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delivering benefits through evidence

Cost estimation for SUDS - summary of evidence

Report –SC080039/R9

Flood and Coastal Erosion Risk Management Research and Development Programme

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Miranda Kavanagh

Director of Evidence

Executive summary

This detailed summary of evidence provides indicative costs and guidance for SUDS and other drainage infrastructure.

Urban drainage and SUDS		
Key cost components	Key cost components are likely to be the enabling costs (procurement, planning and design), capital construction costs and post construction monitoring and maintenance costs.	
Key asset types	Various, including: • Green roofs • Simple rainwater harvesting (water butts) • Advanced rainwater harvesting • Greywater re-use • Permeable paving • Filter drain / perforated pipes • Swales • Infiltration basin • Soakaways • Infiltration trench • Filter strip • Constructed wetland • Retention (wet) pond • Detention basin • Underground attenuation and storage	
Data reviewed in specific guidance	Key datasets include: • Paper by Stovin & Swan 2007 • The CIRIA SUDS Manual (C697). • Environment Agency report on cost-benefit of SUDS retrofit in urban areas • HR Wallingford's work for the DTI • OFWAT unit costs	
Other relevant data	Local or proxy records, e.g. EA SAMPs data, LA information etc	
Relative cost importance	Enabling costs	Costs may be higher than other measures due to the level of consultation, design and preliminary assessments often required in dense urban environments. Cost of land purchase may be significant in some circumstances.
	Capital costs	Variable costs depending on type or range of measure employed, asset length and size, landscaping and environmental enhancements.
	Maintenance costs	Operation and maintenance costs may be significant due to the requirements for regular maintenance and inspections to ensure that the SUDS components are delivering the required attenuation and water quality benefits.
	Other cost considerations	May include environmental costs, habitat creation and decommissioning costs.

Cost estimation methodology	Initial concept / national appraisal	Approximate unit rates for the SUDS measures available for capital and O&M costs.
	Strategic, regional, or conceptual design	Approximate unit rates for the SUDS measures available for capital and O&M costs.
	Preliminary feasibility / design	No specific cost information provided. Guidance on data availability and procedures provided.
Design life information	Variable. Design life for SUDS systems may be indefinite assuming appropriate construction and long term maintenance is undertaken.	
Quality of data	A range of data sources have been collated and are provided suitable for strategic, early or national level appraisals. Indicative unit costs (capital and maintenance) for particular SUDS components have been compiled from relevant industry references. These costs are based on actual costs from a number of projects from within the UK and from a wider literature review. This information provides a range of costs for each type and a relative assessment between different SUDS features. However, the costs associated with any specific site will depend on a number of factors which are discussed in the guidance. Water and sewerage infrastructure costs are also provided based on OFWAT unit rates. Whilst costs will vary depending on the nature of the problem and the appropriate solutions these unit costs may assist those undertaking surface water management plans or integrated urban drainage projects.	
Additional guidance	Information relating to the factors that are likely to influence capital and maintenance costs, and key factors to consider for detailed costs estimation are provided. Links to relevant R&D and general design guidance are also provided.	

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Contents

1 Flood risk management measure - Sustainable Urban Drainage Systems and drainage system costs

Sustainable Drainage Systems (SUDS) are surface water drainage solutions designed to manage surface water runoff and mitigate the adverse effects of urban storm water runoff by reducing flood risk and controlling pollution. SUDS techniques allow surface water runoff from development to be controlled in ways that imitate natural drainage by controlling the rate of discharge to a receiving watercourse. SUDS may also provide valuable habitat and amenity value when carefully planned for in development.

The concept used in the development of drainage systems is the surface water 'management train'[1] whereby drainage techniques can be used in series to change the flow and quality characteristics of runoff in stages that attempt to mimic natural drainage. The key stages of the management train are:

- Prevention;
- Source Controls;
- Site Controls; and,
- Regional Controls.

Although runoff need not pass through each stage, it is preferable to deal with runoff locally and return water to the natural drainage system as near to the source as possible.

There are five general methods of control:

- Filter strips and swales
- Permeable surfaces and filter drains
- Infiltration devices
- Basins and ponds
- Attenuation storage in oversized pipes and underground tanks.

These measures can reduce runoff rates and volumes through infiltration and attenuation of flows. They also provide varying degrees of treatment for surface water, using the natural processes of sedimentation, filtration, adsorption and biological degradation. Typical SUDS options are summarised in the following table:

[1] http://www.ciria.org.uk/suds/suds_management_train.htm

Table 1-1: Typical SUDS options

Option	Description
Green roofs	A planted roof system for roof areas of a building designed to intercept and retain rainfall in ways that aims to reduce the volume of runoff and attenuate peak flows.
Simple rainwater harvesting (water butts)	Small, off-line storage devices that are designed to capture and store runoff for reuse.
Advanced rainwater harvesting	More advanced rainwater harvesting systems that provide a supply of water for a range of domestic uses including washing, laundry and toilet flushing.
Greywater re-use	Systems to collect, cleanse and re-use water from showers, baths, washbasins, washing machines and kitchen sinks. It can operate at a single property scale or on a development-wide scale.
Permeable paving	Surfaces, such as car parks, designed to allow rainwater to infiltrate into the underlying ground.
Filter drain / perforated pipes	Trenches filled with permeable material to collected and convey runoff from the edge of paved areas. A perforated pipe may be built into the base of the trench to convey the water to other parts of a site.
Swales	Broad, shallow grass channels designed to convey and attenuate runoff as well as to allow infiltration into the ground.
Infiltration basin	Depressions and basins that store runoff and allow infiltration into the ground. They may be landscaped to provide habitat and amenity value.
Soakaways	Underground structures or excavations filled with granular material designed to store rapid runoff from a single or multiple properties and to allow efficient infiltration into the surrounding soil.
Infiltration trench	Linear soakaways that allow water to infiltrate into the ground.
Filter strip	Wide gently sloping grass verges that treat runoff from adjacent impermeable areas.
Constructed wetland	Ponds with shallow areas and wetland vegetation to improve the removal of pollutants and enhance wildlife value. Wetlands also provide additional flood storage capacity and attenuation.
Retention (wet) pond	Basins that provide temporary storage for storm runoff above a permanent water level used for water quality treatment. This technique may also provide improved habitat and amenity value.
Detention basin	Normally dry basins but may have permanent pools at the inlet or outlet. Designed to detain a defined volume of runoff and may provide water quality treatment.
Underground attenuation and storage	Oversized pipes and underground tanks to attenuate flows.

Although SUDS are typically located as close as possible to the source of rainwater so that surface water runoff is mitigated at source, other measures may be required as part of a management train. Other measures may also be required in relation to water and sewerage infrastructure that might includes pipes and below ground storage required as part of a wider strategic scheme, to deal with surface water flood risk. Options may include:

- Increasing capacity in drainage systems;
- Separation of foul and surface water sewers;
- Improved drainage maintenance regimes; and,
- Managing overland flows.

1.1 Data requirements

Whole Life Cost is the analysis of all relevant and identifiable financial cash flows regarding the acquisition and use of an asset. In order to compile whole life costs, the following parameters may be required:

- Procurement and design costs;
- Capital construction costs;
- Operation and maintenance costs;
- Monitoring costs;
- Replacement or decommissioning costs.

1.2 Procurement and design costs

Although enabling costs will vary depending on the size of the development or scope of works costs associated with the planning and design of SUDS are typically 15% of the capital costs (CIRIA, 2007). Ellis et. al., (2003) suggests that for a typical flood retention basin, the sum of all costs relating to design, consenting and legal fees, geotechnical testing and landscaping is equivalent to about 15% - 30% of the base construction cost depending on the scale of development.

1.3 Capital costs

The construction of SUDS is highly variable and depends on the proposed design and construction methods. Solutions are site-specific and heavily dependent on the size of the associated catchment area. Furthermore the recording of SUDS implementation within the industry has in the past been poor.

Capital cost estimates will require consideration of the following:

- Site investigation costs;
- Design costs;
- Project management, planning and supervision costs;
- Clearance and land preparation costs;
- Materials;

- Construction costs;
- Design and planning of subsequent maintenance responsibility;
- Landscaping and planting costs (post construction)

Costs available include all of the above apart from the construction overheads costs. These are typically taken to be approximately 15% of the capital costs. Unit costs may be obtained for a range of SUDS techniques (for example the construction cost per system, and the cost per contributing catchment area served.

The cost associated with land purchase may be relevant in some circumstances. Land costs can be zero where the site has dual use or where the scheme is located within public open space. However, in urban areas the cost of land purchase can be significant. Appraisers should consider whether or not the cost of land purchase is included within an appraisal as this will depend on the purpose of the assessment and drivers for the works.

1.3.1 Indicative costs

Unit costs for particular SUDS components are available in a number industry references. These have been compiled in the following table. These costs are based on actual costs from a number of projects from within the UK and from a wider literature review. If used for cost estimating purposes these costs should be costs should be increased to allow for inflation to present day values.

Table 1-2: Indicative costs for SUDS options

Option	Unit cost	Source
Green roofs	£90/m^2 - covered roof with sedum mat £80/m^2 - biodiverse roof (varied covering of plants, growing medium and aggegates) Variable costs for Sedum blanket , turf and growing medium roof options	Bamfield, 2005. Bamfield, 2005. Rawlinson, 2006
Simple rainwater harvesting (water butts)	£100 - £243 per property (includes installation and connection pipe	Stovin & Swan 2007
Advanced rainwater harvesting	£2,100 - £2,400 per residential property £2,500 - £6,000 per residential property £2,600 - £3,700 per residential property £6,300 - £21,000 per commercial / industrial property £45 per m^2 for residential properties £9 per m^2 for non residential properties	Woking Borough Council EA, 2007 RainCycle, 2005 RainCycle, 2005 EA, 2007 EA, 2007
Greywater re-use	£1,900 - £3,500 per residential property £3,000 per property	Woking Borough Council EA, 2007
Permeable paving	£30-£40 per m^2 of permeable	CIRIA, 2007

