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Sustainable urban drainage systems

best practice manual for England, Scotland, Wales and Northern Ireland

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Recent Government reorganisation has meant that DETR responsibilities have been moved variously to the Department of Trade and Industry (DTI), the Department for the Environment, Food and Rural Affairs (DEFRA), and the Department for Transport, Local Government and the Regions (DTLR). References made to the DETR in this publication should be read in this context.

For clarification, readers should contact the Department of Trade and Industry.

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Foreword

Water is a fine servant, but a bad master. Rain provides us with an essential for living, which we waste at our peril. Properly used it is an asset, but disposing of stormwater has for too long been viewed as a problem, and not an opportunity. As a society we have been guilty of wasting this precious asset, of pouring it away down the stormwater drain, with the attendant risk of worsening flooding, and adding to pollution.

There is nothing new about sustainable drainage systems (SuDS), but what is new is the publication of this SuDS best practice guide, which provides much needed advice for disposing of stormwater in a sustainable way; it is an essential supplement to the recently published design manuals. This guide is for developers, planners, and all who wish to deal with rainwater in a better way than just piping it away underground. It offers clear examples showing how SuDS can be used, and it will help to allay the fears of the doubters.

There are still obstacles to promoting SuDS, not least the lack of a national framework agreement for establishing maintenance of the sustainable drainage structures at the planning application stage. Scotland already has a trial agreement, and it is hoped that there will be a comparable framework agreement for England and Wales in the near future. Let us now promise ourselves that we will strive for a better way of draining our new developments, taking the opportunities when presented to build attractive ponds, and swales, and showing responsible stewardship for looking after our green and pleasant land.

Dr Geoff Mance
Director of water management, Environment Agency
and chairman of national SuDS working group

How to use this manual and contents

How to use this manual

This manual is designed to provide good practice guidance on the use of SUDS. It does not give detailed design guidance, but addresses the issues surrounding SUDS and their use. Detailed technical guidance is provided in two companion volumes C521 *Sustainable urban drainage systems – design manual for Scotland and Northern Ireland* and C522 *Sustainable urban drainage systems – design manual for England and Wales*. The above guides also provide relevant information on the current regional legal and regulatory background to SUDS. This best practice manual is not aimed solely at people who are already aware of SUDS, it is intended for use by all parties. It examines issues raised by those who may be sceptical about SUDS, and illustrates how SUDS can help to make developments more sustainable.

The manual is intended for a wide readership including members of the general public, community leaders, planners, developers, designers and many others. Each group or individual may have different opinions, different needs and different levels of initial understanding. This document attempts to cover all these aspects and to have “something for everyone”. For this reason, you may already know or understand some of the information and principles explained here, or in some areas it may seem over-simplified. However, there will equally be parts of the manual which present new information and issues that you were not aware of. There may also be sections that present topics you already understand, but from a different viewpoint. The chapter summaries in the contents pages below and the introductions to each section will help you to identify the sections that are relevant to your interests.

SUDS require a holistic approach, not only to design, but also to the whole implementation process. To encourage use of SUDS on developments, it is important that you have an awareness of the complete range of issues and the concerns of all stakeholders involved. If you understand the potential concerns, you are in the best position to allay them.

If we are to continue developing while maintaining the environment, we must use more sustainable practices.

1 Introducing sustainable urban drainage systems 11

This chapter will be particularly informative if you have no experience of urban drainage, as it introduces the subject and gives an overview of urban drainage techniques. However, the latter part of the chapter contains information that should be relevant regardless of your previous experience. This includes an introduction to SUDS and the principles behind them and a discussion regarding the need for a more sustainable approach to urban drainage.

2 What are sustainable urban drainage systems? 19

This chapter can be used to give a general introduction to the four main groups of SUDS devices, or you may wish to look up details about a particular device. Each sub-section gives you details about how the devices affect quality, quantity and amenity issues, along with brief details of any practical considerations.

3 Why use sustainable urban drainage systems? 29

This chapter is possibly the most important section of the whole manual. For those of you who are strongly in favour of SUDS, it illustrates some of the reservations that others may have. If you are sceptical about the benefits of SUDS, this chapter should help to dispel your doubts. For those of you who are new to the subject, this section will give you a feel for the myriad issues that surround SUDS and their use. In some cases the same issue may be seen as a benefit by one person but a challenge to the use of SUDS by another. It is important to remember that each issue is valuable to someone.

