CIRIA Research Project RP993

Demonstrating the multiple benefits of SuDS – A business case (Phase 2)

Draft Literature Review (October 2013)

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EXECUTIVE SUMMARY

Alternative ways of managing surface water minimising the use of buried pipes and giving preference to surface based systems are used with increasing frequency around the world. Many of these systems incorporate green infrastructure and provide habitat and ecosystem benefits. Sustainable Drainage Systems (SuDS), as they are known in England and Wales and SUDS in Scotland, include a wide range of measures that utilise natural processes which detain and purify surface water. When retrofit they can partly or fully remove surface water from traditional drainage.

Such features as green roofs, water butts, soakaways, grassed areas, depressions known as swales, lowered grassed areas and wetlands all reduce the overall amount of water that ends up in streams, rivers and ponds downstream. Even a green roof has the potential to hold back more than 25mm of rainfall, and any water that comes out is much cleaner. Any water that does eventually run off from the area is cleaner and it's rate of flow much slower, reducing flood risk and disruption to water bodies and the fish and other organisms that live there. Other measures such as permeable car parks and infiltration trenches all help these processes of reducing and slowing the flow. In contrast, piped systems, while being very effective at draining an area with all the flow kept underground, generally provide a much more rapid passage to the flow, and remove very few of the pollutants found in urban run-off.

As well as water quantity and quality benefits, SuDS, by collecting the water locally, can also provide direct sources of water for toilet flushing, garden watering or commercial use. There are also amenity benefits, can enhance biodiversity, support community recreation and education, and help with climate change mitigation and adaptation. The multiple benefits of using SuDS compared with piped drainage systems are only now beginning to be better understood, but their incorporation into decision making is still limited.

It is possible to estimate some of the benefits, such as physical improvements in water and ecological quality, using modelling and economic valuation techniques. However, there are many benefits for which there is no clear procedure for their assessment. For example, how best to identify and assess the value of 'tranquillity' – the benefits of being somewhere that is calm, serene and pleasant? Could a framework such as ecosystem services enable the multiple benefits to be estimated? Equally, can we be sure that SuDS always bring benefits, or can existing or more traditional approaches to drainage deliver just as well for biodiversity and amenity?

It is therefore timely to review the state of knowledge around the benefits that SuDS can bring when used as part of a surface water drainage system. This review considers how SuDS and their equivalent around the world can deliver benefits to society. It also considers how these benefits are being assessed, both qualitatively and quantitatively, and how reliable these assessments and the data they utilise might be. The various tools that have been developed invariably utilise an ecosystem services framework as their foundation in one form or another. Most of the valuations adopt a benefits transfer approach, where economic values from other studies are applied and assumptions made.

Increasingly, such tools and approaches are used to convert benefit assessments into monetised outcomes. For example, in the stormwater management programme

in the City of Philadelphia, the net benefits of using surface techniques has been estimated at almost $3bn compared with less than $100m for the piped alternative. The $3bn figure includes many diverse benefits such as: changes to property values; green jobs created; reduction in greenhouse gas emissions; and reduced crime. We consider the evidence for these and other claims.

We conclude that as yet there are no comprehensive tools or techniques being used anywhere in the world that provide the reliability and validity needed for a robust estimate of the added benefits of SuDS, especially for a monetised assessment. However, existing valuations frameworks such as ecosystem services can be drawn upon to develop a set of tools for estimating the overall benefits.

The costs of undertaking a financial evaluation of SuDS benefits should not be underestimated and could be disproportionately expensive for small developments. Therefore, standardised support for such evaluations is needed that should be simple and accepted as legitimate and trusted by all stakeholders. Such analyses are not needed for all SuDS developments and guidance is needed as to when and how to do this.

There are many ‘sustainability assessment’ tools and methodologies, but none so far is sufficiently robust and reliable to evaluate the benefits provided by SuDS Nevertheless, some existing components and tools can be utilised. For example, life cycle analysis (LCA) is an established and credible method to determine the environmental benefits and costs of a development. This can provide a framework for quantitative information that can be used directly to see for example, how much carbon is being sequestered by a SuDS feature. Economic valuation can then be used to determine a monetary benefit from this. As many of the supporting tools are well established and have been developed in an accredited and standardised way (for example as ISO standards), the resulting benefit estimates are likely to be robust.

We therefore recommend that an inventory of robust SuDS benefit information be created. This information will include:

- Primary data, covering for example flow control, quality improvements, and greenspace created; and
- Secondary data, for example number of properties likely to be affected by SuDS, or numbers of green jobs created.

We argue that a benefits transfer approach to valuing benefits is appropriate in most circumstances. However, certain benefits are not yet fully amenable to monetisation, and we recommend that these should be included separately in any benefit assessment tool. Over time and as knowledge develops, the monetisation of these benefits may be possible, and a ‘SuDS benefit estimation’ tool should provide the opportunity to be able to take on board such developments.

As many of the benefits of SuDS relate to their flexibility and resilience, the value of this also needs to be taken into account. Therefore, a time as well as spatial perspective is needed in any new tool. The value of delaying investment and indeed, doing nothing or very little for a while, needs to be recognised and appropriately included in any evaluation of the benefits of SuDS.

1 INTRODUCTION

This review is intended for those who have an interest in understanding, using, or promoting the multi-functional benefits of Sustainable Drainage Systems (SuDS). It has been written with the intention of being accessible to as wide a range of interested parties as possible and although it presumes a basic knowledge of SuDS, it introduces a range of benefit assessment approaches and tools that are in use or under development presuming limited prior knowledge on the part of the reader.

The aim of the literature review is to gain an underlying understanding of the current state of the art in this area. It determines current practice in relation to using valuation tools and approaches to assess the value and distribution of the wider benefits of SuDS beyond water quantity management alone. There is growing evidence that suggests that SuDS can be more cost beneficial than conventional measures. However, particularly in the UK, predicting the costs and furthermore the benefits of SuDS in new development and retrofit scenarios is uncertain due to the lack of experience with these systems and more significantly the lack of monitoring, data collection and reporting. If the costs and benefits could be determined with greater certainty, then their economic justification will become stronger and less open to challenge. Here it is intended to collate the necessary knowledge to understand how the benefits of SuDS can be assessed in their entirety. Although costs are also important when comparing the relative value of utilising SuDS, established methods already exist to determine these. This review therefore concentrates on identifying current practices and exemplar case studies related to the valuation of the benefits of SuDS in the UK and their equivalent in other countries.

