6. SUSTAINABLE DRAINAGE SYSTEMS

6.1 Introduction

The previous chapters of this report have highlighted how traditional drainage systems have been unable to prevent deteriorating water quality and flooding problems in the Greater Dublin Area. Consequently, there is greater recognition that current practices cannot continue, particularly given the requirements of the WFD and other environmental legislation. Sustainable Drainage Systems (SuDS) now offer an excellent alternative to traditional systems and have been utilised successfully overseas for many years. The terminology Sustainable Drainage Systems is adopted throughout this document rather than Sustainable **Urban** Drainage Systems, as such systems are not limited to strictly urban environments.

This chapter introduces SuDS and the available techniques to control the quantity and quality of runoff. It provides guidance on the selection of SuDS for particular sites and discusses issues such as operation and maintenance, cost effectiveness, recreation and amenity, habitat potential and safety. In addition, guidelines on volumetric design required to provide water quality treatment is provided while the volumetric design of SuDS for runoff attenuation and flood control is dealt with in detail in **Volume 2 (New Development).** To supplement this chapter, SuDS policies and case studies drawn from international experience are provided in **Appendix D** and an information sheet for each structural SuDS option is provided in **Appendix E** and the Executive Report on Environmental Management.

SuDS will be mandatory for new developments unless the developer can demonstrate to the Local Authority that its inclusion is impractical due to site circumstances or that its effect on the control of run-off would be minimal, such as for rural sites. Volume 2 of the Regional Policies (New Development) discusses the key issues surrounding the standardisation of sustainable drainage systems in new development across the Dublin Region, provides key recommendations and the procedures required in order to implement them.

6.2 Overview of Sustainable Drainage

As indicated in the preceding chapters, urbanisation has had a profound effect on the aquatic environment. During urban development, vegetation is removed and replaced by roads, car parks, driveways and rooftops that are impervious to rainfall. Unable to percolate into the soil, rainfall becomes almost completely converted to runoff.

To date, traditional drainage practices have relied on conveyance of runoff through pipes, accelerating the speed of runoff and bypassing the natural buffering effect of soils and vegetation. Consequently, both volumes and rates of runoff increase significantly after development. This can lead to a variety of problems including flooding, soil erosion, reduced recharge of groundwater and reduced river baseflow. Furthermore, the impermeable surfaces associated with urban development are often contaminated by a variety of pollutants (such as gross pollutants, detergents, trace metals, hydrocarbons, nutrients, pesticides and herbicides) which are entrained in the runoff and discharge into receiving waters, causing pollution.

Sustainable drainage systems aim towards maintaining or restoring a more natural hydrological regime, such that the impact of urbanisation on downstream flooding and water quality is minimised. Originally, SuDS were introduced primarily as single purpose facilities however this has now evolved into more integrated systems which serve a variety of purposes, including habitat and amenity enhancement. The main advantages of an integrated SuDS facility are the savings on land-take and maintenance.

6.3 Philosophy of SuDS

SuDS involve a change in our way of managing urban run-off from solely looking at volume control to an integrated multi-disciplinary approach which addresses water quality, water quantity, amenity and habitat (**Figure 45**). ***When implementing SuDS, it is essential to consider all of these issues.***

SuDS minimise the impacts of urban runoff by capturing runoff as close to source as possible and then releasing it slowly. The use of SuDS to control runoff also provides the additional benefit of reducing pollutants in the surface water by settling out suspended solids, and in some cases providing biological treatment.

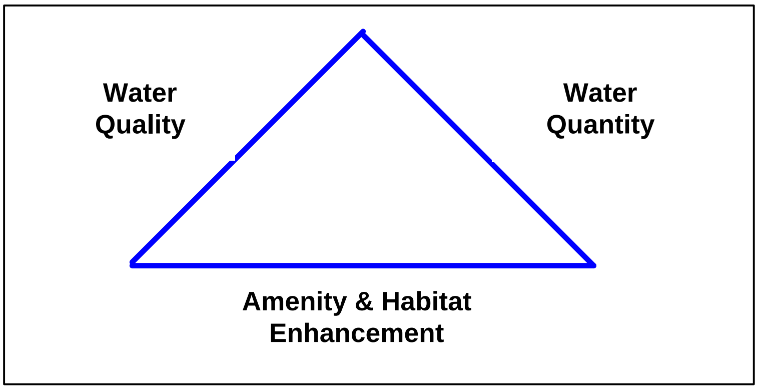


Figure 45: The Sustainable Urban Drainage Concept

The successful achievement of sustainable urban drainage does not solely rely on the use of engineered techniques to control and treat runoff. 'Good housekeeping' measures, such as safe storage and handling of oils and chemicals, street sweeping and control of sediment run-off from construction sites are an essential component of SuDS. Public awareness is also an important factor in ensuring the successful implementation of sustainable drainage practices.

Recommendations

49. Environmental Policy to incorporate sustainable drainage systems which balance the impact of urban drainage through the achievement of quantity control, quality control and amenity/habitat enhancement.

50. Authorities to promote the prevention of pollution through 'good housekeeping' measures.

51. Local Authorities to undertake stakeholder awareness programs to maximise participation of all stakeholders, including the public, thus ensure successful adoption of the SuDS.

6.4 Sustainable Drainage Techniques

6.4.1 SuDS Options

SuDS are a flexible series of options which allow the designer to select those systems that best suit the circumstances of a site. There are 2 basic mechanisms by which SuDS remove pollutants, i.e.:

- Sedimentation / filtration;
- Biodegradation.

Some systems are primarily designed to capture suspended material (e.g. swales, detention basins, filter drains and grass filter strips). Infiltration systems provide filtration in top layers of soil/subsoil, and assume sufficiently low levels of contamination by water-soluble pollutants to rely on degradation and subsequent dilution and dispersion. ***Only retention ponds and stormwater wetlands have sufficient retention time to allow for breakdown of many pollutants***. They also provide significant storage for persistent pollutants adsorbed on deposited sediments. These ponds and wetlands also allow for storage of significant flood volumes. Biological degradation of pollutants deposited in the vegetation of swales and detention basins will also occur, but may only be a modest proportion of the influent load (D'Arcy, 2001).

Several systems strive to prevent the generation of runoff by reducing the impervious cover within an area, thereby reducing the quantity of surface water entering the sewerage network during storm events and reducing the amount of water which requires treatment. These focus on disconnecting roofs and paved areas from conventional drainage systems and conveying runoff to soakaways, vegetated open spaces, gravel areas (such as the use of gravel driveways or permeable paviours) and the use of water butts.

The primary functions of different types of SuDS, are described in **Table 14** below. Detailed information on their function and performance are described in **Appendix E**. For these options to be effective, a treatment train approach which combines a number of SuDS options in sequence is advocated. This concept is described in more detail below.