If you want to know how to put all the theory into practice, this is the chapter to read. It looks at the different actions that must be taken to facilitate the implementation of SUDS. It then guides you through the development process looking at the potential problems you may encounter at each stage. It also looks at practical examples of how problems have been overcome on real sites.

This manual highlights the necessity for a more sustainable approach to surface water drainage management. It also illustrates how SUDS can help us to achieve the goal of sustainable development. This chapter summarises how SUDS can provide sustainability using a team-based approach. It also identifies on-going initiatives and sources of further information.

This manual addresses the variety of issues that surround urban drainage systems. Two companion volumes discuss the technical issues in more detail. CIRIA publication C521 covers Scotland and Northern Ireland and CIRIA publication C522 is for England and Wales.

Glossary

attenuation	To reduce the force of a flow through a system, which has the effect of reducing the peak flow and increasing the duration of a flow event.
balancing pond	A pond designed to attenuate flows by storing runoff during peak periods and releasing it after the flood peak has passed.
basin	Flow control or water treatment structure that is normally dry.
catchment	The area contributing flow to a point on a drainage system.
combined sewer	A sewer designed to carry foul sewage and surface runoff in the same pipe.
CSO (**Combined Sewer Overflow)**	An outfall from a combined sewer designed to prevent the capacity of sewage treatment works from being exceed under storm flow conditions by allowing the discharge of excess diluted sewage to a watercourse.
curtilage	Land area within property boundaries.
design criteria	A set of standards agreed by the developer, planners and regulators that the proposed system should satisfy.
detention basin	A basin constructed to store water temporarily to attenuate flows.
dry	Free of water under dry weather flow conditions.
dry weather flow	All flow within a drainage system except that caused directly by rainfall
environmental footprint	A measure of environmental impact based on the distance that resources for a development are transported.
environmental management	A management agreement for an area or project set up to plan and make sure the declared management objectives for the area or project are met. Environmental management plans are often undertaken as part of an environmental impact assessment and are set out in several stages with responsibilities clearly defined and environmental monitoring procedures in place to show compliance with the plan.
extended detention basin	A detention basin where the runoff is stored beyond the time for attenuation. The extra time allows natural processes to remove some of the pollutants in the water.
filter drain	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.
first flush	The initial runoff from a site/catchment following the start of a rainfall event. As runoff travels over a catchment it will pick up or dissolve pollutants and the “first flush” portion of the flow may be the most contaminated as a result. This is especially the case in small or more uniform catchments; however, in larger or more complex catchments pollution wash-off may contaminate runoff throughout a rainfall event.
flood frequency	The probability of a flowrate being equalled or exceeded in any year.
floodplain	Land adjacent to a river that is subject to regular flooding.
hydrograph	A graph illustrating changes in the rate of flow from a catchment with time.
HOST	Hydrology of Soil Types. A classification used to indicate the permeability of the soil and the percentage runoff from a particular area.
infiltration – to the ground	The passage of surface water though the surface of the ground.

infiltration – to a sewer	The entry of groundwater to a sewer.
infiltration basin	A dry basin designed to promote infiltration of surface water to the ground.
infiltration trench	A trench, usually filled with stone, designed to promote infiltration of surface water to the ground.
interflow	Shallow infiltration to the soil, from where it may infiltrate vertically to an aquifer, move horizontally to a watercourse or be stored and subsequently evaporated.
lagoon	A pond designed for the settlement of suspended solids.
natural capital	The natural resource stocks from which resources useful for livelihoods are derived, eg water, land, environmental resources.
offstream	Dry weather flow bypasses the storage area.
onstream	Dry weather flow passes through the storage area.
permeable pavement	A paved surface that allows the passage of water through voids between the paving blocks/slabs.
permeable surface	A surface that allows water to infiltrate through itself into a permeable sub-base, before disposal.
pond	Flow control or water treatment structure that is wet.
porous paving	A permeable surface allowing the passage of water through voids within, rather than between, the paving blocks/slabs.
pound	A section of a swale designed to detain runoff.
recurrence interval	The average time between runoff events that have a certain flow rate; eg a flow of 2 m/s might have a recurrence interval of two years in a particular catchment.
requisition sewer (or sewer requisition)	A sewer built by a sewerage undertaker in response to a "requisition" notice served under Section 98 of the Water Industry Act (WIA) 1991. The requisition may be served on the undertaker by any of the bodies listed in subsection 1c of the Act (including the owner/occupier of the premises or the relevant local authority); see the WIA 1991 for specific details.
residuarity	The principle of ensuring that runoff is controlled as close as possible to the source if it cannot be completely dealt with at source.
retention pond	A pond where runoff is detained (eg for several days) to allow settlement and biological treatment of some pollutants.
RoSPA	Royal Society for the Prevention of Accidents.
runoff	Water that flows over the ground surface to the drainage system. This occurs if the ground is impermeable or if permeable ground is saturated.
SEPA	Scottish Environment Protection Agency.
separate sewer	A sewer for surface water or foul sewage, but not a combination of both.
SNH	Scottish Natural Heritage.
soakaway	A sub-surface structure designed to promote the infiltration of surface water.
SOIL	Soil index value obtained from the WRAP soil classification, used in the Wallingford Procedure to calculate the treatment volume.
source control	The control of runoff or pollution at or near its source.
STORM	A computer model based on equations used in the *California Stormwater Best Management Practice Handbook*. Used to assess detention basin performance.