This report highlights the key references that have been identified during the literature review and briefly describes their relevance in context. It provides a summary to date of the material obtained, however, further material will be collected during the project as the work develops.

This literature review has been completed using a variety of sources. These include:

- Abstract databases using keyword searches (e.g.: Web of Knowledge)
- Key journals
- Personal networks and communications
- Project Steering Group and Stakeholders' information
- Internet using keyword searches and websites
- Existing design guidance and regulations
- "Paper chasing" and "grey literature"

More than 400 sources have been identified during this review, although many were discarded at an early stage. Of the literature, reports, guidance and other information that has been obtained, approximately 300 have been identified as being important or useful and support this literature review.

Although the valuation of the benefits of SuDS is undertaken here from the perspective of the management of surface water, as the range of benefits is so wide, encompassing *inter alia* social, ecological, environmental, economic domains; alternative viewpoints are also used in the framing from the green, ecosystem, liveability and sustainability literatures. The literature review is, however, written to support those who are responsible for and have an interest in surface water management in urban areas.

The context within which the valuation of SuDS is and needs to be carried out in the UK is also included here. The growing use of partnerships to develop consensual and jointly-funded schemes, where the various partners have specific and sometimes disparate responsibilities, mandatory or otherwise, or other motives for engagement, has highlighted the need to consider if and how a formalised approach to the valuation of SuDS can be developed that is generic enough to be usable by these various organisations and institutions in providing best overall value to society from their joint and individual endeavours. It also addresses what 'best overall value to society' may mean in the context of surface water management.

2 VALUE AND WHY ASSESS BENEFITS – SUSTAINABILITY AND LIVEABILITY

The Natural Capital Committee (2013) define valuation as "the process of expressing a value for a particular good or service in a certain context (for example, of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on)". Value is defined as "the contribution of an action or object to user specified goals, objectives, or conditions." They also define Natural Capital as "those elements of nature which either directly provide or underpin human wellbeing. As such, natural capital generates value for people." These definitions are helpful when considering the value and benefits that may be provided by SuDS, especially those that are surface based and utilise green options.

2.1 Getting best value for society

At a time of economic constraint and significant uncertainty about the future (Milly et al, 2008), it is even more important to ensure that the overall best value is obtained from society's investments. Even where private bodies make the investment, such as by the Water and Sewerage Companies (WaSCs) in England; ensuring best value to society is still essential as ultimately it is the members of society who have to pay for the goods, services and utilities that they access and use. Currently HM Government's view aligns with OECD and others' in that there is a need to ensure that investments contribute to growth and that 'green' investments need to be considered in this way (e.g Eftec et al, 2013; Merk et al, 2012). The former specifically mentions SuDS as a potential means to support economic growth and points out the importance of 'displacement' in this regard, where one activity simply displaces or acquires the benefits from another, resulting in no net overall benefit increase.

Concepts of sustainability and liveability now influence how benefits and value are seen (Section 3.1.1). Successive governments' in the UK continually attempt to redefine 'sustainable development' as there are as yet no agreed definitions of what this really means. In Australia, liveability is increasingly being linked with green spaces and SuDS in urban areas (Johnstone et al, 2012).

Yet, getting best value for society is not straightforward; the very definition of what would constitute best value implies moral and personal judgements (e.g. Sim, 2012). Traditional reductionism, whereby the financial outlay and deferred costs are compared with the financial benefits, assumes that all elements of the costs and benefits can be expressed in monetary terms. But there are many intangible benefits that are not amenable to monetisation especially social and environmental factors (e.g. Marlow et al, 2013; 2013a). Despite this, regulators such as Ofwat still try to reduce 'value' to an accounting tool in the way in which the WaSCs are regulated (Cavill & Sohail, 2003) and do not consider the wider societal aspects of sustainability (CIWEM, 2010), preferring to concentrate on asset values and the 'value of water' (Cox, 2013) rather than what is best overall value to society.

Best value is not about cheapness and hence the draft National SuDS Standards statement: "If full compliance with the Standards would necessitate the construction of a drainage system that is more expensive than an equivalent conventional design then full compliance is not required, and instead the drainage system must comply with the Standards to the greatest extent possible without exceeding the cost of the equivalent conventional design" misses the opportunity to seek and obtain best overall value.

Ironically other Defra policy statements require the incorporation of wider values into policy and project appraisal (e.g. Defra, 2010) with different approaches to this applied across government departments. The Department for International Development (DFID) for example require value from infrastructure investments in developing countries (Adam Smith International, 2012). However, in promoting 'more open and efficient public services' in their Best Value Statutory Guidance (DCLG, 2011) HM Government state that Local Authorities and other public service providers:

> *"should consider overall value, including economic, environmental and social value, when reviewing service provision. As a concept social value is about seeking to maximise the additional benefit that can be created by procuring or commissioning goods and services, above and beyond the benefit of merely the goods and services themselves."*

This view is not applied when considering SuDS and housing developments.

The problem of ensuring maximum value, rather than least cost, is further exacerbated by the multiplicity of interested parties involved in decision making for investments; all with differing responsibilities, duties and rationales for their actions and needs. Many of the benefits of SuDS (e.g. enhanced biodiversity) are 'public goods', whilst the costs are often borne by private entities. In other words, the parties responsible for bearing many of the costs in a societal investment are often not those who accrue the benefits. Reconciling the payers and the beneficiaries is also complicated, even where there are clear duties involved. It is the responsibility of all professionals to seek maximum value for society as well as to serve the needs of their clients (van den Hoven et al, 2012). However, defining the best outcomes and value from an investment is difficult, especially at a time when we know how uncertain our data are (Naustdalslid, 2012).

Research in Australia has identified that one of the greatest barriers to changing decision making processes is that there is a perception of risks that prevents stakeholders from innovating; as there is a perceived financial risk to this (CWSC, 2013). This was also found in a European study (Dudley et al, 2012) of partner working in learning alliances. The first of these studies states "the full impact of any given context requires a shift to value-based decision-making across both space and time so that the full spectrum of costs and benefits, including the flexibility and resilience of systems can be taken into account." Resilience is a key objective in a recent study whereby a multi-valuation assessment has been applied to inter alia, surface water management in Birmingham and Coventry, termed 'the Ripple Effect' (AECOM & Severn Trent Water, 2013); more details are given in Section 3. In this, a business case has been developed for taking a multiple benefits approach to retrofit surface water management. A major consideration has been climate change resilience. The business cases were estimated based on the value of:

- Daylighting a local river;

- Retrofitting certain streets with SuDS measures that would support more green infrastructure (GI)
- Creating a 'water sensitive' Gateway.