6.4.2 The SuDS Management/Treatment Train Concept

Effective stormwater management is best achieved from a management systems approach, rather than an approach which focuses on individual practices. Some individual practices may not be very effective alone, but in combination with others, may provide a key function in highly effective systems.

A stormwater management or treatment train approach (**Figure 46**), assures that runoff quantity and quality is addressed. The following four objectives of the treatment train provide an integrated and balanced approach to help mitigate the changes in stormwater runoff flows that occur as land is urbanised and to help mitigate the impacts of stormwater quality on receiving systems:

1. **Pollution prevention**; spill prevention, recycling, public awareness and participation.
2. **Source control:** conveyance and infiltration of runoff;
3. **Site Control:** reduction in volume and rate of surface runoff, with some additional treatment provided; and
4. **Regional Control:** Interception of runoff downstream of all source and on-site controls to provide follow–up flow management and water quality treatment.

Type of System	Device	Primary Function	Primary Characteristics	Example
Water conservation & re-use (Source Control)	*Water butts, Rain tanks, Greywater re-use, Rooftop greening*	Collection and re-use of surface water	Provides offline attenuation of stormwater	
Infiltration systems ***(Source Control)***	*Infiltration Trenches, Infiltration Basins, Permeable Paving*	Encourage stormwater to soak into the ground while filtering pollutants	Permeable features allowing infiltration	
Filtration systems ***(Source Control)***	*Swales, Bioretention Systems, Filter Strips*	Capture heavy metals, grease, oil, nutrients and sediment	Grassed or planted features such as channels	
Retention systems ***(Site / Regional Control)***	*Retention ponds*	Primarily designed to retain pollutants	Artificial lake with fringing vegetation	
Detention systems ***(Site / Regional Control)***	*Detention basins, filter drains*	Primarily designed to reduce runoff rate	Vegetated depressions	
Constructed wetlands ***(Regional Control)***	*Stormwater wetlands*	Filter stormwater and reduce runoff rate while providing a wildlife habitat	Heavily vegetated hydrologically charged area	

Table 14: Functions of SuDS Devices

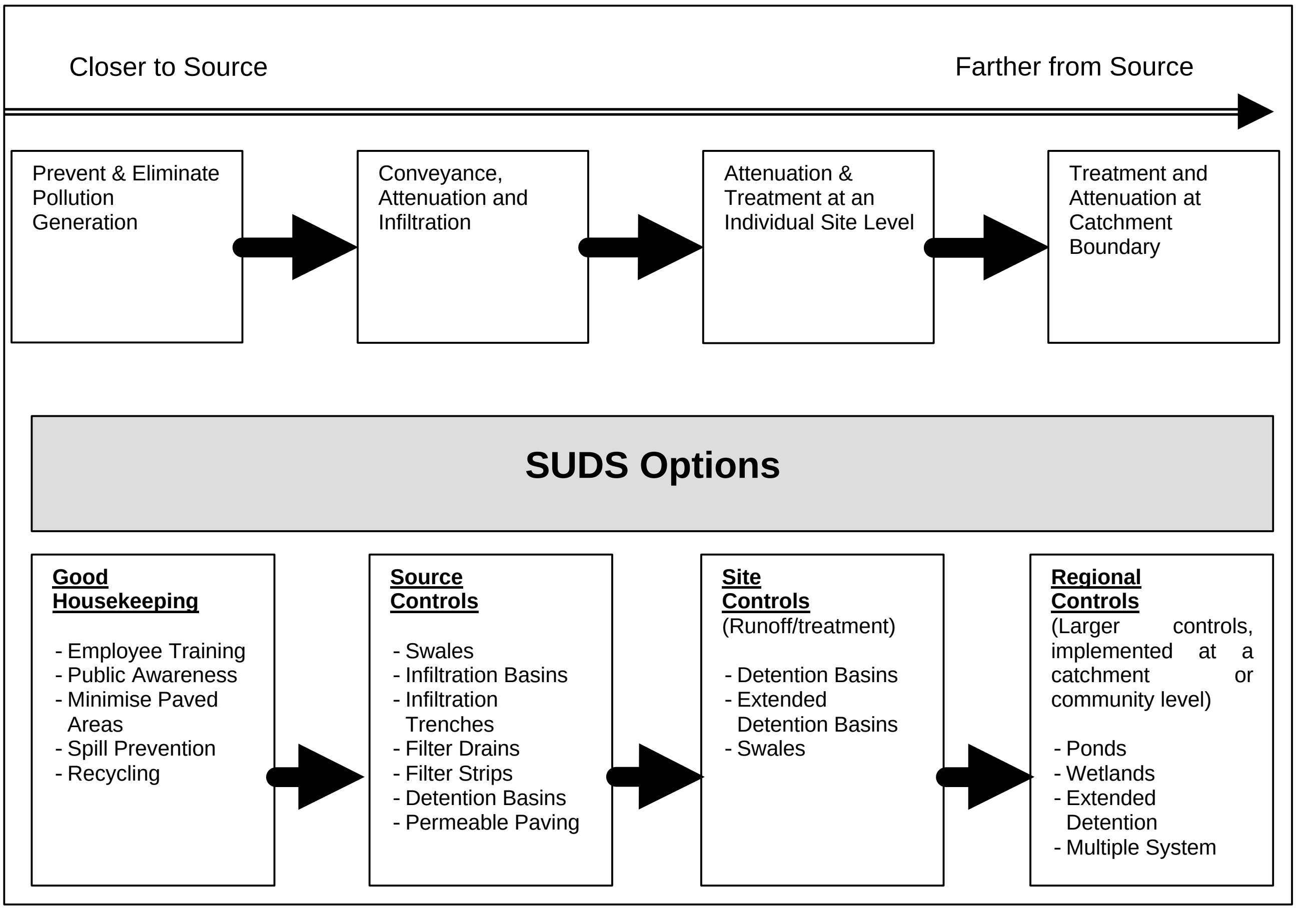


Figure 46: The Stormwater Treatment Train Concept

The first line of defence is pollution prevention (***good housekeeping***). Incorporating pollution prevention before an activity takes place is more practical and cost effective than remediating pollution afterwards. The best defence against urban runoff pollution is to prevent chemicals and other pollutants coming into contact with rainfall through appropriate storage and management and through public education.

The second line of defence is to detain or infiltrate runoff in vegetated areas such as filter strips, infiltration devices and swales which are located as close to the point of origin as possible (***source control***). The employment of source control devices reduces the peak runoff rate, placing less stress on any facilities downstream, allowing them to be smaller in size and also ensures that the quantity of unavoidable pollutants to be dealt with is small and manageable. Source controls can also consist of devices such as water butts which can be incorporated into developments as small as the size of a single house. The collection of surface water on such small sites, individually may not be very important, but collectively can have a significant impact.