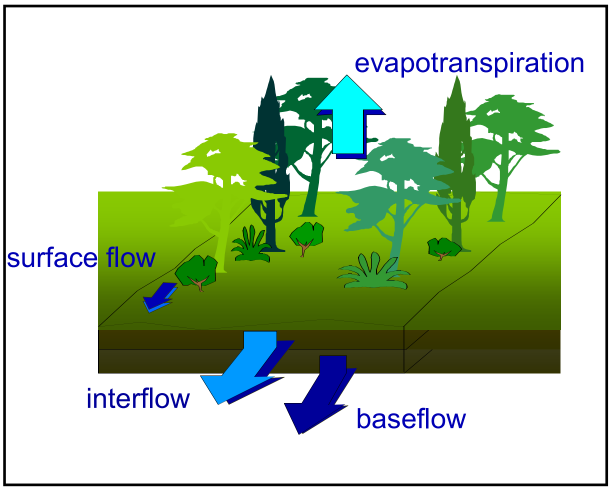
sub-base	A layer of material on the sub-grade that provides a foundation for a pavement surface.
sub-catchment	A division of a catchment, allowing runoff management as near to the source as is reasonable.
sub-grade	The surface of an excavation prepared to support a pavement.
subsidiarity	The principle that an issue should be managed as close as is reasonable to its source.
SUDS	Sustainable urban drainage systems: a sequence of management practices and control structures designed to drain surface water in a more sustainable fashion than some conventional techniques (may also be referred to as sustainable drainage systems SuDS).
surface water management train	The management of runoff in stages as it drains from a site.
swale	A grass-lined channel designed to control the flow rate and quality of water as it drains from a site.
treatment volume	The volume of surface runoff containing the most polluted portion of the flow from a rainfall event.
watercourse	Any natural or artificial channel that conveys surface water.
WRAP	Winter Rain Acceptance Potential. Classification used to calculate the permeability of soils and the percentage runoff from a particular area.
wet	Containing water under dry weather conditions.
wetland	A pond that has a high proportion of emergent vegetation in relation to open water.

1 Introducing sustainable urban drainage systems

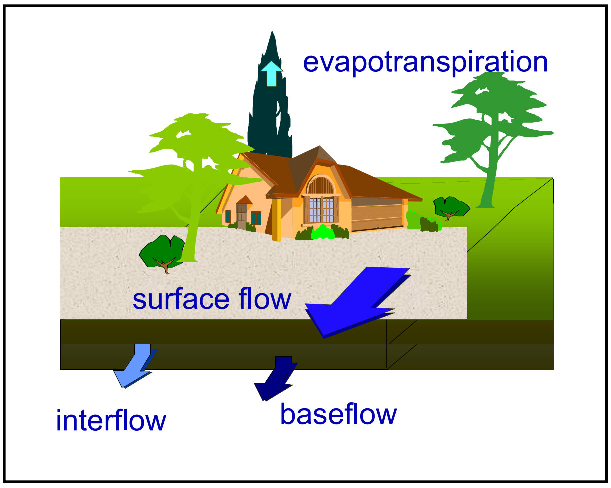
Sustainable urban drainage systems (SUDS) are a concept that focuses decisions about drainage on the environment and community. This takes account of surface runoff quantity and water quality equally with the amenity value of water in the built environment. In order to establish a more sustainable approach to managing surface runoff in urban areas, it is useful to examine conventional practice and see how it can be improved.