	surface £27 per m^2 of replacement surface £54 per m^2	 Stovin & Swan 2007 EA, 2007
Filter drain / perforated pipes	£100 - £140 per m^3 stored volume £61 per m £120 per m^2	CIRIA, 2007 Stovin & Swan 2007 Environment Agency, 2007
Swales	£10-£15 per m^2 swale area £18-£20 per m length using an excavator £12.5 per m^2	CIRIA, 2007 Stovin & Swan 2007 Environment Agency, 2007
Infiltration basin	£10-£15 per m^3 stored volume	CIRIA, 2007
Soakaways	>£100 per m^3 stored volume £454 -£552 per soakaway	CIRIA, 2007 Stovin & Swan 2007
Infiltration trench	£55-£65 per m^3 stored volume £74-£99 per m length £60 per m^2	CIRIA, 2007 Stovin & Swan 2007 Environment Agency, 2007
Filter strip	£2-£4 per m^2 filter strip area	CIRIA, 2007
Constructed wetland	£25-£30 per m^3 treated volume	CIRIA, 2007
Retention (wet) pond	£15-£25 per m^3 treated volume £80,000 per 5000m^3 pond (£16 per m^3)	CIRIA, 2007 SNIFFER, 2007
Detention basin	£15-£20 per m^3 detention volume £35-£55 per m^3 stored volume £18 per m3	CIRIA, 2007 Stovin & Swan 2007 SNIFFER, 2007
Onsite attenuation and storage	£449-£518 per m^3 for reinforced concrete storage tank. No data available for oversized pipes	Stovin & Swan 2007

The above costs are provided as an indicative cost for each type of SUDS. Whilst they provide a range of costs for each type and a relative assessment between SUDS features, the costs associated with any specific site will depend on a number of factors as follows:

- Scale and size of development;
- Hydraulic design criteria (design event, volume of storage required and impermeable catchment area);
- Inlet/outlet infrastructure design (volume and velocity of anticipated flows and the capacity of drainage system beyond site boundary);
- Water quality design criteria;
- Soil types (permeability and depth of water table), porosity and load bearing capacity;
- Materials availability;
- Density of planting;
- Specific Utilities requirements;
- Proximity to receiving watercourse;
- Amenity / public education / safety requirements

Example of the distribution of Wetland Capital Costs
The Environment Agency R&D Technical Report on constructed wetlands (Ellis et. al. 2003) provides the following breakdown of an example of the distribution of capital costs associated with a stormwater wetland system.

Item	Proportion of costs	Typical unit costs
Geotechnical testing, excavation and compaction	16-20%	
Substrate	3-5%	
Geotextile liner	20-25%	£15-20 per m^2
Plants	10-12%	£3-5 per m^2
Control structures	10-15%	
Formwork, pipework	10-12%	
Design and landscaping	8-12%	
Other and contingency	6-10%	

Detailed costs

The costs above provide broad brush estimates of costs for implementing SUDS options. Detailed design and costing would be undertaken at later stages following preliminary investigative work of the site specific conditions and development proposals. The above estimates for unit costs are not suitable for detailed costing.

Practitioners may also have their own experience they may contribute to the detailed costing and implementation of SUDS. Other methods are also available for detailed cost estimates, such as the use of engineering price books.

1.3.2 Retrofit costs

The installation of SUDS in new housing developments will not make a significant contribution to reducing existing flood risk as these systems are design to offset the impact of the developments for a defined pluvial flood event.

The ability to retrofit SUDS to existing developments has the potential to reduce urban water quality and flooding problems through the disconnection of stormwater from the formal drainage system and installing source control SUDS instead. The methods employed are similar or the same as those discussed above, but the costs may differ due to the secondary costs arising from disconnection and transfer of storm water from the existing systems.

Comparisons between the variation in cost for new developments and those associated with retrofitting are limited. Whilst there has been some research into this, previous studies have assumed that the secondary costs are approximately 20% of the cost of the actual SUDS construction (SNIFFER, 2006). However, this is considered and underestimation and costs could be far greater in some circumstances.

1.3.3 Water and sewerage infrastructure costs

In 2009 investment of £15 million was provided to help Local Authorities in England co-ordinate and lead local flood management work to deal with surface water flood risks.

Funding was provided to develop six first edition surface water management plans (SWMPs). The results of which were fed into the updated SWMP Technical Guidance Document (Defra, 2010). The final reports from these six initial local authorities are now available on the Defra website[2].

In addition to the SWMPs, 15 integrated urban drainage pilot studies were undertaken in 2007 to provide an integrated approach to managing the complex interaction of drainage systems and flooding in urban areas[3]. Whilst these studies included recommendations for achieving successful management, the costs of implementing these schemes is difficult to determine and no specific guidance on the costs associated with these schemes was included.

Wider strategic approaches to surface water flood risk may require works associated with upgrading and increasing the capacity of drainage systems. These measures may provide opportunities that deliver multiple benefits.