Site controls are runoff and treatment controls that serve individual developments such as swales and detentions basins. A site could be a shopping centre, an industrial site, or a residential development of 10 to 50 homes.

The last line of defence are ***regional controls*** which are used to remove pollutants from contaminated runoff and have the potential to provide biological treatment. These structures deal with runoff on a catchment scale rather than source (usually drain areas of 2 hectares or larger) and are often end of pipe facilities. These could incorporate gross pollutant traps such as trash racks and hydrodynamic separators which could also be considered at the ‘site control’ stage.

The treatment train concept promotes the division of the area to be drained into sub-catchments with different drainage characteristics and land uses, each with its own drainage strategy. Dealing with the water locally, reduces the quantity that has to be managed at any one point. This approach can also successively reduce the pollutants in the runoff passing through the train.

Figure 47 below shows a typical treatment train layout.

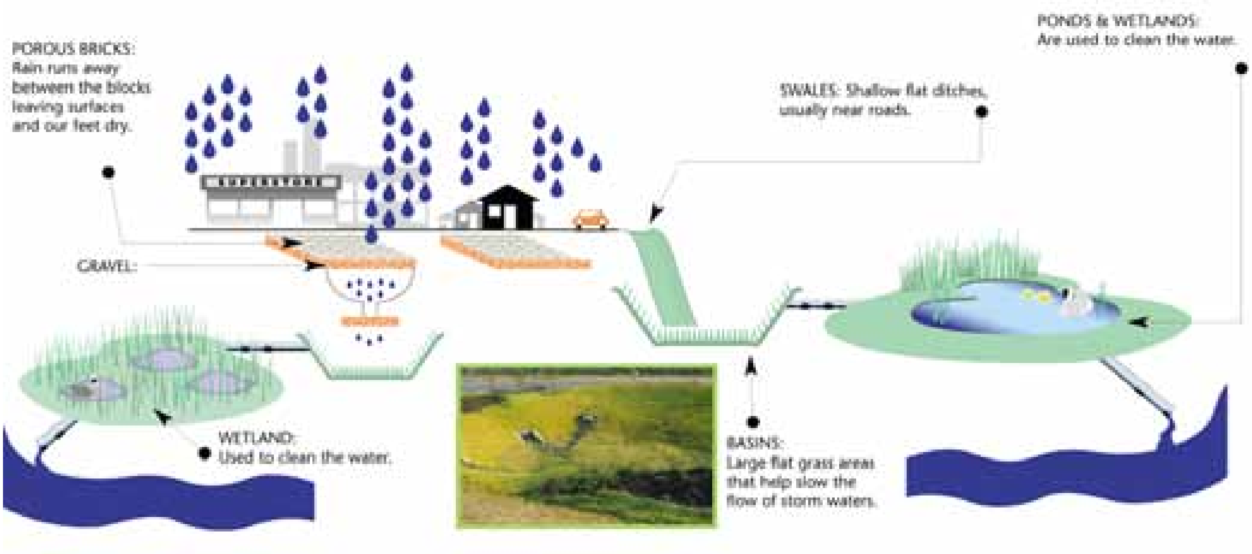


Figure 47: A Typical Treatment Train Layout

In larger developments and in pollution hotspots, the use of only source controls such as filter drains, will not suffice. Treatment controls or a combination or 'treatment train' of processes can be employed to successively reduce the pollutants in the water passing through the train until the pollution is removed. The storm water management train assures that runoff quantity and quality is addressed at all levels of development, making it easier and generally more cost effective to control. This approach is also useful in containing pollution incidents and protecting regional facilities from intermittent serious pollution risks.

6.4.3 Other SuDS Options

Other options which also can be used to assist runoff control include water-reuse, roof water collection, rooftop gardens, tree preservation and roof drainage connection to bioretention areas. The general approach of these devices is to emulate natural landscape functions. Case studies in water re-use and conservation are available from the Low Impact Development webpage (www.lowimpactdevelopment.org).

Landscaped areas such as lawns and garden beds offer a wide range of possibilities for providing surface storage and can enhance the aesthetics of a site. Careful consideration must be given to the design of the storage outlet as landscaped storages are most susceptible to blockage by wash off of leaves, branches, and lawn clippings.

Runoff can also be detained on flat roofs. However, care should be taken to ensure that adequate strength and protection against leakage is provided in the structural design of the building. This type of storage has limited application in residential areas and is more suited to commercial and industrial buildings where flat roofs are more common. Careful consideration must also be given in design for the anticipated design hydraulic loadings and adequate provision made for bypassing flows in the event of a blockage of roof outlets.

Recommendations

52. **Authorities to promote the use of the management train/treatment train approach involving a sequential ordering of pollution prevention and treatments to achieve optimal pollution control.**

53. **Authorities to promote the concept of re-use of water at source. Incentives for this should also be explored.**