Why are urban areas drained?

When rain falls on to undeveloped land, most of the water will soak into the topsoil and slowly migrate through the soil to the nearest watercourse or groundwater. A small proportion of the rainfall – usually 15 to 20 per cent – becomes direct surface runoff that usually drains into watercourses slowly because the ground surface is rough (eg because of vegetation). This means that the effects of rainfall are spread out over a period of several hours. Even short, heavy storms may have little impact on flow rates in the receiving waters because much of the rain water may be absorbed into the ground.



When a catchment is developed, the proportion of land covered by impervious surfaces (roads, parking areas, roofs, driveways and pavements) will increase, preventing the natural infiltration of rainfall into the ground. Often the remaining open ground cannot accept water as rapidly as it did in its natural state, because during construction topsoil is removed, compacted or mixed with low-permeability subsoil. In developed catchments, direct runoff can increase to more than 80 per cent of the rainfall volume. At the same time, because paved surfaces may be less rough than natural surfaces, water may travel over them faster and as a result runoff will reach the receiving watercourses more quickly. The flow rates in the receiving waters are therefore much more sensitive to rainfall intensity and volume than those in an undeveloped catchment.



Volumes and rates of runoff both increase significantly after development. Peak flow rates can increase by a factor of up to ten, which means that streams and rivers have to cope with larger and often sudden runoff flows. It also means that drainage is needed to reduce flood risk within the developed areas.

Reasons for drainage

Urban runoff causes problems. These become obvious when a constructed drainage system fails. If the water flows across the surface of an urban area, there may be soil erosion and subsequent deposition of silt and debris. Large storms may result in uncontrolled floods, damaging property.

Where the water cannot drain away, puddles will form. This is not just an inconvenience for pedestrians but can be dangerous for road users. Waterlogging of the ground may contribute to ground heave, subsidence, dampness and other damage to property. Where the water forms stagnant pools, it can become a hazard to health and/or a breeding site for mosquitoes as well as being unsightly and foul-smelling.

Industrial estates are generally regarded as the most likely sources of surface water contamination. Oils and trace metals associated with motor vehicles and road runoff are generally regarded as toxic in increased concentrations, as are pesticides and oil detergent mixtures. The more pollutants produced within a catchment, the greater the risk of significant contamination of surface water.

Flooding in Belfast

How are urban areas drained?

The traditional approach to urban drainage is to remove the runoff from impervious surfaces in developed areas as quickly as possible, usually by collecting it in pipes. The main objective is to minimise the flood risk in the immediate area of concern.

Traditional drainage systems generally fall into two categories – combined sewers and separate sewers.

Some developments may be drained by combined sewer systems, where a single pipe is used to convey foul sewage and surface runoff. Combined systems usually carry sewage to a treatment works of limited capacity, requiring stormwater overflows that may allow some sewage to spill into watercourses during periods of heavy rain.

It was thought that these overflows were acceptable since the sewage is diluted by rainwater, reducing pollution, and the flows in the receiving watercourse provide further dilution. It is now recognised that combined sewer overflows can cause serious pollution, and significant investment is being made across the UK to minimise their impact.

In addition to combined sewers, an urban area may be drained using separate sewers. In separate systems, runoff and foul sewage are conveyed in separate pipes – the sewage to a treatment works, and the runoff to a nearby watercourse. Separate sewers appear to solve the problems, but this may not be the case.

As it flows across the ground, runoff can become contaminated with pollutants – for example metals, oils and petrol from vehicles; organic debris from litter; silt and dust; pesticides and detergents from gardens and car washing. In separate systems, this pollution may then be discharged directly into watercourses.