SUDS options that don't reduce the total volume of surface water runoff may include the following causes:

- Increased capacity in drainage systems:
    - Conveyance solutions - increasing capacity and upsizing of drainage systems and the, provision of new or replacement pumping stations.
    - Storage solutions involving attenuation of flows in sewer systems.
- Control of flows entering the sewer system by the separation of foul and surface water sewers;
- Managing the flow in the sewer system by diverting flows to other sewer systems which have spare capacity, upgrading of pumping stations, or by provision of a new Combined Sewer Overflow (CSO);
- Isolate from the drainage system by preventing storm water and sewage from escaping from the system, for example by providing a non-return valve or a pumping station. These solutions may be applied to individual properties or to a sewer catchment;
- Improved sewer maintenance regimes;
- By a combination of the above; and by,
- Managing overland exceedence flows.

Costs will vary depending on the nature of the problem and solutions required as well as the number of properties affected at any particular location. The costs associated with the replacement of a significant length of sewer with a larger pipe will clearly be greater that making small change to the local network. However, if further investment solves flooding problems for a gretaer number of properties then the unit cost per property will reduce.

OFWAT unit costs

Costs for water and sewerage infrastructure that may be relevant for SUDS projects are available from the water services regulation authority (OFWAT). This information provides unit costs for capital works in the water industry. OFWAT reviews the cost base of a number of infrastructure types to assess relative efficiencies, in the

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[2] http://archive.defra.gov.uk/environment/flooding/manage/surfacewater/info.htm
[3] http://archive.defra.gov.uk/environment/flooding/manage/surfacewater/urbanrisk.htm

procurement and implementation of capital projects, by comparing company estimates of capital works and unit costs for a range of standardised projects.

This process is well established and was first used in the 1994 price review. It has been developed and revised in 1999 and 2004. The Ofwat report and data on the capital expenditure unit cost submissions presented by companies as part of the Ofwat price control review 2009 (OFWAT, 2008) are available on the Reckon website (http://www.reckon.co.uk/item/1622cb35). Costs are available for the following works:

- Mains laying;
- Mains rehabilitation;
- Communication pipes;
- Household meters;
- Water treatment works;
- Water storage;
- Water pumping stations;
- Sewer laying;
- Sewer rehabilitation;
- Sewer structures;
- Sewage pumping stations;
- Sewage treatment works; and,
- Sludge treatment and disposal

A summary of the information is provided here for items most likely to be used for flood risk management purposes. It is important to note that these costs represent projects where adverse complications are excluded and all other assumptions are consistent with relevant design and construction guidelines. Specific factors, such as regional construction prices may increase these costs.

For more detailed or site-specific costs, it may be more appropriate to contact utilities companies directly and to use their internal cost models to determine costs for flood risk management solutions.

Table 1-3: Standard costs for sewer laying (£ per m)

Water infrastructure	150mm	225mm	300mm	450mm
Sewer laying - grassland	118 (101 - 151)	140 (117 - 201)	165 (127 - 245)	209 (161 - 321)
Sewer laying - rural / suburban highway	209 (172 - 277)	249 (198 - 313)	308 (250 - 337)	406 (291 - 489)
Sewer laying - urban highway	234 (187-316)	290 (244-387)	337 (281-414)	438 (339-606)
Costs per m April 2008 price base Median values (range in brackets)				

Table 1-4: Standard costs for water storage (£ per unit)

Water infrastructure	Cost per unit	Cost per m^3
Storage tank to combined sewer overflow, capacity $750m^3$	£322,000 (277,000 - 759,000)	£429
Large storage tank to a combined sewer overflow, capacity $3,000m^3$	£801,000 (486,000 - 1,614,000)	£200
April 2008 price base Median values (range in brackets) 4 Ml (4,000m3) capacity, two compartments, good ground conditions, including all necessary pipe work and telemetry but no treatment.		

1.3.4 Cost of dealing with sewer flooding (OFWAT)

In May 2003, Babtie Group was commissioned by Ofwat (Babtie, no date) to review costs for all 10 water and sewerage companies. The data collated as part of this review is presented in Table 1-7 and provides costs associated with a number of identified solutions to sewer flooding.

In addition, the research analysed the relationships between costs per property and the cause of flooding, design return periods and a comparison of costs between water companies. The causes of flooding were classified as follows:

- Localised problem;
- General problem – local sewer;
- General problem – collector sewer;
- General problem – main sewer; and,
- General problem – trunk sewer.

The available data available provides a check on the order of magnitude as opposed to a defined cost per property to be used in a study. Care should be taken when using these costs for appraisal as there is no such thing as a typical solution and each problem will require a bespoke engineered solution.

A summary of the costs are provided below although the analysis of costs is provided in the Babtie report available on the OFWAT website[4].

Table 1-5: Average costs per property for sewer flooding solutions

Solution	Min Average Cost per Property (£K)	Mean Average Cost per Property (£K)	Max Average Cost per Property (£K)
Flow Attenuation	6	58	482
Sewer Upsizing	3	48	530
Manage Flow	1	32	465
Isolate from the System	5	18	150
New Pumping Station	10	15	60
All costs were re-based to the third quarter of 2003 for comparison. The data available is not sufficient to give an accuracy of the average cost per property to better than +/- £10,000.			