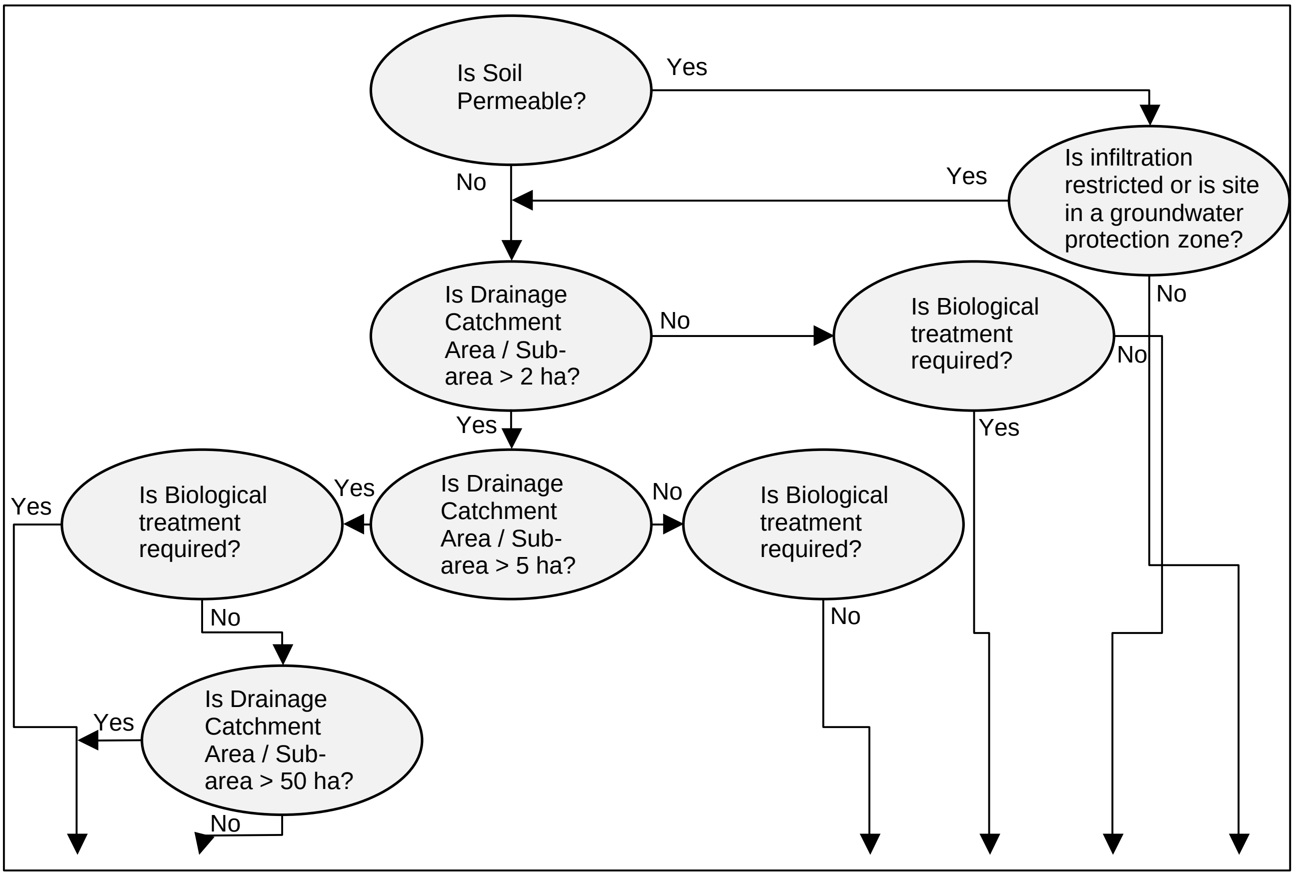
6.5 SuDS Selection

This section describes the SuDS selection process and provides guidance on factors to consider when deciding on their suitability for a site. No single type of SuDS can address all runoff problems. Each type has certain limitations based on drainage area served, available land space, cost and pollutant removal efficiency. There are also site specific factors such as soil types, slopes, and the depth to the groundwater table (USEPA factsheets, details of which can be downloaded from the USEPA webpage). Careful consideration of all these factors is necessary in order to select the appropriate system / systems for a particular location.

The objectives of any SuDS must be clearly defined from the outset and the site condition investigated in enough detail to match the system to the site. Objectives should include the degree to which quality and quantity control, and habitat and amenity enhancement are required. Many SuDS in the UK are being constructed without such full understanding of their limitations and their effectiveness.

SuDS involves balancing the impact of urban drainage between quality, quantity and amenity/habitat. The ideal solution achieves all three objectives. When selecting SuDS the most important question to ask is what specific problem the SuDS system is supposed to be addressing? For example, is it the removal of suspended solids, the removal of dissolved metals or perhaps the focus is on water quantity control? If the removal of dissolved metals is its primary purpose then a device such as a filter drain will possibly not be effective, whereas a stormwater wetland has the potential to be more effective at pollutant removal.

Figure 48 below provides a simplified selection matrix, which can be used for most types of site. However there are other important issues to consider such as slope, depth to bedrock as well as community acceptance.



	✓	**Extended Detention/Attenuation Basins**	✓		?	
	?	**Filter Drains**	✓	✓	✓	
		Filter Strips	?		✓	✓
		Infiltration Basins				✓
		Infiltration Trenches				✓
		MDCIA	?		✓	✓
	?	**Porous and Permeable Pavements**	✓	?	✓	✓
✓	✓	**Retention Ponds**	?	?		
		Soakaways				✓
		Swales	?		✓	✓
✓	✓	**Wetlands**	?	?		

Figure 48: Basic BMP Control Selection - Hydrologic & Biological Treatment Considerations (Source: SEPA)

Notes: Catchment area is the total drainage or sub-drainage area served by the SuDS control;
For smaller sub-catchments within a larger catchment, the SuDS controls indicated on the table may be used, in which case the size of the SuDS control to the larger catchment can be reduced;
Permeable soils means the soil is W.R.A.P. Type 1or 2, and the depth to any impermeable layer or winter high water table is greater than 1 metre;
MDCIA = Minimise Directly Connected Impervious Area;
? indicates questionable.

SuDS manuals developed in the US often suggest a 3-step approach to SuDS selection:

Step 1 - Assessing the Suitability of Systems

- Can the system adequately control the rates of runoff?
- Can the system cope with the volume of runoff involved?
- Can the system achieve the water quality treatment requirements?
- What is the resource to be protected?

This step will allow the designer to narrow down the types of SuDS available for selection. However, if a system does not meet the full requirements, it should not necessarily be eliminated for consideration, but the designer may have to consider using more than one type of system (e.g. swale upstream of a pond).

Step 2 - Physical Feasibility Factors

- Are there any particular design constraints imposed by physical factors?
- Are soils permeable enough to allow for infiltration practices to be used?
- Is the water table a suitable depth below the base of the system?
- What size of development is draining to this system?
- Is their enough pressure available for gravity operation?
- Is there enough land available to develop this system?
- What is the depth to bedrock and the depth to groundwater table?
- Is open space available?

In existing highly urbanised areas there may be little opportunity available for retrofitting SuDS. It is such densely populated areas, which have large amounts of impervious surfaces that produce large quantities of runoff. However, there are systems available which occupy relatively little space and can still be effective at controlling runoff, such as bioretention basins (refer **Appendix E** for details and **Appendix D** for a case study example) and therefore SuDS should not be ruled out.

Another consideration should be to determine the type of development which is to be drained. Contaminated runoff hotspots such as industrial estates may need SuDS which provide biological treatment and impermeable liners may be required in facilities that may receive runoff from spills. **Table 15** describes the land use SuDS selection matrix, used in the Texas Nonpoint Sourcebook.

SuDS	Land Use		
	Residential	**Commercial**	**Industrial/ Hotspots**
Detention Basin	Y	Y	L
Wet Extended Detention Basin	S	S	L
Dry Extended Detention Basin	Y	Y	L
Bioretention	Y	S	N
Swale	Y	S	S
Stormwater Wetland / Retention Ponds	S	Y	Y
Filter Strip	Y	S	N

Table 15: Land Use Selection Matrix

Notes: Y: Yes
S: Sometimes
N: No
L: Only use with an impermeable liner

Step 3 - Community and Environmental Factors

- Do the remaining SuDS have any important community or environmental benefits or drawbacks that might influence the selection process?
- What are the costs associated with developing such a system (relative construction cost per ha)?
- What are the maintenance requirements (frequency of maintenance/ cost of maintenance)?
- Will the relevant authority be happy to adopt these systems?
- Community Acceptance (will there be any safety issues/ will there be any benefit to the community/ will the system have a pleasant aesthetic appearance)?
- Is there any habitat enhancement potential?