Delivering outputs that are as 'sustainable' as possible in the widest sense require the collection of prodigious amounts of information about the issues being addressed (e.g. Ashley et al, 2004; 2008; 2012). Even were it possible to collect all the information needed, decision making will still be beset by multiple dilemmas as described by Laws & Loeber (2011), requiring negotiation and legitimisation of views to arrive at a consensual final decision. Even expert professionals will disagree on what is best (Rogers, 2012; Sim, 2012).

Many developers and especially City planners and strategists have shifted from a problem-centred approach to one of taking of opportunities and green infrastructure is seen as a major opportunity for this (EEA, 2012; EA, 2013b; Eftec et al, 2013). The new water plan for the City of Rotterdam for example, is opportunity focused and has led to developments there such as the water squares where excess runoff floods public space in a controlled manner.

The way in which benefits are determined for Flood and coastal erosion risk management (FCERM) (EA, 2010) is often seen as 'negative impacts', Box 2.1, i.e. all changes lead to 'impacts', some of which are beneficial, whereas others are not.

Box 2.1 definition of benefits, from - Key Principles: Describe, quantify and value costs and benefits (EA, 2010)

Benefits are positive impacts and include damages avoided as a result of implementing an option. Damages avoided arise from reducing the likelihood of flooding or erosion and/or by reducing the consequences (for example, through flood resilience measures). Positive impacts also include environmental (including biodiversity) benefits associated with increasing the frequency of flooding or geological and geomorphological benefits from allowing erosion to continue.

Wherever possible and necessary, costs, damages and benefits should be valued in monetary terms. However, it is important that valuations in monetary terms are appropriate. When deciding whether to value impacts in monetary terms, it is important to consider whether the money estimate will capture the whole impact or just part of it and if the money value is likely to be meaningful and reliable.

Much research and development of the ideas, methods and approaches to storm and surface water management and its' place within wider societal considerations has taken place outside the UK and here the story of storm and surface water management is presented so that the new vision which seeks to maximise the value of urban water in all its' forms can be better understood in context. From here on, the terms 'storm' and 'surface' water management are used interchangeably as they are used variously in different countries around the world to mean the same thing.

Most of the developments began in the USA in the 1970s, in part due to the Clean Water Act 1972. These were complemented subsequently by Scandinavian and German ideas, and most recently by Australian initiatives from the 1990s. Each country had different drivers for why the use of traditional piped stormwater drainage systems began to be questioned, although there was a growing interest in the concept of sustainability in each (Chocat et al, 2007).

2.1.1 A short history of storm and surface water management

Managing surface water has long been seen as a societal need in order to protect the health and welfare of citizens and protect property and the normal functioning of society, although the original motives were to raise the moral status of the labouring classes by improving sanitation (e.g. Allen, 2008; Rayner & Lang, 2012). The evolution of ideas about how best to manage surface water is outlined in Chocat et al (2007) with the primary approach being to consider surface water from rainfall as mainly a problem and hence draining it away from urban areas as rapidly as possible.

Brown et al (2009) trace the development of the stages of cities in relation to water and the concept of the water sensitive city (WSC), as illustrated in Figure 2.1 from Ashley et al (2013). With a growing interest in sustainability, resource use minimisation, reuse and recycling and an awareness of climate change; surface water in urban areas is now beginning to be seen as a potential resource, rather than a problem.

The Centre for Water Sensitive Cities[1] in Australia is now pursuing a vigorous research programme to further develop this idea and to also consider surface water management as a key element within an interconnected web of urban systems and services for which each component (resource) provides maximum benefits (Centre for Water Sensitive Cities, CWSC, 2013; Howe et al, 2012). The current perspective on surface water in many parts of the world is therefore to see it as a resource to be exploited as much as possible rather than a problem or nuisance (Howe & Mitchell, 2012).

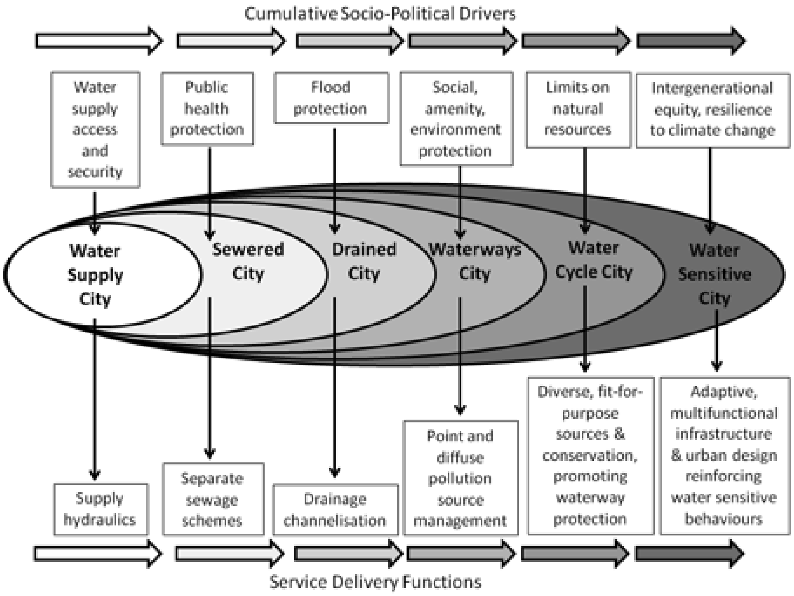
Perspectives on the water sensitive city (WSC) compared with the current fragmentation of the way in which urban water systems are managed are summarised in Table 2.1 (Brown & Keath, 2009). A major component of the WSC is water sensitive urban design (WSUD). This is the process for the journey towards the WSC (Fletcher et al, *subm*.):

"*WSUD…integrates the social and physical sciences and brings sensitivity to water into urban design. It defines a planning and design approach that supports the transition to water sensitive cities*." (CWSC, 2013).

This definition of the role of WSUD has evolved in Australia from a predominantly stormwater focused vision[2] into one which now encompasses the entire water cycle.