[4] http://www.ofwat.gov.uk/pricereview/pr04/

The data and summarised above provides a general indication of the relative cost effectiveness of solutions to flooding problems at a property scale. The optimum solution will need to be determined on a site by site basis.

Discussion of sewer flooding costs

The impact of new development and growing demand will also need to be considered in the case of sewer flooding. As a result, maintaining current service levels is not solely a matter of allocating expenditure to maintain the serviceability of existing assets, but the acknowledgement of the need to make provision for additional future demands likely to be placed on the network. It should also be noted that due to current sewerage systems designed to cope with storms which might be expected to occur once in 30 years, the costs of altering systems to cope with rarer events may be excessive.

There is also be need to understand of the scale of the current problem, prior to establishing the potential cost of tackling sewer flooding problems. To do this the quality of the information held also needs to be understood and there may be significant costs associated with this. This information will be held by the water and sewerage companies and any assessment and improvement works will need to be undertaken in close collaboration with these Utilities.

1.4 Operation and maintenance costs

As with any other flood risk management measure, sustainable drainage systems require ongoing maintenance to ensure the system remains in good working order and the design life of the system is extended as long as possible. Operation and maintenance activities will include the following:

- Monitoring and post-construction inspection;
- Regular, planned maintenance (annual or more frequent); and,
- Intermittent, refurbishment, repair/remedial maintenance;

Additional costs may include disposal of materials as a result of operational and maintenance activities.

The long-term maintenance costs associated with SUDS are relatively poorly understood as these costs are normally absorbed by operators responsible for maintaining the infrastructure as part of their wider asset base.

Whilst the construction costs of SUDS ponds and wetlands are relatively straightforward to calculate, the maintenance costs may be more difficult to estimate due to a lack of basic information and resolution of legal issues regarding the responsibilities for ongoing maintenance. Key factors that will affect maintenance costs are:

- The type and frequency of maintenance required (e.g. sediment removal, inlet/outlet maintenance, landscaping, litter removal);
- The costs of maintenance (materials, labour and equipment costs);
- The availability and source of materials and disposal costs; and,
- The responsibility for maintenance (e.g. local authority, highways agency, residents, developer).

1.4.1 Maintenance frequencies

Costs associated with maintenance will depend on the frequency of maintenance activities required. These frequencies may be specified by manufacturers for specific asset types. In the absence of these, the following maintenance items and frequencies have been based on material in the SUDS Manual (CIRIA, 2007). This is a summary of the information and practitioners are advised to review the SUDS Manual for more detailed information for each SUDS measure. An additional good practice manual (Anglian Water Services Limited, No Date) provides a similar summary of SUDS maintenance activities and frequencies.

Table 1-6: Typical maintenance works and frequencies for a range of SUDS measures

Option	Annual or sub annual maintenance	Intermittent
Green roofs	6 monthly - remove debris and litter 6 monthly - remove weeds 6 monthly - mow grass (if applicable)	
Simple rainwater harvesting (water butts)	Annual - cleaning inlets, outlets, gutters and tanks	
Advanced rainwater harvesting	3-6 monthly - self cleaning and coarse filter checks and clean 6-12 monthly - check and clean roof and gutters 6-12 monthly - UV unit operation checks Annual - pump operation checks	
Permeable paving	4 monthly - brushing and vacuuming	Stabilise and mow contributing areas, removal of weeds Remedial work to any depressions or broken blocks Rehabilitation of surface and upper sub-structure where significant clogging occurs Replacement of filter material (20-25 years)
Filter drain / perforated pipes		Replacement of filter material (10 – 15 years)
Swales	Monthly - litter and debris removal, grass cutting Annual - manage vegetation and remove nuisance plants Annual - checks for poor vegetation growth and re-seed	Repair erosion or damage, re-level uneven surfaces Remove sediment and/or oils
Infiltration basin	Monthly - litter and debris removal, grass cutting of landscaped areas Half yearly - grass cutting of	Re-seed areas of poor vegetation growth Prune and trim trees Remove sediment when 50% full

Option	Annual or sub annual maintenance	Intermittent
	meadow grass and around basin Annual - manage vegetation and remove nuisance plants	Repair of erosion or other damage Repair/rehabilitation of inlets, outlets and overflows Re-level uneven surfaces and reinstate design levels
Soakaways	Remove sediment and debris Clean gutters and filters Trim roots that cause blockage	
Infiltration trench	Monthly - litter and debris removal Annual - weed/root management Annual - removal and washing of exposed stones Annual - removal or sediment from pre-treatment devices	Replacement of filter material (20-25 years)
Filter strip	Monthly - litter and debris removal, grass cutting Annual - vegetation management Annual - checks for poor vegetation growth and re-seed	Repair erosion or damage, re-level uneven surfaces Remove sediment and/or oils
Constructed wetland	Monthly - litter and debris removal, grass cutting of landscaped areas Half yearly - grass cutting of meadow grass Annual - manage vegetation including cut of submerged and emergent aquatic plants and bank vegetation removal	Remove sediment Repair of erosion or other damage Repair/rehabilitation of inlets, outlets and overflows Supplement plants if establishment not complete
Detention basin	Monthly - litter and debris removal, grass cutting of landscaped areas Half yearly - grass cutting of meadow grass Annual - manage vegetation including cut of submerged and emergent aquatic plants and bank vegetation cutting	Remove sediment Repair of erosion or other damage Repair/rehabilitation of inlets, outlets and overflows