Table 16 below describes the principle considerations when selecting appropriate types of systems and assessing their applicability to different types of development. The matrix contains scores of 0 to 10, where 10 equals the score for the highest positive aspect and 0 equals the least positive aspect.

Recommendations

54. A range of factors to be considered when selecting SuDS such that the most appropriate technique is adopted and SuDS are successfully implemented. Such factors include site suitability, available land space, cost, maintenance issues and community acceptance.

							Applicability for Given Land Use			Robustness				
SuDS Option	Water Quality Improvement	Flow Rate Control	Runoff Volume Reduction	O & M Needs [1]	Sensitivity to Site Conditions	Failure Potential	Low to Medium Density Residential	High Density Residential or Medium Density Commercial	High Density Commercial or Industrial	Hydrologic & Hydraulic	Water Quality	Potential for Groundwater Contamination	Average Score	Rank Order of Average Scores
Minimised Directly Connected Impervious Area [2]	9	10	10	3	3	3	10	9	5	9	9	3	6.9	**2**
Extended Detention Basin	9	10	6	3	3	3	9	9	8	9	9	3	7.0	**1**
Retention Pond	10	10	6	3	2	4	8	9	8	9	9	3	6.8	**3**
Stormwater Wetland	10	10	7	2	1	4	9	8	8	9	8	3	6.6	**4**
Permeable Pavement [2]	9	8	9	2	3	3	8	8	8	8	8	3	6.4	**5**
Infiltration Basin [2]	9	10	10	1	0	1	7	6	5	8	8	1	5.5	**10**
Infiltration Trench [2]	8	9	9	0	0	1	9	7	5	8	9	1	5.5	**9**
Swale [2]	8	8	8	3	3	3	10	8	6	8	6	3	6.2	**6**
Filter Strip	8	7	7	3	3	3	10	8	5	7	5	3	5.8	**8**
Bioretention[2]	9	7	6	2	4	2	9	9	5	6	8	3	5.8	**7**

Table 16: Usability of Different Types of SuDS

Notes: [1] Routine or rehabilitative maintenance, or both
[2] When site conditions permit.

6.6 Water Quantity – Control of Runoff

Rural runoff to rivers, when it occurs for the majority of events, is slow and generally relatively clean. In the urban environment, rainfall runoff takes place instantly and nearly all the rain falling on hard surfaces runs off. The rate of runoff and volume of runoff are therefore the two most important components in analysing the performance of drainage systems.

SuDS cover a range of drainage methods that are used in designing modern drainage systems and are recognised as being important in providing best practice design of drainage, particularly for, but not limited to, new developments. The objectives of SuDS are to attenuate volume and quality aspects of urban development. To try and replicate rural runoff, different SuDS devices can be used to slow, attenuate and store urban runoff, which must also be heavily constrained to prevent scour effects and minimise sediment load and pollutant concentration in rivers. Storage is preferably to be provided in the form of ponds or other biological retention systems. Although it is possible to use conventional tank storage for volume control, these have virtually no water quality benefits.

It must be recognised as a limitation of SuDS systems that extreme events can produce excessive volumes of runoff which can overwhelm the SuDS units depending on their design. This means that their performance in terms of attenuation and volume reduction could be significantly reduced. This should not be regarded as a failure, but a normal consequence that should be explicitly catered for in the design process (with emergency overflow arrangements built in).

The design approach should use hydrograph methods for storage sizing. Time Series Rainfall and design storms should be used depending upon the units being designed. Other empirical rules are also used for certain SuDS items.

Regional Policy, Volume 2 (New Development) details the methods and equations to be used to enable the determination of flow rates and volumes for Greenfield and post development conditions to enable calculation of the throttle rates and storage volumes.

In summary the procedure is:

- Assess the Greenfield peak runoff rate.
- Assess the Development runoff rate.
- Assess the Development runoff volumes.
- Determine the volume of storage for the development runoff.

The above procedure has defined the criteria to be applied to enable storage volumes and discharge limits to be calculated. However, these numbers need to be applied in reality using a range of drainage components. In each case there are practical issues that need to be considered to enable an effective hydraulic design of the drainage system to be built. The Regional Policy, Volume 2 (New Development) deals with each of these components in turn to provide guidance in their construction and proposed use. Further details on volumetric design of SuDS are also provided on the information sheets in **Appendix E** of this document.

There are effectively three categories of SuDS units. These are:

- Attenuation only - Retention and Detention Ponds, Tanks.
- Runoff reduction and attenuation - Swales, permeable pavements and filter trenches.
- No runoff – Soakaways, and indirect infiltration.

Regional Policy, **Volume 2 (New Development)** provides hydraulic design guidance. Some guidance is also provided in the information sheets in **Appendix E.** It is important to be aware that design of these units for hydraulic performance needs to take a precautionary approach especially when selecting infiltration rates for soils which need to work during wet winter conditions.

Recommendations

55. Emergency overflows should be built in to SuDS to cater for extreme events.

56. Hydrograph methods are to be used in the design of SuDS.

57. In addition, a range of drainage components should be considered to enable effective hydraulic design.

58. A precautionary approach is recommended for the design of SuDS for hydraulic performance, especially when selecting infiltration rates for soils.

6.7 Water Quality Design

Most water quality treatment facilities can be designed to incorporate flood control storage volume, above the permanent pool level required for water quality treatment. In these cases multi-staged outlets will be required to provide flow control for the range of design storms. Since water quality storms are much smaller events than those liable to cause serious flooding, it is relatively easy to accommodate SuDS for water quality in the design of flood control facilities.

The use of an appropriate design storm to size a facility is probably the most important consideration in designing an effective device. This is discussed in detail in the **Volume 2 (New Development).** It is not true that the bigger the design storm, the more effective the device will be. Controls designed to improve water quality and to control downstream flow rates need to be matched with the type of facility being used, local hydrology and the receiving system needs.

The treatment volume is calculated based upon capturing 90% of storms in a year. At this level, most small storms and the first flush components of larger storms, are captured and treated. There are several methods of determining the treatment volume requirement for SuDS. The current guidelines for the SuDS manuals in the UK (CIRIA C522 and C521) adapts the Wallingford Procedure variables:

$$Vt\ (m^3/\text{Total Area, ha}) = 9.D(SOIL/2 + (1\text{-}SOIL/2).I)$$

Where:

I = fraction of the area which is impervious (30% impermeable area = 0.3)
D = M5-60 rainfall depth, Volume 3 Wallingford Procedure (60 minute, 5 year return period)
SOIL = WRAP Soil Classification

To compute the total design treatment volume, multiply Vt by the catchment area in hectares, that drains to it. The application of the design treatment volume to various types of treatment controls are described below.