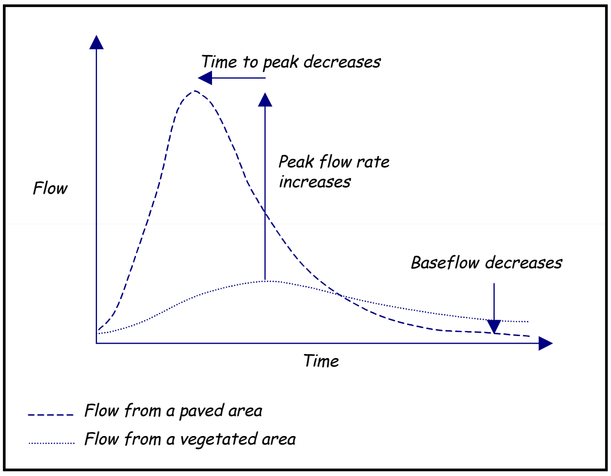
Drainage problems

Litter, sediment build-up and oil sheens on the water surface are common visible effects of urban pollution on surface water. They can be caused by conventional drainage practices and can also result in a reduction in the numbers of aquatic plants and animals.

The increased flows that may result from traditional drainage systems can cause further problems. They may, for example, cause streams to scour deeper and wider channels, adversely affecting aquatic habitats. Eroded sediments may be deposited downstream in slower-moving reaches of the river, damaging aquatic habitat in these areas and increasing sedimentation in wetlands. These increased flows can also lead to flooding downstream if the existing channel is too small for the larger volumes and faster rates of surface runoff.

Urbanisation can also lead to a lowering of the groundwater table under a development by reducing the surface water recharge to the ground. This has environmental and economic impacts, it contributes to water shortages, and can cause soil subsidence and consolidation problems.

The hydrological impacts associated with urbanisation are the reason why many urban rivers flow through concrete channels, or are culverted, destroying their amenity and wildlife value.



Hydrograph showing potential impact of development on the flow regime

To make matters worse, many existing piped drainage systems are operating at full capacity. They may be unable to take additional runoff and will require major work to enlarge their capacity if they are to cater for new developments.

Traditional drainage practices in general are not sustainable environmentally, economically or socially. If we are to continue developing without having a detrimental effect on our environment, we must find an alternative approach to urban drainage.

What are the alternatives?

There are two very different solutions to the urban drainage problem:

- improvements in conventional engineering practices
- sustainable urban drainage.

Surface water runoff can be polluted with silt, oil and other rubbish

Improvements in conventional engineering practices include:

- flood defences
- end-of-pipe treatment
- new-generation screens on CSOs
- managing flows within the sewerage network.

Flood defences require land take, extensive modelling and major construction works. Increases in flooding that may result from developments usually affect downstream communities, who may then have to bear the costs of the flooding and any flood defences.

Treating surface water in a traditional sewer system is difficult as the treatment works have to be able to cope with the large variations in flow rate and pollution load that may occur, for example, following a storm. Trying to treat all the flows from a large catchment results in large treatment facilities. Water from less polluted areas is mixed with contaminated water and it all requires treatment.

The continuing use of CSOs will not solve flooding or pollution problems and CSO screens only remove gross solids. They are an attempt to mitigate a problem caused by developments upstream.

Flow-restricting devices or real-time control can both be used to manage flows within a sewerage network. Flow-restricting devices mobilise the latent storage capacity present in a new or existing sewerage system (combined or separate). Real-time control can help by monitoring flows and moving sewage around to wherever there is capacity in the system, reducing the need for major construction work to increase the size of the sewers. Real-time control, which is outside the scope of this manual, uses a mix of active and passive control techniques and facilities. It can be a good solution in some towns and cities, but it is a high-technology solution. The main potential problem with real-time control and other techniques for managing of flows within the system is that they do not help in the drive towards sustainability.

A more sustainable approach

A sustainable urban drainage system will satisfy the following basic requirements:

- runoff from a developed area should be no greater than the runoff prior to development
- runoff from a developed area should not result in any downgrading of downstream watercourses or habitat
- pollution in the runoff generated by a development should be treated within the development area before discharge
- consideration should be given at the design stage to water resource management and control in the development area
- the wider needs of the community are considered in the development of the design.

What is sustainable urban drainage?

Sustainable urban drainage is an alternative concept in planning, design and management of storm drainage systems. It focuses on people and the environment, and gives equal consideration to water quality, water quantity and public amenity. These are drainage systems that work to reduce flood risk and pollution, and improve the urban environment for those who live and work in it.

Sustainable urban drainage techniques are often called best management practices (BMPs). The term SUDS also includes source control techniques. Examples of typical devices are described in Chapter 2.

SUDS are more sustainable than traditional drainage methods because they:

- reduce the impact of additional urbanisation on the frequency and size of floods
- protect or enhance river and groundwater quality
- are sympathetic to the needs of the local environment and community
- provide a habitat for wildlife in urban watercourses
- encourage natural groundwater recharge (where appropriate).