The above maintenance works and frequencies provide current best practice. It may be possible to reduce the frequency or type of maintenance if best practice is followed. Furthermore, if SUDS systems are designed to prevent silt and debris reaching permeable paving, ponds etc and captured in areas that are easy to maintain then the design life or frequency of maintenance of the more expensive or difficult to maintain assets may be increased.

As with other asset types, the frequency of inspection and maintenance of assets will depend on local conditions and may be reduced if appropriate steps are taken and experience dictates. A risk-based approach to define inspection and maintenance may be appropriate where the degree of operational works varies significantly.

1.4.2 Maintenance costs

HR Wallingford's work for the DTI (HR Wallingford, 2004) on whole life costing for SUDS components suggested that the estimates of annual operational and maintenance costs as a percentage of construction costs ranged from 0.5 – 10% for all components with the exception of an infiltration trench for which a 20 % figure was cited as a maximum.

Generic annual maintenance costs

The following table indicates possible annual maintenance cost ranges, based on a review of literature and some UK costs, undertaken in 2004 by HR Wallingford This has been extended through additional literature reviews to cover additional SUDS components.

Table 1-7: Indicative annual maintenance costs for key SUDS options

Option	Annual maintenance costs	Source
Green roofs	£2,500 per year for first 2 years for covered roof with sedum mat, £600 per year after. £1,250 per year for first 2 years for covered roof with biodiverse roof, £150 per year after.	Bamfield (2005) Bamfield (2005)
Simple rainwater harvesting (water butts)	Negligible	
Advanced rainwater harvesting	£250 per year per property for external maintenance contract	RainCycle
Permeable paving	£0.5 - £1 / m^3 of storage volume	HR Wallingford, 2004
Filter drain / perforated pipes	£0.2 - £1 / m^2 of filter surface area	HR Wallingford, 2004
Swales	£0.1 / m^2 of swale surface area £350 per year	HR Wallingford, 2004 Ellis, 2003
Infiltration basin	£0.1 - £0.3 / m^2 of detention basin area £0.25 - £1 / m^3 of detention volume	HR Wallingford, 2004
Soakaways	£0.1 / m^2 of treated area	HR Wallingford, 2004
Infiltration trench	£0.2 - £1 / m^2 of filter surface area	HR Wallingford, 2004
Filter strip	£0.1 / m^2 of filter surface area	HR Wallingford, 2004
Constructed wetland	£0.1 / m^2 of wetland surface area Annual maintenance of £200-250/yr for first 5 years (declining to £80 -£100/yr after 3 years).	HR Wallingford, 2004 Ellis, 2003
Retention (wet) pond	£0.5 - £1.5 / m^2 of retention pond surface area £0.1 - £2 / m^3 of pond volume	HR Wallingford, 2004 HR Wallingford, 2004 Ellis, 2003
Detention basin	£0.1 - £0.3 / m^2 of detention basin area £0.25 - £1 / m^3 of detention volume £250-£1000 per basin	HR Wallingford, 2004 HR Wallingford, 2004 Ellis, 2003

An alternative method of estimating maintenance costs is to assess the annual cost per m^2 of contributing area (a residential house is often assumed to represent a contributing area of $50m^2$). The EA report (Environment Agency, 2007) collated various operational expenditure cost estimates for a number of SUDS types based on property floor areas for different property categories. These are summarised in the table below:

Table 1-8: Indicative annual maintenance costs by contributing area

Option	Annual maintenance costs
Rainwater harvesting	£0.4 per m^2 for detached/semi detached residential properties £0.1 per m^2 for non-domestic properties
Permeable paving	£0.4 per m^2
Filter drain / perforated pipes	£0.6 per m^2 for regular maintenance £3.0 per m^2 for intermittent maintenance £0.2 per m^2 for monitoring
Swales	£0.1 per m^2 for regular maintenance £0.15 per m^2 for intermittent maintenance £2.0 per m^2 for remedial maintenance £0.05 per m^2 for monitoring
Infiltration basin	£0.6 per m^2 for regular maintenance £3.0 per m^2 for intermittent maintenance £2.0 per m^2 for monitoring

Specific annual maintenance costs

Specific annual maintenance activities and unit costs for various SUDS types are quoted in the HR Wallingford 2004 report and repeated in the SUDS Manual. The costs are summarised below and are based on a specific case study example, however they provide an example of unit rates applicable to certain maintenance activities.