To check where this equation was applicable to, an analysis was undertaken to compare the runoff from recorded annual time series events in Dunfermline, Edinburgh, Belfast and south-west England and the treatment volume calculated using the method above. The Modified Rational Method and a standard set of assumptions were used to calculate the runoff from all of the time series events. The average runoff was calculated and compared against the treatment volume arrived at using the Wallingford Procedure calculation. A correlation between Vt for each site calculated from the Wallingford Procedure and the annual average rainfall was obtained. This indicated that the Wallingford Procedure equation was suitable for the calculation of treatment volume in the locations mentioned above.

Where the main requirement is the removal of suspended solids and related pollutants, treatment facilities such as extended detention basins and swales should be used. In these cases the treatment facility should be designed and constructed to have a volume equal to the catchment area design treatment volume (Vt).

The Vt figure is multiplied to suit the type of treatment facility proposed and retention time required. Where there is a requirement for biological treatment to remove biodegradable pollutants and nutrients, treatment facilities such as ponds and wetlands with permanent water pools and significant areas of aquatic vegetation would be more appropriate. Retention ponds should generally have a minimum permanent pool volume of 4 x Vt. Whereas wetlands, due to the increased amount of vegetation, the minimum permanent pool volume required would be 3 x Vt. Refer to the information sheets in **Appendix E** for detail on SuDS design.

For all types of system mentioned in this section, it is important that some kind of emergency overflow device is incorporated into the design, to ensure flooding does not occur during extreme events. Larger storms can also be diverted around treatment facilities, with only initial runoff being treated.

Recommendations

59. **The calculation of water quality treatment volume for SuDS facility should be based upon capturing 90% of storms in a year. At this level, the first flush of large storms as well as most smaller storms are captured and treated.**
60. **The design process and parameters for stormwater control as contained in the Regional Policy for New Development should be adopted.**

6.8 Operation, Maintenance and Responsibility

As with conventional drainage systems, maintenance of SuDS is required for their successful operation. It is essential that provision is made for adequate access to the facility. Maintenance plans should be developed prior to the adoption of all systems. Much of the maintenance required for the routine maintenance of SuDS would be carried out anyway on most landscaped areas. Maintenance can be categorised into 3 groups:

- Expected routine maintenance;
- Non routine (repair) maintenance; and
- Occasional maintenance.

Table 17 below describes the key maintenance requirements for SuDS.

<table>
<tr><th rowspan="2">System</th><th colspan="3">Maintenance Requirements</th></tr>
<tr><th>Routine</th><th>Non Routine</th><th>Occasional</th></tr>
<tr><td>Passive Treatment Systems (Ponds, Wetlands, Swales, Detention Basins, Bioretention)</td><td>Litter Removal
Replacement of dead plants
Weed Removal
Sediment removal at inlets/outlets
Cross cutting (in swales, filter strips and detention basins only)
Regular inspections for defects</td><td rowspan="2">Digging out of blocked devices, Replanting</td><td rowspan="2">Dredging, sampling and disposal of sediment</td></tr>
<tr><td>Below Ground Systems (infiltration trenches, filter drains and permeable pavements)</td><td>Litter removal
Regular inspection for clogging
Sweeping/ jetting (permeable pavements only)</td></tr>
</table>

Table 17: Routine Maintenance Requirements for SuDS

Experience has shown that maintenance of SuDS systems need not necessarily be an onerous task. For example, a blocked infiltration trench may only require half a day, one man and a wheeled excavator to resolve. Sampling of pond sediment for dredging and disposal may only need to be undertaken at intervals of years.

Routine maintenance should be flexible enough to accommodate fluctuations in weather conditions. Non-routine maintenance (such as dredging of ponds) should be carried out when required. Routine maintenance plans should also include a timetable for inspections, which should be reassessed once the system comes into operation. Checks should also be carried out on each system when completed, to ensure it has been designed correctly (possibly developing adoptable standards similar to the 'Sewers for Adoption' which is used in the UK for sewerage networks). The parties responsible for SuDS need to inspect the facilities at regular intervals, so that any problems with operation can be addressed at an early stage. Regular checks on a facility will also ensure the system is kept in good working order. Cost considerations and maintenance issues for each SuDS device are included in **Appendix E**.

It is essential that the owners understand the requirements of the systems they are maintaining. The regulator/inspectors should be provided with a checklist for each system, which should be used to record:

- The date of construction of the facility;
- Details of each type of SuDS minimum performance expectations;
- Design criteria for each type of facility;
- Structural specification;
- Expected lifespan.

The checklists should also be used to record whether there is any sediment accumulation at inlets and outlets, whether any litter removal is required, replanting requirements, algal removal or any other type of maintenance which may be required.

In Scotland, designs are checked on paper by the environmental regulator: the Scottish Environmental Protection Agency (SEPA), the Planning Authority, Building Control Authority, the Water Authority and the Roads Authority. However, once the system has been constructed, in many cases there have been no checks on the system subsequently. What was shown on paper did not always reflect what had been constructed and few checks were made on the adequacy of the planned maintenance regimes. This had led to a number of inappropriately designed systems with the potential to fail and further systems which have been designed correctly, being neglected. Both the regulators and the adopting authority need to ensure that a framework is in place to allow regular inspection and maintenance of these systems.

In the UK, the responsibility of adoption has remained a grey area. A framework agreement was developed in Scotland between the Water Authorities and Local Authorities and resulted in confusion. Originally, the agreement was based upon splitting the maintenance responsibility, with the local authority adopting above ground structures and the Water Authority adopting below ground structures. Currently, legislation is being altered such that Scottish Water is the responsible party for shared public road/house SuDS systems.

Further information on approval and taking in charge of SuDS facilities is contained in the Regional Policy on New Development.

Recommendations

61. Local Authorities to ensure that maintenance plans are developed prior to the adoption of all SuDS.

62. Authorities to ensure that responsibility for maintenance is clearly defined at the outset.

6.9 Effectiveness of SuDS

6.9.1 Performance of SuDS

Considerable research has been carried out into the performance of SuDS which has shown that in general SuDS features are successful in significantly attenuating pollutants such as suspended solids, phosphorus and nitrogen, creating habitat and amenity as well as mitigating the impact of flooding. Further information on the performance of each type of system can be found in **Appendix E**. Monitoring results are given where available for individual case studies.

The American Society of Civil Engineers has developed a database to record some of these findings. The database consists of the findings of research into 24 Detention Basins, 30 Media Filters, 1 Infiltration Trench, 5 Porous Pavements, 33 Retention Ponds, 15 Wetland Basins and 14 Wetland Channels. Further details can be downloaded from the National Stormwater database (www.bmpdatabase.org).

6.9.2 Cost Effectiveness

SuDS are relatively simple structures and therefore are simple to design, construct and maintain. Many perceive SuDS to be expensive however, the cost of not using SuDS is significant in terms of hefty fines if prosecuted under EU law, and it is widely accepted that traditional drainage practices are unsustainable. SuDS, when appropriately designed, can be extremely cost effective. In general the capital costs are low in relation to traditional drainage systems, and although ongoing maintenance costs apply during the lifetime of the device, maintenance costs can be considerably less than the cost of maintaining traditional drainage systems (see below). SuDS eliminate the need for other drainage devices such as gullypots and complicated drainage networks.