They do this by:

- dealing with runoff in the locality of the rainfall
- managing potential flooding at its source, now and in the future
- protecting water resources from point pollution (such as accidental spills) and diffuse pollution.

They also may allow new developments in areas where existing sewerage systems are close to full capacity, therefore enabling development within existing urban areas.

The document *Building a better quality of life: a strategy for sustainable development in the United Kingdom* (DETR 2000) confirms the UK Government's strong commitment to sustainable development from an environmental viewpoint. In particular it states the need for:

- social progress that recognises the needs of everyone
- effective protection of the environment
- prudent use of natural resources, and
- maintenance of high and stable levels of economic growth and employment.

Attenuation and storage provided by SUDS can help to reduce flood risk in urban areas

Benefits of sustainable urban drainage

The use of sustainable urban drainage to reduce and control surface runoff means there is less need for existing trunk sewers to be enlarged to cope with increased flows. They also reduce the need to upgrade sewage treatment works to treat flows that are mostly runoff.

The natural attenuation and storage provided by sustainable urban drainage systems can reduce flood risk within a development area and prevent any increases in downstream flood risk that might otherwise have resulted. SUDS could also potentially reduce flood risk if retrofitted to existing developments, but there is likely to be a requirement for positive drainage and flood attenuation measures in flood hazard areas.

The retention of surface water within a development can help to maintain both natural recharge and groundwater balance. This helps to ensure the survival of natural vegetation within the urban environment and prevents potential ground support problems that may result from the ground drying out.

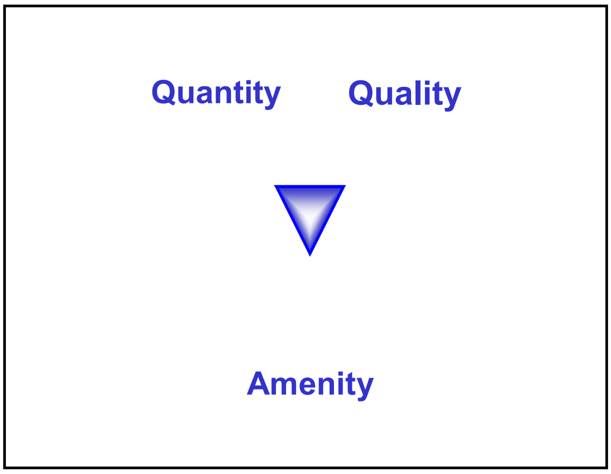
These runoff management systems, controls and techniques should therefore be adopted as the basis for sustainable urban drainage. SUDS can then play a fundamental part in enabling sustainable development

It must be remembered that source control and other sustainable solutions for urban drainage are generally preventative systems, naturally controlling both water quantity and quality. Using these systems within a development site will often avoid the need to provide complicated and expensive drainage solutions further downstream.

For many new urban developments, the attenuation of surface runoff within the development may be essential to reduce flood risk. In addition, if water quality as well as quantity considerations are given adequate attention at the outset, they can both be integrated into flood reduction measures and equally, flood reduction can be incorporated with water quality treatment.

Developments that integrate runoff treatment and flood control have many advantages. One economic benefit is that treatment can be combined with the flood control system with little added space requirement, thus increasing the available land for development. Also, some flood storage areas can serve as useful landscaping or amenity areas. Treatment facilities can also be designed as a water amenity within the general landscaped area of a site.

This holistic approach results in the surface water drainage system providing combined water quality control, water quantity control and amenity value. The three-way concept outlined below clearly shows the main goals that this approach to urban drainage is attempting to achieve. The goals have equal standing, and the ideal solution achieves all three.



The urban drainage triangle – balancing the impact of urban drainage on the environment

Thinking globally, acting locally

In the past, runoff treatment and drainage facilities have been designed, constructed and operated as single-purpose facilities. However, they can be integrated into a development so that they serve multiple purposes. Treatment facilities can, for example, be designed as community water features of amenity value in the urban landscape, providing a pleasing open space within a development. Landscape areas and footpaths can be developed in the flood plain, providing the developer with more land to develop. For a scheme to be successful, a master plan must be drafted that has the support of all interested parties, ie the developer, municipal planning, highway and drainage staff, the water authority, the environmental regulator and the public. If the project does not seek and gain this consensus by evolving an integrated plan, then it is possible that a development proposal could be delayed or even fail.