[1] http://watersensitivecities.org.au/ accessed 30-07-13

[2] Mouritz et al (2006): "*in its broadest context, WSUD encompasses all aspects of integrated urban water cycle management, including water supply, sewerage and stormwater management. It*



.Figure 2.1. Evolution of the Water Sensitive City (Ashley et al, 2013; adapted from Brown et al, 2009)

Table 2.1 attributes of the water sensitive city compared with current water management (Brown & Keath, 2009)

Attributes	Traditional Regime	Water Sensitive Regime
System Boundary	Water supply, sewerage and flood control for economic and population growth and public health protection	Multiple purposes for water considered over long-term timeframes including waterway health and other sectoral needs i.e. transport, recreation/amenity, micro-climate, energy, food production, etc.
Management Approach	Compartmentalisation and optimisation of single components of the water cycle	Adaptive, integrated, sustainable management of the total water cycle (including land-use) designed to secure a higher level of resilience to future uncertainties in climate, water services requirements while enhancing the liveability of urban environments.
Expertise	Narrow technical and economic focused disciplines	Interdisciplinary, multi-stakeholder learning across social, technical, economic, design, ecological spheres, etc.
Service delivery	Centralised, linear and predominantly technologically and economically based	Diverse, flexible solutions at multiple scales via a suite of approaches (technical, social, economic, ecological, etc.)
Role of public	Water managed by government on behalf of communities	Co-management of water between government, business and communities
Risk	Risk regulated and controlled by government	Risk shared and diversified via private and public instruments

In Australia the transition to a water sensitive city is part of the extensive and multi-disciplinary research programme for the Cooperative Research Centre (CRC) – Centre for Water Sensitive Cities (CWSC, 2013). The process of effecting a

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represents a significant shift in the way water and related environmental resources and water infrastructure are considered in the planning and design of cities and towns, at all scales and densities".

transition entails developing a vision and backcasting, with scenario analysis to formulate a roadmap (e.g. Ferguson et al, 2013a).

Recent initiatives in the UK have reviewed and redefined WSUD in a European and EU context and positioned SuDS in context (Ashley et al, 2013; CIRIA, 2013) as outlined in Section 3.1. Here it is important to appreciate the relationship between SuDS and other similar concepts and practices worldwide especially when considering the function and added value benefits of SuDS. Most of the lessons need to be drawn from other countries with a longer history of utilising non-piped surface or stormwater drainage systems. A detailed history of the development of terminology and stormwater practices that do not rely on piped systems is given in Fletcher et al (*subm.).* What follows draws on this review.

SuDS are a UK term, although it is also being used elsewhere in countries like Germany. The concepts are equivalent to BMPs (Best Management Practices) in the USA and their equivalent in Australia as a vital component of WSUD. In the USA, BMPs are part of Low Impact Development (LID) which originated in a “design with nature approach” (Barlow, et al., 1977). LID is about minimising impacts and has helped to drive a new focus on urban stormwater runoff and water quality, contributing in part to the development of the US National Urban Runoff Program which is aimed at managing stormwater pollution (Torno, 1984). LID misses the resource opportunity emphasis that WSUD promotes.

The original intent of LID was to achieve a “natural” hydrology by use of site layout and integrated control measures. “Natural hydrology” referred to a site’s balance of pre-development runoff, infiltration, and evapotranspiration volumes, achieved through a ‘functionally equivalent hydrologic landscape’ (USEPA, 2000). LID discouraged large end-of-catchment solutions, because of their inability to meet this catchment-wide hydrologic restoration. The term LID was used to distinguish the site-design and catchment-wide approach from the traditionally used stormwater management approach at that time, which typically involved networked conveyance to large facilities (usually a pond) at the outlet of the catchment[3]. In contrast, LID was characterised by smaller scale stormwater treatment devices such as bioretention systems, green roofs and swales, distributed throughout the catchment and close to the source.

The use of LID concepts is now mandated for all federal projects with built up area footprints exceeding 462 m^2 (United States of America, 2007). LID is known to be a cheaper approach to stormwater management than piped systems (USEPA, 2007) and has become a mainstream, though not ubiquitous, means of stormwater management in the USA and also in Canada (e.g. NC State University, 2009; Thurston, 2012). A similar term is used in New Zealand, where the emphasis is on site design to avoid pollution (rather than flow regime management) followed by remedies using source control and treatment devices (Shaver, 2000; 2003). The national “clean-green image” there has led to a focus on ecosystem health (van Roon, 2011).

[3] Sadly, such schemes are common place in the UK and often badged as ‘SuDS’ when they do not fulfill the criteria for this.

To add to the proliferation of terms in the USA, surface water drainage also became synonymous with green infrastructure (GI) (see Section 2.1.5) within the last decade (e.g. Thurston, 2012). Cities like Seattle award building credits for the use of 'green stormwater infrastructure' (GSI) (Seattle Public Utilities, 2009). In many documents and guidance manuals, 'green infrastructure' also means stormwater management.

The incorporation of the term BMP into regulations in the USA has resulted in almost every US state adopting the term BMP into stormwater control guidance[4]. However, it has gradually become apparent that much of what was and is being constructed is clearly not "best practice" and that the term BMP is too vague and hence open to misinterpretation. In view of this, the US National Research Council of the National Academies of Engineering and Science reviewed stormwater management in the USA in 2008. This resulted in a national agreement to abandon the term BMP in favour of Stormwater Control Measure (SCM).

In the USA, SCMs are referred to both as structural (e.g. bioretention systems) and non-structural (e.g. downspout disconnection programmes) control measures. The new terminology does not convey an implied judgement as to whether a selected practice functions "best." Many US institutions have now adopted the term SCM, including the US Federal Highway Administration, State Departments of Transportation, and in academic publications (e.g. Davis, et al., 2012). However, the term SCM is still being used alongside BMP as the term persists in many State manuals and in the design community at large.

BMPs/SuDS "manage rainwater which falls on roofs and other surfaces through a sequence of management practices and control structures designed to drain surface water sustainably". The key objectives of a SuDS scheme are "to manage the flow rate and volume of surface water runoff to reduce the risk of flooding, to protect and improve water quality and to enhance amenity and biodiversity" (Defra, 2012).