Table 1-9: Indicative annual maintenance activities and unit costs for various SUDS features

SUDS feature	Activity	Frequency	Unit rates
Peripheral planting	Grass cutting and collection / disposal	Monthly	£150
	Meadow grass cutting/management	6 monthly	£400
	Woodland grass cutting/management	Annual	£250
	General vegetation management	4 monthly	£60
	Litter removal during monthly site visits	10 visits a year	£30
Drainage features	Litter removal during monthly site visits	Monthly	£20 per visit
	Grass cutting April - October	Fortnightly	£25 per visit
	Swale grass cutting	Monthly	£25 per visit
	Wetland ditch vegetation management	6 monthly	£40 per visit
	Aquatic plant management	5 visits a year	£100
Inlets and outlets	Remove debris, strim, remove accumulated silt	Monthly	£50
	Inspection of valves	6 monthly	£10

SUDS feature	Activity	Frequency	Unit rates
	Rip-rap inspection	Monthly	£10
	Grass weir inspection	Monthly	£10
	Stilling area inspection. 12 visits 10 120	Monthly	£10
Visual monitoring		Monthly	£15

Intermittent maintenance

Intermittent operations may be needed for certain SUDS measures to ensure that the measures achieve the stated benefits of the works. Costs for these items are particularly site specific and variable with few real examples from which to base cost estimates on. If regular inspection and monitoring of the system is undertaken, the necessary activities and frequencies will be able to be defined more accurately for a particular system.

The type and frequency of some typical activities are quoted in the HR Wallingford 2004 report and repeated in the SUDS Manual. The costs are summarised in Table 1-12 with some additional data sources where available. Most of these costs will depend on the length or size of the SUDS feature so the costs provided are indicative.

Table 1-10: Intermittent maintenance activities and unit rates for SUDS measures

Measure	Frequency	Rate and activity	Source
Advanced rainwater harvesting	5-7 years	£500 for pump replacement	RainCycle
Swale	3	£250 for removal of silt	SUDS Manual (C697)
	3	£250 for surface treatments to encourage infiltration	SUDS Manual (C697)
	25	£2,000 for replacement of topsoil and disposal of silts	SUDS Manual (C697)
Filter drain / filter strip	3	£250 for removal of silt	SUDS Manual (C697)
	3	£50 for limited weed control	SUDS Manual (C697)
	25	£1,000 for removal and cleaning of stone and the removal, disposal and replacement of geotextile.	SUDS Manual (C697)
Ponds and wetlands	3	£500 for partial silt removal and disposal to land	SUDS Manual (C697)

Remedial operations

Remedial or corrective operations may be needed for certain SUDS measures. These works may also be required following erosion or high silt loads discharged during a single event.

The type and frequency of some typical activities remedial are quoted in the HR Wallingford 2004 report and repeated in the SUDS Manual. The costs are summarised below with some additional data sources where available.

Table 1-11: Intermittent maintenance activities and unit rates for SUDS measures

Measure	Frequency (years	Rate and activity	Source
Swale	10	£3,000 for reinstatement and general repairs, repairs to structure elements	SUDS Manual (C697)
Filter drain / filter strip	10	£3,000 for reinstatement and general repairs, repairs to structure elements	SUDS Manual (C697)
Ponds and wetlands	10	£5,000 for removal of silt, repairs to structure elements, replacement of planting.	SUDS Manual (C697)
Ponds and wetlands	N/A	£3-5 per m^2 for replanting of aquatic plants.	Ellis (2003)
Ponds and wetlands	N/A	£50-60 per m^3 for disposal of contaminated sediment.	Ellis (2003)

1.5 Disposal and decommissioning

As the end of the design life SUDS components will require either rehabilitation or decommissioning. Components of the system that may require disposal include fill material, block paving, geomembranes and sediment.

Where ground features are used such as swales, the costs are likely to be minimal. However, the use of filter drains, ponds or pervious pavements where a volume of construction material or sediment requiring disposal is required, the costs could be significantly higher due to the need to consider landfill charges and the possible impact of pollutants in the disposal materials.

Some decommissioning assumptions for SUDS features are provided by Taylor (2005) who undertook an analysis of project costs for real examples and literature values from storm water treatment measures around Australia. Despite acknowledgements with regard to the uncertainty of this information and a high degree of variability in these measures, this information provides indicative values for the proportion of decommissioning costs associated with a number of different measures. Typical decommissioning costs are 35 - 42% of the total construction costs.

1.6 Other cost estimate requirements

In addition to the above cost estimates required, the following parameters are required to ensure whole life costs are correctly defined in order to incorporate these into an appraisal.

1.6.1 Appraisal period/design life

The design life is typically defined as the minimum length of time that a scheme is required to perform its intended function. The design life for appraisals is typically taken to be 100 years, although alternative periods can be used. The design life is also an important consideration in whole life costing as component assets may have a shorter service life than the design life.

Design life for SUDS systems may be very long assuming appropriate construction and long term maintenance is undertaken over the system life. There is a low risk of structural failure of SUDS components that can help to extend the structural design life.

