan, C.S., (2003). Use of SUDS in High Density Developments: Defining hydraulic performance criteria, SR Report 640, Rev 2.0, HR Wallingford, Wallingford, UK

Kellagher, R.B.B. and Lauchlan, C.S., (2004). Use of SUDS in High Density Developments: Analysis of combined SUDS systems, SR Report 656, Rev 0.0, HR Wallingford, Wallingford, UK

Lauchlan, C.S. and Kellagher, R.B.B., (2004). Use of SUDS in High Density Developments: Land-use analysis for new developments, SR Report 655, Rev 0.0, HR Wallingford, Wallingford, UK

Lauchlan, C.S. and Kellagher, R.B.B., (2004). Use of SUDS in High Density Developments: Performance analysis of SUDS units. SR648, Rev 1.0, HR Wallingford, Wallingford, UK.

HR Wallingford
Working with water

HR Wallingford Ltd
Howbery Park
Wallingford
Oxfordshire OX10 8BA
UK

tel +44 (0)1491 835381
fax +44 (0)1491 832233
email info@hrwallingford.co.uk

www.hrwallingford.co.uk