The concept of a sustainable drainage system was developed by the Sustainable Urban Drainage (Scotland) Working Party, and built upon the BMP concept from USA. However, it goes further in that it advocates an integrated stormwater management plan that addresses pollutant reduction and flood control, while providing habitat and aesthetic amenities (WERF et al, 2005). Both BMP and SuDS strategies attempt to mimic the runoff characteristics of the natural watershed, and provide a degree of treatment needed to improve the quality of the water discharged to an acceptable level. As D'Arcy and Frost (2001) noted, the concept recognizes that the needs of flood control and stormwater treatment must be integrated if the environment is to be adequately protected. For the facilities to be acceptable for adoption and maintenance, they must, where appropriate, be attractively landscaped and integrated into the local community as amenity green space.

BMPs/SuDS are not WSUD, nor are WSUD a form of 'super-BMP/SuDS'. They typically only focus on one component of the urban water cycle, stormwater, albeit ideally in a multifunctional manner (CIRIA, 2007). The more comprehensive process of WSUD, linked closely with urban design and explicitly aiming to exploit all of the

[4] Note that every State, some cities and towns in USA each have their own interpretations and standards for BMPs and LID

opportunities in the water cycle, may make its uptake easier and more appealing in many parts of Europe than BMPs/SuDS, as their focus is on surface water management (despite incorporating source controls, water harvesting and the use of green infrastructure). It is unlikely that the Australian vision of the water sensitive city and the WSUD process as practiced there are readily translatable to the EU, nor will the American LID approach, which is based on greater availability of land than in much of Europe. Hence the recent reinterpretation of how the concept fits in the UK has been important (Ashley et al, 2013; CIRIA, 2013).

In UK practice, SuDS consist of a range of measures used to drain surface water in a manner that is (arguably) more sustainable[5] than conventional solutions. They are based on the philosophy of replicating as closely as possible the natural, pre-development drainage from a site, consistent with the previously described principles behind LID. Typically, SuDS are configured as a sequence of surface water measures and approaches that work together to form a management train.

Here, it is the intention to focus primarily on SuDS and their potential to provide additional benefits to only managing surface water. However, in this respect, SuDS cannot be separated from the wider context that development of WSUD ideas provides. It is only the greywater[6], foul or sanitary[7] wastewater aspects of WSUD that will not be considered here in this review (Figure 2.2), although source control SuDS provide the opportunity for harvesting rainwater that can be used for toilet flushing and non-human consumption purposes. Figure 2.2 shows the urban water cycle, with conventional water cycle management connected with the solid arrows and the additional WSUD opportunities shown with dashed arrows, although no links to flood risks are shown, nor the management and interrelationship between flood risks and WSUD.

As flood management is a primary objective of SuDS especially in England and Wales (Pitt, 2008), opportunities from managing a range of rainfall right up to extreme events using SuDS need to be considered as illustrated in Figure 2.3. This has been formulated to assist in placing urban surface water within the land use, urban design and planning process so that maximum value can be obtained.

Three types of rainfall event are shown in Figure 2.3: design (1); extreme (2); and everyday (3); each being important in the way in which urban areas are laid out and managed to utilise their potential benefits and manage any adverse impacts. The Figure helps to turn the ‘problem’ of adapting to changing flood risks into a positive opportunity for the development and enhancement of urban areas through utilising the interactions and synergies between the surface water management system and society. The 3 regions in Figure 2.3 are defined as (adapted from Fratini et al, 2012):

1. **Technical optimisation:** where design standards for sewers and other infrastructure apply. This considers technical solutions to deal with defined design storms, to prevent damage and meet service levels;

[5] Sustainability is a contested term (van Egmond et al, 2011) and may only be considered in the context within which the scheme is set; so far there have been no sustainability assessments published for SuDS or BMPs anywhere in the world.

[6] Arisings from kitchen sinks, baths, showers and washing

[7] Toilet flushing

2 **Urban resilience and spatial planning:** involves dealing with extreme events, which become of necessity multi-disciplinary. The aim is to mitigate the impacts of future extreme events and allow adaptation.

3 **Day to day values:** enhancing the value provided by options, awareness, acceptance and participation amongst stakeholders. Attention is given to the way urban space is used and perceived.

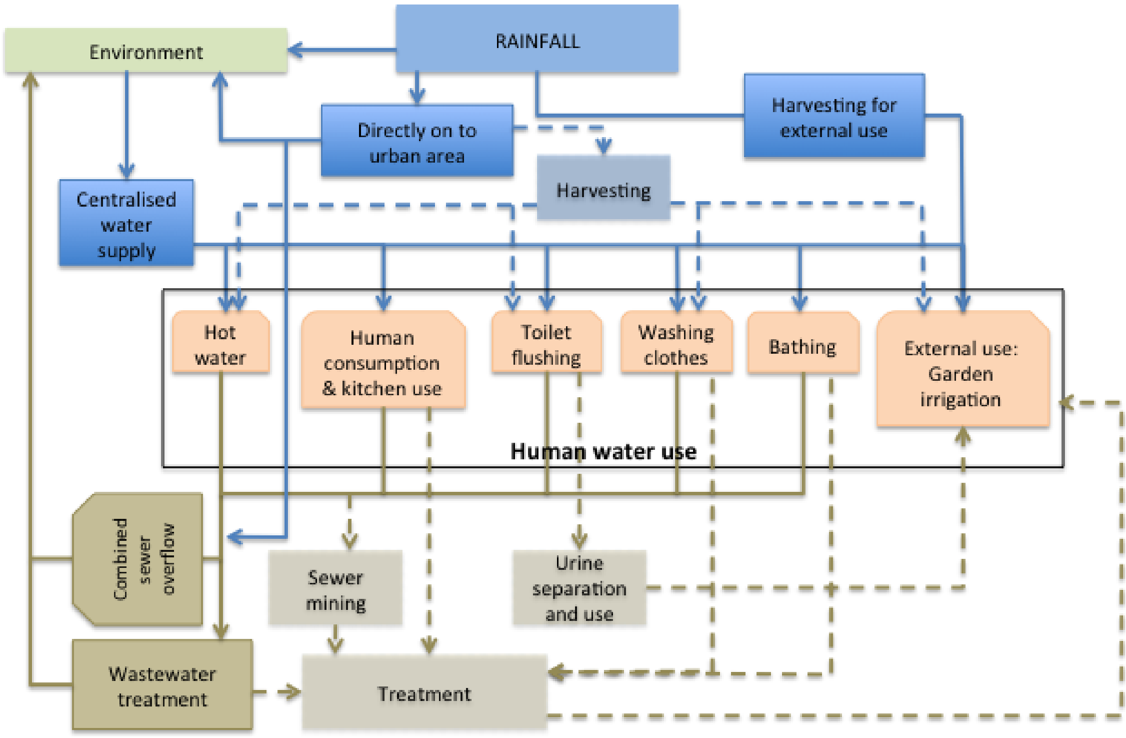

Figure 2.2 the water cycle as envisaged in WSUD linked to human uses (Ashley et al, 2013)