Although the benefits of an integrated approach combining water quality, water quantity and amenity are emphasised above, it may not always be a practical possibility. This is particularly true of smaller development sites. Their size may limit the choice of drainage system and make full integration impossible. However, even in these cases SUDS techniques may help to improve the sustainability of a site, even if they are incorporated only to a limited extent. It should be remembered that implementing best practice as standard at the local scale means that we are working together to achieve sustainable development on a larger scale.

When implementing SUDS it is important to remember that there are regional differences between England, Wales, Scotland and Northern Ireland in the legal and regulatory frameworks behind surface water drainage. These issues are covered in more detail in Chapter 3 and also in the SUDS technical guides C521 *Sustainable urban drainage systems – design manual for Scotland and Northern Ireland* and C522 *Sustainable urban drainage systems – design manual for England and Wales.* Further information on SUDS is also available from the EA/SEPA, through their guidance booklet *Sustainable Urban Drainage Systems an Introduction* and their video *Designs that hold water*.

Principles underlying SUDS

SUDS are designed to provide an approach to urban drainage that includes a long term view of the problems and opportunities. The concept of **sustainable development** includes a recognition of the interests of all the stakeholders in a project, present and future, directly and indirectly involved, including both social and environmental factors.

One of the problems with conventional drainage practice is the creation of **external costs**. A developer may pay for the drainage system within its boundaries, but the costs of controlling the flooding and pollution that may occur downstream will be borne by others. In order that those who benefit from a drainage system also bear the costs, the principle of **polluter pays** should be applied. By including all the costs that result from a development, economists argue that the most economically efficient outcome will result.

A practical application of this is the idea of **subsidiarity** – ie that an issue should be dealt with as locally as is reasonably possible. Source control of runoff is a good example of both of these principles. If runoff cannot be managed effectively on site, where it arises, then it must be adequately conveyed to a point where it can be discharged to the environment without causing excessive problems for others. This principle of ensuring that any runoff that cannot be fully controlled at source is dealt with as soon as possible further down the surface water management train, is called **residuarity**. This is particularly relevant to the surface water management train which works in stages, each level building on the flow and pollution control provided by stages further up the drainage system. The impact from one sub-catchment may not be dramatic, but the cumulative effect should make a major contribtution to runoff management.

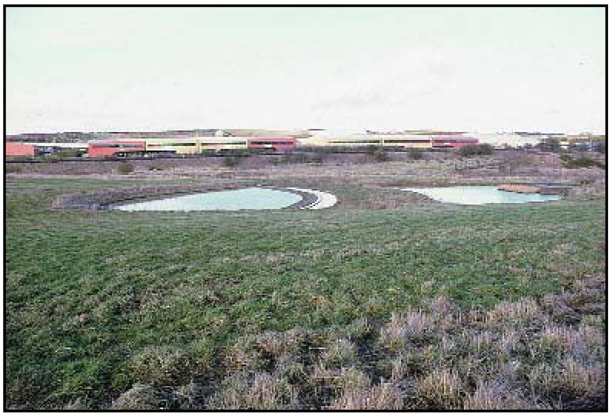
By managing the runoff as locally as possible, separate areas are being treated equally. If the water is conveyed off site as rapidly as possible, the problems are not only being moved to another area, but will become more polluted and may cause flooding problems on the way.

Equity is also a principle of sustainable development. Subsequent generations should not have to bear excessive maintenance or repair costs. However, the present generation should not have to pay for facilities that would reduce future risks to below reasonable levels. Unwarranted spending on runoff controls may reduce the opportunities for more advantageous investments in other fields. As part of this, it is worth remembering that SUDS have ongoing maintenance requirements (as do traditional systems) and that in some cases these can be higher than other options, although the initial capital costs are generally lower.

Thinking about the whole life of a drainage system does not simply affect the costs associated with its design and construction, but also the way in which it is carried out. In order to make a drainage system that is robust and has a long working life, it is often advisable to work with nature rather than trying to constrain or even oppose it. By mirroring nature and minimising radical change the **precautionary principle** is invoked. If major changes are made to complex ecosystems, the results cannot be forecast and so care should taken in any departure from the present situation. The idea of the precautionary principle is to proceed cautiously, and thus avoid unforeseen problems. Where the consequences may be serious (such as groundwater pollution), runoff treatment levels may need to be conservative, or, in extreme cases, conventional systems may need to be used. The possible future risks have to be balanced with current problems such as flooding and pollution from conventional systems.