Whilst this is the case, regular maintenance and inspections may be required to ensure that the SUDS components are delivering the required attenuation and water quality benefits. This requirement may limit the operational life of the assets or a component of a system that requires some level of intermittent maintenance or rehabilitation. This highlights the two elements of design life:

- Design life of the system as a whole.
- Component life of a system element, the failure of which may reduce the system's ability to achieve the stated function.

A review of available design lives for various SUDS measures are provided in the table below, based on a review of literature undertaken in 2004 as part of HR Wallingford's work for the DTI on whole life costing for SUDS components.

Table 1-12: Design life estimates for SUDS measures

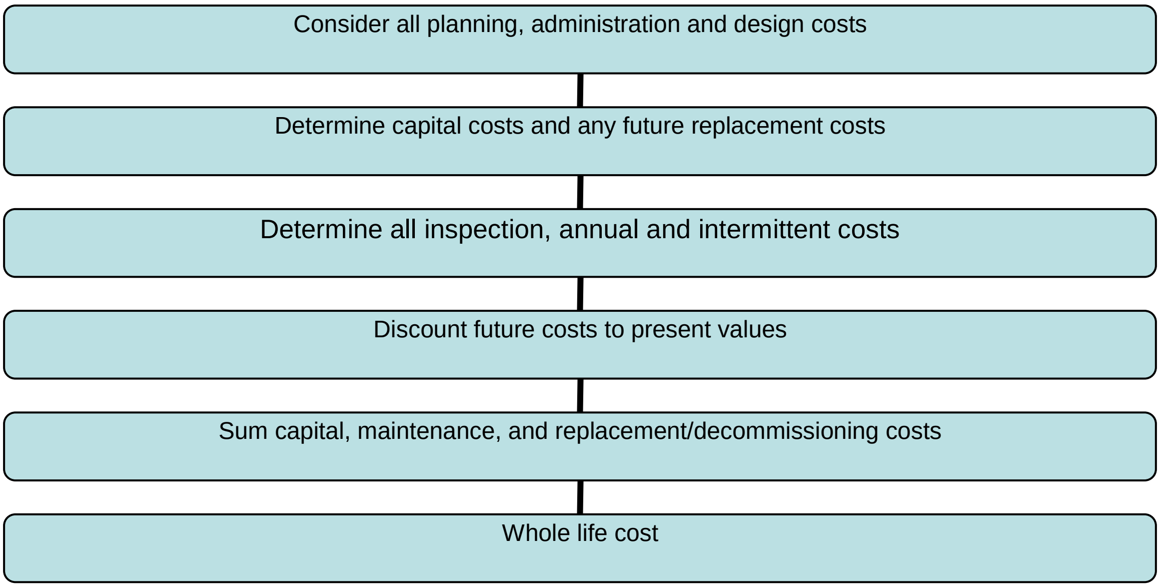
Option	**Design life**	**Component life**
Green roofs	Unlimited design life	N/A
Simple rainwater harvesting (water butts)	Unlimited design life	No reliable information
Advanced rainwater harvesting	Unlimited design life	No reliable information.
Permeable paving	Unlimited design life	20-25 years before replacement of filter material
Filter drain / perforated pipes	Unlimited design life	10 – 15 years before replacement of filter material
Swales	Unlimited design life	5 – 20 years before deep tilling required and replacement of infiltration surface
Infiltration basin	Unlimited design life	5 – 10 years before deep tilling required and replacement of infiltration surface
Soakaways	No available information	
Infiltration trench	Unlimited design life	10 – 15 years before replacement of filter material
Filter strip	Unlimited design life	20 – 50 years before replacement of the filter surface
Constructed wetland	20 – 50 years	sediment disposal after 10-15 years
Retention (wet) pond	20 – 50 years	
Detention basin	20 – 50 years	sediment disposal after 10-15 years

The above intervals of component replacement/refurbishment will depend on site characteristics, system design, and the degree of maintenance undertaken over the asset life. However, the above component design life estimates can be incorporated into whole life cost estimates to provide an estimate of the intermittent costs required.

1.7 Cost estimation methodology

The following diagram shows the key aspects required to generate a whole life cost estimate for a SUDS scheme.

Figure 1: Flow diagram for SUDS whole life costs



1.8 Relevant R&D and general design guidance

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1.9 Checklist

The following checklist should be followed to ensure all relevant cost items are included and incorporated within a whole life cost estimate.

Item	Description	Frequency	Comment
Planning costs			
Professional fees	Initial appraisal and design costs.	One off	
Consultation	Includes planning, management and agreements.	One off	
Licences and consents	Planning permission, land drainage consent and others.	One off	
Capital			
Construction costs	Construction costs.	One off	
Replacement / decommissioning	Any intermittent component replacement costs. Future one off refurbishment or decommissioning costs.	One off or recurring	
Operation & maintenance			
Operational inspection	Inspection and general operational works undertaken during inspections	Annual	
Annual maintenance	Annual or sub-annual maintenance works. These will depend on the type of SUDS features proposed.	Annual	
Intermittent maintenance	Any specific longer term maintenance aspects such as silt removal and disposal.	Intermittent	
Remedial maintenance	Specific remedial or corrective actions to structural aspects.	Intermittent	

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