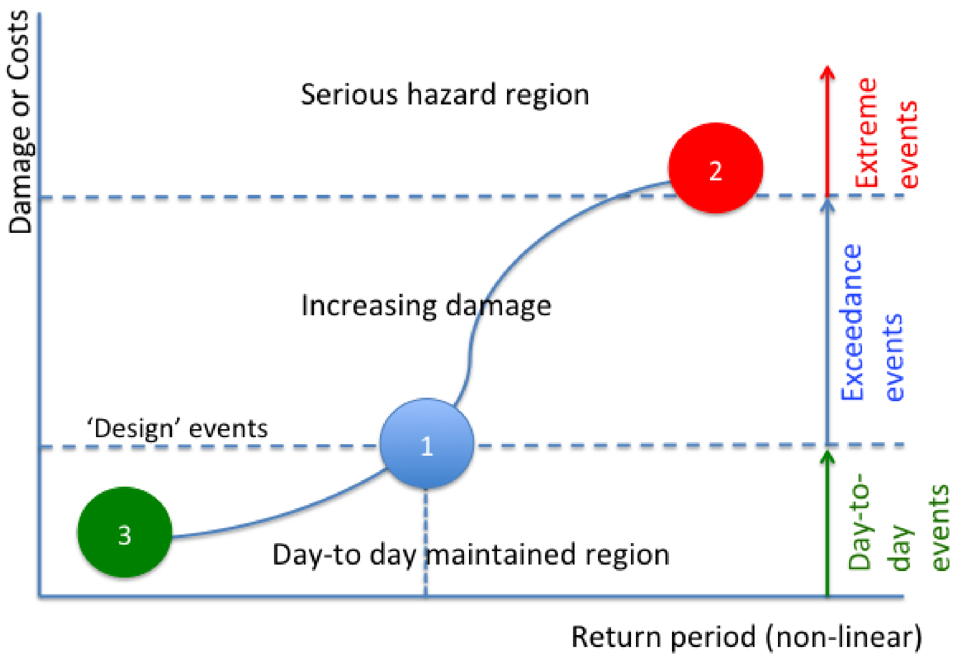

Figure 2.3. The '3 points' approach (3PAs) (adapted from Fratini et al, 2012)

Design rainfall (1) is what the performance standard is based on and design standards for urban drainage are laid out in e.g. BS EN752 where return periods of storm events are specified. Levels of Service, however, which may also be expressed as return periods, relate more to the outcomes from the services provided. Hence flooding frequency may be specified in terms of e.g. the risk of internal property flooding from the sewerage network due to hydraulic restrictions or other causes in the system and will be expressed as numbers of properties per year. In designing, Point No.1 if specified appropriately should result in no flooding. If flooding occurs, then in Figure 2.3 this corresponds to region 2. Most of the time rainfall will provide surface water that corresponds to region 3, causing no problems and providing the main irrigation water source for green areas.

Traditional approaches do not consider the water resource opportunities available for the three types of event illustrated in Figure 2.3. Rainfall is considered part of the urban hydrological cycle that ‘discharges’ to one of the following destinations: “the ground, a surface water body, a surface water sewer or a highway drain, or to a combined sewer” (Defra, 2011). Defra does suggest, however, that SuDS can improve amenity, despite the need for there to be a discharge to one of these destinations.

Nowadays performance specifications usually recognise the three different regions shown in Figure 2.3 and require consideration of what will happen when the designed system is no longer able to contain the flow. The layout and design of urban areas is usually defined in terms only of the lower magnitude rainfall and other events (Regions 1 and 3), with surface and below ground drainage systems automatically providing safe and secure environments for all events up to and including the design event (1). Typically urban planning and design sets out developments based on the use of space, land, functionality, movement of people and safety presuming that water systems can be dealt with using conventional means of supply, drainage and flood protection. Therefore, historically, the added-value of water and what it can provide within urban landscapes has been considered only in term of aesthetics and sometimes recreationally (Figure 2.4).

Figure 2.4 Aesthetic and recreational use of water in an urban environment in central Bradford. Sadly, this is groundwater and not collected rainfall – however, health concerns may preclude using rainwater without treatment.

In summary, the history of surface water management concepts and approaches has been a journey from dealing with a problem or a nuisance, to one in which it is increasingly being recognised that to obtain maximum societal value consideration needs to be given to rainfall events that correspond to each of the three domains in Figure 2.3, but with differing perspectives and measures for each. The main opportunity for adding value from water is in Regions 1 and 3, where the urban landscape features that collect, use, convey, store and dispose of water can be used synergistically with other urban systems and services in a variety of added-value ways. Under extreme conditions, however, urban planning and city layouts need to be able to deal with surface and sub-surface flows in ways that minimise their impacts and can even provide opportunities via e.g. blue or green corridors especially earmarked for such events (London Borough of Croydon et al, 2011) as shown in Figure 2.5.

Figure 2.5 Image of a green park area which can also store excess water (London Borough of Croydon et al, 2011)

2.1.2 Surface water management and the Wallingford Procedure for the design and analysis of urban storm drainage

The 1980s saw the development of a number of new computationally based analytical procedures for designing and analysing storm drainage systems. For the first time 'standardised' models became available that allowed the simulation of the hydraulic performance of urban drainage systems. Some of the first models appeared in the USA – Stormwater Management model (SWMM) and in the UK – Wallingford Storm Sewer Procedure (WASSP). Here the rationale behind the costs and benefits analysis used in the 'Wallingford Procedure' (DoE/HR, 1981), the principles, methods and practices from which WASSP had been set up, are outlined in order to track the development of benefits thinking in the UK.