Cost of Not Addressing Urban Runoff

- Failure to achieve the requirements of the Water Framework Directive and failure to pass European Union Water Quality Directives, potentially leading to prosecution;

- Bacteria and other pathogens in high concentrations discharging to watercourses resulting in unsafe water for swimming, leading to loss of "Blue Flag" status and closure of bathing beaches, unsafe water for recreational purposes such as boating and windsurfing, and potentially closure of shellfish production areas. This could result in socio-economic impacts, particularly in coastal areas;
- Urban runoff can contaminate or suffocate fish through clogging of their gills, increase sediment in watercourses and erode banking due to high flows;
- Covering the landscape with roads, rooftops and car parks increases the frequency and magnitude of floods which can lead to property damage and potentially loss of life;
- Can result in an overloaded sewerage system.

Benefits of Using SuDS

- Assists in compliance with legislation such as the Water Framework Directive and other EU water quality directives;
- Less surface water in sewer network;
- Reduces the potential property damage from flooding;
- Reduces the potential for human illness, as some types of system can reduce pathogens, metals and synthetic organics;
- Can increase property values. Many studies show that people are attracted to features in the landscape, especially when they include views, park-like landscapes or water;
- Protects waters used for recreation;
- Groundwater recharge;
- Improves aesthetic value for local residents;
- Provides wildlife habitat/ ecological benefits;
- Flow control reduces risk of flooding;
- Improved fisheries;
- Protects streams and watercourses from channel erosion and flooding;
- Provides public education opportunities;
- The use of permeable paving can prevent puddles forming in car parks, driveways and pedestrian areas;
- Easier maintenance/control as visible structures and easier to police misconnections.

Negative Aspects of SuDS

- Can lead to reduced property values where inappropriate design or lack of maintenance results in them becoming a nuisance;
- Safety concerns (need to design to reduce risk);
- Some systems require large amounts of land;
- Require regular maintenance;
- A framework is required to ensure these systems are correctly designed and maintained;

Financial Implications of SuDS - Case Studies

In New York, the Staten Island Blue Belt project uses soft engineering systems and processes to control flooding and prevent diffuse pollution. The city developed a stormwater masterplan which covered 11 catchments covering approximately 6,000 acres. Where existing surface water sewers are located, settling ponds, infiltration systems and stormwater wetlands provide water quality and quantity control. Including the cost of land acquisition, the city expects to save approximately $50 million by avoiding the construction of expensive subsurface sewer lines. (Clark GA et al, 2002).

Built in 1993, the Sale Lake development in Boulder, Colorado consists of single family homes surrounding a 4-acre constructed wetland. Homes alongside the wetland sold for as much as $134,000, up to a 30% premium over homes with no waterfront view. (USEPA, 1995). Another case study is in Wichita, Kansas. A new 72.3 acre development called the 'Landing' was constructed around stormwater wetlands. Waterfront properties were found to sell for a premium of up to $21,000 (150 percent) above comparable plots with no water view.

Table 18 below provides other US examples of premiums charged for properties overlooking SuDS.

Location	Base Costs of Lots/ Homes	Estimated Water Premium
Centrex Homes at Barkley Fairfax Virginia	Home with lot: $330,000 - $368,000	Up to $10,000
Townhomes at Lake Barton Burke Virginia	Townhome with lot: $130,000 - $160,000	Up to $10,000
Lake of the Woods Orange County Virginia	Varies	Up to $49,000
Ashburn Village Loudon County, Virginia	Varies	$7,500 - $10,000
Weston Development Broward County, Florida	Home with lot: $110,000 - $1,000,000	$6,000 - $60,000 depending on lake size, location and the percent of lake front property in the neighbourhood
Highland Parks, Hybernia, Illinois	Waterfront lot: $299,900 - $374,900	$30,000 - $37,500

Table 18: Examples of Real Estate Premiums Charged for Property Fronting Urban Runoff Controls

There is very little cost information on SuDS available outside the US. In the UK, SuDS are a relatively new practice and therefore there is minimal cost information available. However, the limited information which has been published to date suggests that in some cases the maintenance of SuDS may be less costly than maintenance of conventional systems. Bray (2002) carried out a comparison of SuDS maintenance with that of conventional drainage for two sites in England. The first is the Oxford Motorway Service Area MSA M40, which comprised a full suite of SuDS techniques.

The annual maintenance cost of conventional drainage was estimated to be £2800 (including 6 monthly cleaning of 100 gully pots and 2 petrol interceptors, but not including rodding or jetting). In comparison, assuming the cost of sweeping the site, cutting grass areas and managing the retention pond are the same for each approach, then the additional costs for SuDS care were advised by the landscape contractor to be £917, a saving of £1,883.

A similar exercise was carried out for another service area at Hopwood Park, MSA, M42. The estimated annual maintenance cost of conventional drainage was £2,800. The cost of maintaining SuDS on the same site (on top of normal site care) is £1,580, a saving of £1,220.

Implications for Sustainable Urban Drainage

SuDS have been proven to perform well when properly designed and maintained.

SuDS generally have lower capital costs than traditional drainage systems.

The main additional cost of SuDS is in their long term maintenance, however this need not be any more costly than maintaining traditional systems and may, in fact, be cheaper.

The cost of not implementing SuDS could be far greater than not if prosecutions result when legislative requirements are not met.

6.10 Recreational Amenity

SuDS can provide an array of recreational and ecological benefits. The SuDS concept allows water to be used as a feature rather than being conveyed as quickly as possible in below ground structures. Ponds and wetlands can be assets to the community, as they can enhance the quality of life by providing attractive and tranquil green space in the midst of an urban environment. Swales can also be used to provide recreational linkages (such as maintained paths and trails) which can double as wildlife corridors between systems or between other waterbodies (refer **Figure 49** below).

Figure 49: A Stormwater Wetland with a Footpath/Cyclepath

Recommendation

63. Local authorities to ensure that SuDS are designed with the local community in mind as due to the potential for significant recreational amenity. Community involvement should be ensured from the outset such that the facility will be accepted and valued.

6.11 Habitat Enhancement

SuDS can be designed to improve the biodiversity and provide the opportunity for habitat enhancement of an area, as well as improving water quality and controlling water quantity. The Residential Density Guidelines for Planning Authorities (September 1999) state ''Layouts should encourage biodiversity by preserving and providing cover for species and where appropriate avoiding the culverting of watercourses and providing new water areas''. It is essential that no natural ponds or wetlands should be used as SuDS features. SuDS should be specifically designed for the sites' requirements. SEPA suggest the following simple measures to enhance the habitat value of SuDS:

- Where possible, locate SuDS close to but not directly connected to existing wildlife areas, so plants and animals can naturally colonise the new SuDS;
- When using ponds and stormwater wetland, create well vegetated shallow bays and establish areas of marsh;
- Avoid smoothly finished surfaces; although they give the impression of tidiness, they provide less physical habitat diversity for plants and animals;
- If planting ensure only native plants of local origin are used.