Stakeholder participation

The design methods used in applying SUDS will frequently require a change from conventional practice. To date, designs of traditional systems have generally been carried out with little consultation. Increasing the number of parties to be consulted means that the design process will change. Early consultation, listening to all parties involved and making open, transparent decisions will ensure that all groups have input into the design of this public infrastructure.



SUDS work in series: here a settling pond used to take out coarse sediment is followed by a filter strip

The surface water management train

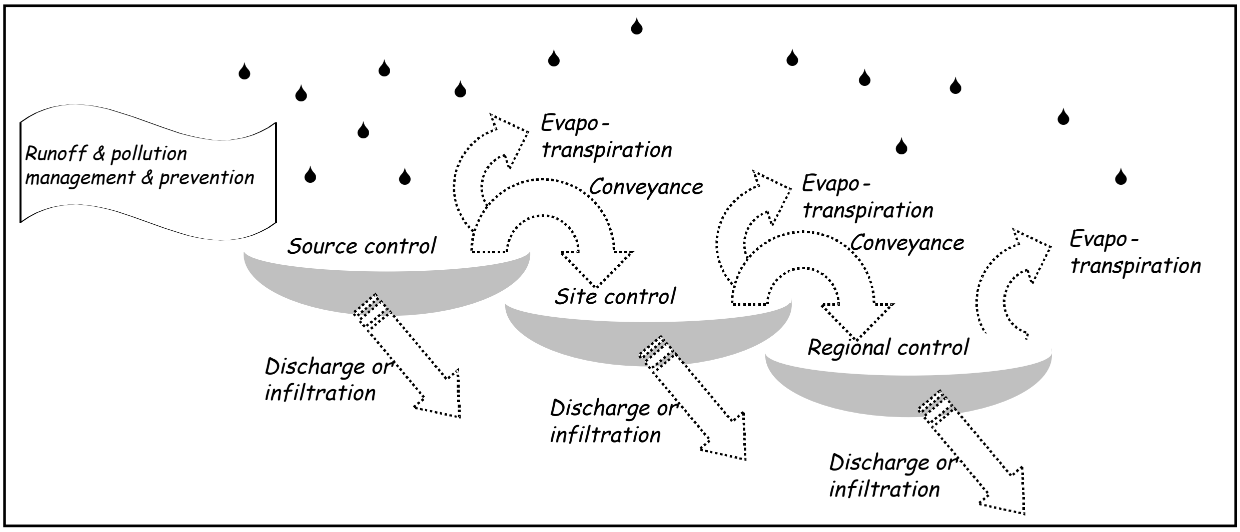
One of the differences in designing SUDS, compared with conventional drainage, is the variety of options available to designers. To give some structure to the design process, it is helpful to use the principles of the **surface water management train**. This reinforces, and where possible follows, the natural pattern of drainage. Ideally, surface water should be returned to the natural environment as soon as is reasonable. A design should start by preventing problems arising in the first place. The use of impermeable areas should be minimised, therefore, and where they are used they should not be connected to the drainage system if possible, but directed back into the natural water cycle.

If impermeable areas are used they should be kept clean to prevent pollution of the runoff. If the water never gets contaminated, it will not need to be treated before it is returned to the land.

If runoff cannot be avoided, then it should be dealt with at source. If the water is too polluted or the flows are too great to be discharged back to the environment immediately, the runoff will have to be conveyed to a site control to be managed before discharge. In these cases, it is still important to use source controls, as they will reduce the size of other drainage devices further down the surface water management train. This means that the design should define and utilise small sub-catchments, dealing with runoff locally, before grouping these sub-catchments together if needed. This is a good example of subsidiarity in action.

The management train shows how runoff can be managed using a series of processes. Each process changes the characteristics of the runoff until it can be discharged. Regional controls should only be required if the runoff cannot be managed in full locally.

The management train is a guide that demonstrates the principles that should be used wherever possible. However, SUDS have to fulfil a variety of functions, and designers may have to review a design and use devices further down the management train if need be. A fuller explanation of the SUDS design selection process is provided in Appendix C.



The surface water management train