Although most economists recognise Adam Smith's (1776) 'Wealth of Nations' as a seminal work that has influenced modern economic practice, his 'Theory of Moral Sentiments' (Smith, 1759) is less well recognised in terms of it's relevance today. The former deals with self-interest as the driver for economic growth whereas the latter considers individual behaviour in terms of virtue and justice framed for the good of society as a whole. The stance taken by Smith (1759) that the best decisions are made by utilising the "*sympathetic feelings of the impartial and well-informed spectator*" were taken up by Semple (1991) in the assessment of how best to make decisions related to conflicting values potentially impacting on environmental systems and specifically in relation to urban storm drainage systems. With these ideas in mind, Semple contributed the section in the Wallingford Procedure in 1981 (DoE/HR, 1981) on economics in relation to what the design storm should be when designing and managing urban storm drainage, taking an equity stance to promote justice for society as a whole. This set out for the first time in a UK context a method to balance investment in managing storm flows; defining a specified magnitude that was also considered affordable and sufficient to avoid unacceptable environmental impact, as illustrated in Figure 2.6 (Ashley, 2009).

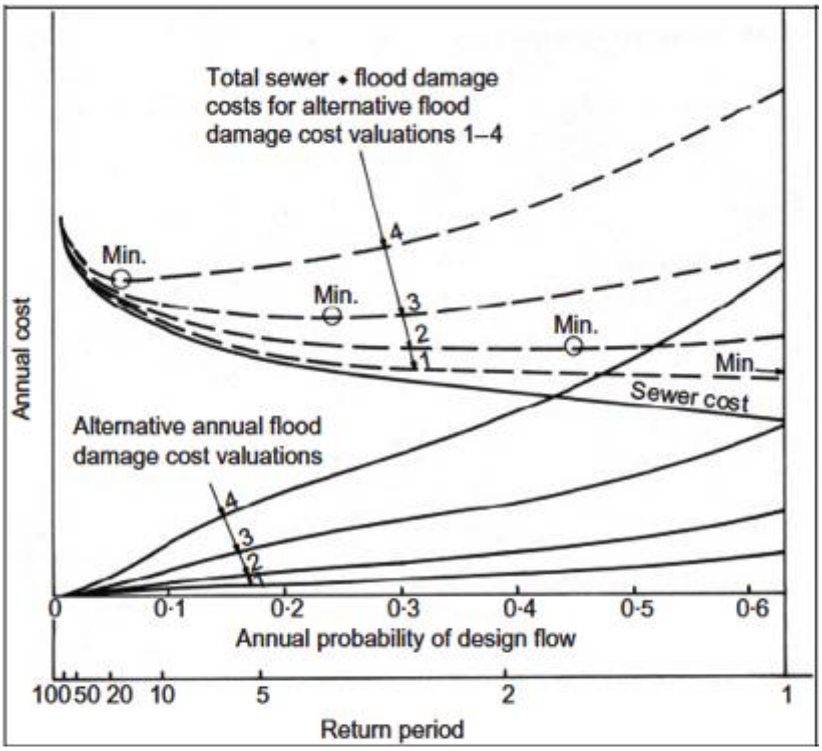

Figure 2.6 Identification of optimum design condition (DoE/HR,1981)

Semple (1991) illustrated, as shown in Figure 2.6, that the costs of investing in managing societal and environmental damage mitigation, specifically in relation to urban drainage, could rise disproportionally if the expectations and standards were not set appropriately. At the time, the scope of the benefits considered in managing flooding and storm drainage were relatively narrowly defined; dominated by the avoided property flood damage and the ways of managing this were almost entirely by using below ground piped drainage systems. The Wallingford Procedure stated that there were particular problems in the application of economic valuation tools due to:

1. the importance of intangible benefits
2. the difficulty of defining flooding depths
3. the enhancement of land values

It was also stated that it was only possible to recommend a 'cost-effectiveness' approach at the time as the complexity of these and other considerations meant that a fuller cost-benefit approach could not then be used.

Deciding on the balance as to how much to invest and what returns to expect from such investments is complex when considering surface water drainage systems especially as the beneficiaries are not necessarily the same as those who fund the investments and there also issues about social justice in relation to benefit accruals (Digman et al, 2012). In 1981, it was found that expenditure on dealing with a sewer flooding problem often exceeded the economic value of the properties being protected. It was concluded that other intangible considerations such as political factors played an important role in these investment decisions. At the time, predicting the extent of flooding was not possible, unlike today where 1D/2D models can provide sensible estimates of flooding extent and impacts (e.g. Aronica et al, 2013). As regards land values, this was also considered problematic as enhanced sewerage provision would inevitably increase land values, but it was concluded that this added value could not be differentiated from other infrastructure benefits and that there was a risk of double counting.

Even in 1981, it was recognised that there were decisions about the required level of service "..must involve judgements of a social and financial nature that are beyond purely technical considerations..". It is this, linked with the influence of Smith (1759) that led to the concept of 'equitable level of service' where an equivalent 'utility' was seen as needing to be provided to everyone, whatever the context and locality. However, this service utility could vary from location to location and even with time dependent on local and contextual factors. The Wallingford Procedure allowed for the first time, a standardised determination of costs against service levels expressed in terms of return periods for which no flooding occurred. With this information, the performance against cost could be weighed up and a service level defined by what the community were prepared to pay. The benefits were a lower risk of flooding and a qualitative assessment of a range of other accrued benefits such as *inter alia* less splashing of pedestrians by road vehicles.

As climate change was not on the horizon in 1981, provision for adapting the storm drainage system was considered necessary only where future urban development was expected in the lifetime of the system. In advocating 'spare' hydraulic capacity in the system, the dangers of poor sediment transport by too low flows were overlooked. For adding spare capacity, a discounted cash flow analysis was advocated as no additional infrastructure development was to be considered as happening before 10 to 15 years after the inception of a scheme. In a visionary recommendation, it was recommended that energy assessments should also be considered alongside hydraulic design.

Many of these problems and issues are still apparent today when attempting to determine the added values from the provision of effective surface water drainage, be it from sewered or SuDS measures.

3 IDENTIFYING THE BENEFITS OF SUDS

In many countries there is a desire to try to better account for the multiple values of managing surface water. Components of the natural environment in cities providing ecosystem services (ES) (see Section 3.1.3) in addition to social and other services are considered in an Australian context by CWSC (2013). The various aspects of economic incentives for stormwater control in the USA are dealt with comprehensively in Thurston (2012) who also considers various models for costing LIDs and benefits framed mainly around runoff quality control. Examples, from 13 case studies that have identified a wide range of benefits from the use of GI/SuDS in the USA are given in USEPA (2013). Each of these many examples from around the world use a diverse range of approaches to estimate benefits and although ES benefits have been standardised to some extent worldwide (Section 3.1.3), there are no internationally or nationally agreed methods or tools for estimating the wider benefits of SuDS[8]. Studies are still pilots, demonstrations and 'one-offs', such as for MayesBrook Park in London (Everard, 2011).