Further information which describes the habitat enhancement potential of SuDS can be downloaded from the SEPA website (www.sepa.org).

6.11.1 Case Study: Ecological Value

SEPA funded research was carried out by Pond Action in 2000, to investigate the ecological value of a few example stormwater ponds in Scotland. Initial indications suggest that SuDS ponds and wetlands can provide a valuable habitat as illustrated by **Figure 50** below. **Table 19** below describes the number of invertebrate species and plants found in the monitored SuDS ponds, which were monitored. The Dunfermline stormwater wetland, which was included as part of this investigation, had a high conservation value (even by comparison to natural ponds elsewhere in the UK).

Figure 50: Swans Nesting in a Regional Treatment Facility in Dunfermline

	Motorola Motorway	Motorola	Freeport	Houston Cawburn	Dunfermline Stormwater Wetland
Invertebrates					
Number of Species	40	37	58	24	40
Number of Uncommon Species	0	1	1	0	0
Conservation Value	High	High	Very High	Moderate	High
Plants					
Number of Native Species	17	12	24	13	25
Number of Uncommon Species	3	2	1	0	4
Plant Conservation Value	Moderate	Moderate	High	Moderate	High

Table 19: Conservation Value of SuDS Ponds

The Pond Action survey highlighted problems as well as successes: notably the presence of nuisance species, New Zealand Pygmyweed (*Crassula helmsii*) and other non-native plants. It also found the presence of UK species that were out of place (e.g. a red data book species from Southern England, Hampshire Purslane *(Ludwigia palustris*). Other survey work has identified a water vole (*Arvicola terrestris*) population within the Dunfermline site (which incorporates a full suite of SuDS); a Biodiversity Action Plan Species that has suffered a serious decline in the UK associated with habitat loss and mink predation.

Recommendation

64. Local Authorities to ensure that SuDS are designed in order to improve biodiversity and provide the opportunity for habitat enhancement.

6.12 Safety Issues

Concerns have been expressed over the safety of some types of SuDS systems such as ponds, wetlands and swales, especially in urban areas. It is acknowledged that bodies of water do present a danger to children. However, to keep the danger of these systems in perspective, it is widely acknowledged that roads pose a far greater danger than SUDS and there are also many more dangers in the home. In addition SuDS are sometimes located close to much larger natural water bodies, therefore their presence poses an insignificant additional danger.

Table 20 below describes the number of drowning incidents in the UK during 1998, which totalled to 568. However, to date, there have been no reported drownings in the UK associated with SuDS. In comparison, 1995 data indicates that in the UK there were 4,066 deaths due to accidents in the home and in 1996 there were 3,598 road deaths (source: UK Royal Society for the Prevention of Accidents (RoSPA)). In Orlando Florida, there have been two deaths in SuDS ponds, due to a road traffic accident (failure to stop at a T-junction).

Drownings Location		
Rivers, streams	239	42%
Coastal	129	23%
Lakes & Reservoirs	55	10%
Home Baths	53	9%
Canals	47	8%
Docks & Harbours	19	3%
Swimming Pools	17	3%
Garden Ponds	9	2%

Table 20: Drownings in the UK in 1998 by Location

(Source: Royal Society for the Prevention of Accidents (RoSPA))

Careful design of SuDS systems, for example to incorporate shallow sloped margins, should minimise the risk of accidents occurring. However, the following measures will also assist in improving public safety:

- Public education, especially targeting school children and warning them of the dangers of water;
- Carry out a risk assessment/ safety audit if necessary;
- Construct homes overlooking ponds and wetlands, so that if anyone does get into difficulty they can easily be spotted.
- Provide barrier planting (e.g. using thorn bushes) to deter young children from attempting to reach the waters edge. This should be maintained at a certain height, which is tall enough to act as a barrier, but low enough that the view of the open water is not restricted;
- Safety railings and fences in areas considered to be potentially dangerous and where the risk of accident cannot be addressed by barrier planting alone. Fencing will prevent younger children reaching the waters edge, but they are unlikely to act as a deterrent to older children and young adults. According to figures produced by RoSPA, the greatest risk is for young men between the age of 16 and 34 (SEPA, 2000);
- Provide safety equipment (grab rails, ladders) and rescue equipment if necessary;

- Provide gentle side slopes in devices such as ponds, wetlands and swales. So that if anyone does get into difficulty, it would easy for them to climb out;
- Minimise the depths of ponds and wetlands, with the maximum depth of water located away from the margins.

Figure 51 below illustrates how appropriate landscape design features can protect public safety while adding to the amenity value.

Figure 51: Dense Fringing Vegetation Protects an Attenuation Basin, Scotland

Research has shown that the local community accept SuDS when they move into an area and the feature is already there, rather than when introduced in retrospect.

Recommendations

65. SuDS should be designed to minimise the risk of accidents occurring.

66. SuDS to be incorporated at the planning and design phase of a development rather than being an afterthought or for example, waiting for community approval.

6.13 Sediment and Erosion Control

Construction runoff and other sources of sediment, can pose a significant threat to the environment. Sediment conveyed in runoff can carry a number of pollutants such as metals, hydrocarbons, nutrients and oxygen demanding substances, while the sediment itself can also be a problem, such as blocking out sunlight in watercourses and clogging fish gills. Phased removal of vegetation or topsoil will minimise the soil exposed to rainfall and limit the amount of sediment conveyed in the runoff. However, these measures will not eliminate this problem. Temporary SuDS measures can be used to trap this potentially harmful sediment. Ponds and basins are often an effective way of collecting construction runoff and removing suspended particulates from the water column through gravitational settling. These features have been successfully employed in the construction of the M74 in Scotland and have been retained as permanent features after construction (refer **Figure 52** and case study in **Appendix D**).

Filter drains can also be used to trap sediment and then become redundant once the construction of the site has been completed. In no circumstances should construction runoff be routed through permanent SuDS facilities (especially infiltration devices), unless remedial measures are planned. Runoff should only be routed through permanent SuDS, once the site has been completely stabilised. **Figure 53** shows an example of the damage that can be caused by inappropriate management of construction runoff.

Figure 52: Roadside Retention Pond, Scotland

Figure 53: An Example of Damage Caused by Routing Construction Runoff through a Permanent Swale

<u>Recommendations</u>

67. Site management plans for the control of pollution from construction sites should utilise SuDS such as settlement ponds and basins to minimise pollution impacts.

68. Design SuDS features utilised during construction so they can be retained for permanent water quality control.

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