Being comprehensive and equitable about benefits and costs is now seen to be important in the planning of many current developments. In a number of ways GI based SuDS rely on ES as much as helping to provide the main functions of surface water management. Although SuDS have been traditionally devised to deliver water quantity, quality and also amenity benefits (CIRIA, 2007), the latter has been poorly defined up until now (e.g. Fowler, 2012). In England the first of these functions is currently considered to be the most important, whereas in Scotland water quality aspects are also deemed to be important (e.g. Duffy et al, 2011; Duffy et al, 2013).

Amenity value is recognised especially for vegetated SuDS measures, such as swales and wetlands. However, it is normally only considered as an additional benefit of secondary importance when selecting SuDS to manage surface water quantity and even quality (Digman et al, 2012).

In the UK there is a strong vision originally set out in the Natural Environment White Paper (HM Government, 2011) regarding green infrastructure and more specifically natural capital. The definition of natural capital is given in Box 3.1 and as well as being seen in relation to the natural environment, also encompasses economic growth and green jobs.

When considering SuDS, their potential to contribute to natural capital, together with at the same time, economic development, is seen as extremely important especially in urban areas. As yet the UK Government has not developed the framework as to how best to assess this (Natural Capital Committee, 2013).

Balancing needs between built (human) capital and natural capital is not straightforward, and traditionally humans have preferred the former, especially for flood management. This has been increasingly questioned and now the use of natural capital such as upland wetlands to manage downstream urban flooding is being seen as providing multiple benefits (e.g. Eftec, 2010; van den Belt et al, 2013; Zevenbergen et al, 2013). van den Belt et al (2013) used a systems model to look at

[8] SuDS here are taken to mean the diverse range of systems used to manage surface water (Fletcher et al, 2013).

the added benefits of restoring wetlands in a catchment in New Zealand instead of adding to structural flood defences and found that the avoided costs for one flood event alone were some NZ$5.2m as part of a broader range of overall benefits. The ‘investment trap’ was highlighted whereby the building of more flood defences leads to more urban development, which in turn leads to the need for yet more defences. Investing in natural capital instead can break this cycle, although it may lead to the loss of productive land (e.g. Eftec, 2010). It can also be done in stages, a key element of adaptation.

Box 3.1 Natural Capital (Natural Capital Committee, 2013).

“Natural capital‟ refers to those elements of nature which either directly provide benefits or underpin human wellbeing. In this way, natural capital generates value for people. However, the ubiquitous nature of the relationship between the natural environment and human wellbeing means that the definition of natural capital is necessarily wide and includes many different types of assets. The term natural capital therefore embraces the more immediately obvious assets associated with land (such as woodlands, fields, urban parks and subsoil assets), the water environment (for example, rivers, lakes, groundwater and seas) and the atmosphere (for example, clean air, and an equable climate). However, natural capital also includes the myriad processes which underpin and generate the services which the natural environment provides (for example, the water cycle, soil fertility processes and atmospheric gas exchange). Therefore, natural capital comprises, quite literally, a wealth of component parts; parts whose sum underpins not only all economic activity but life on earth itself. If properly measured and managed, the living aspects of natural capital, at least, can continue to provide these (ecosystem) services and benefits indefinitely. The problem is that whilst some of the benefits can be measured and are clear to see (for example, timber has a market price), most are difficult to quantify and are often invisible in our day to day lives. This results in natural capital not being properly accounted for in decisions about what to produce and consume; the risk being that we fail to manage it sustainably.”

3.1 SuDS benefits

It is becoming increasingly difficult to separate the value and benefits of managing water in an urban environment into neat and unique categories or criteria. This is because of the interactions between water and the wider urban environment as illustrated in Figure 3.1 (CIRIA, 2013). It shows WSUD as part of the place making, urban design, productive landscapes and urban planning processes. Although shown centrally in the Figure, water is not and can never be at the heart of urban development processes, but rather a key component of the essential systems and services in urban areas. SuDS, as shown in Section 2.1.1 are but one component of managing the urban domain and WSUD.

Figure 3.1 The linkages between the three streams of the urban water cycle, brought together in an integrated way that forms the WSUD process (CIRIA, 2013)

SuDS are therefore one part of any wider urban development or regeneration programme. Hence distinguishing between what values and benefits can be brought by an individual or train of SuDS and what benefits accrue from other urban systems, is often difficult. For this reason many assessments of the added value benefits of SuDS are criticised for 'double-counting' or providing only 'benefit displacements'. For example, a benefit is already being provided by a green space, only for the green space to be replaced by a SuDS measure which simply 'takes-over' the benefits that were already being provided without adding any additional benefits (GINW, 2011).

Despite these challenges, estimating the wider benefit value of using SuDS is important. Without this, many SuDS could in certain cases appear financially unattractive when compared with traditional below-ground piped drainage systems (Digman et al, 2012). Although in the USA, green SuDS are invariably cheaper than grey infrastructure (USEPA, 2013). Considering the benefits that SuDS can bring in the context of the wider aspects of urban planning and urban design, place making and liveability provides the basis for their considerable added-value over and above managing surface water quantity and quality.

The benefits can be considered in terms of:

1. Direct economic value – e.g. increased land value due to flood reduction; more productive fisheries etc. because of pollution control (e.g. Penning-Rowsell et al, 2005)
2. Added aesthetic and amenity value via e.g. additional green infrastructure (e.g. Natural England, 2009)
3. Added environmental or ecosystem value due to less stress on environmental systems or the creation of new biodiversity in urban areas – many of these benefits relate to ecosystem services (Sukhdev et al, 2010)
4. Social benefits which tend to be diverse and less easily quantifiable, but attempts such as Social Return on Investment have been made (SROI, 2012)

These benefit categories are not mutually exclusive and they both overlap and reinforce one another. Over-arching benefits can be considered in terms of adding to sustainability; which includes community resilience, liveability and balancing human needs with environmental. As regards resilience, there is a new duty regarding asset resilience in the water industry in England and Wales, now considered in terms of PR14 by Conroy et al (2013). Given their fundamental resilience capabilities, SuDS may provide an opportunity for the water companies in England and Wales to help deliver this duty.

Many SuDS are also referred to as green infrastructure (GI) (Section 3.1.2). The known benefits from greening and GI will often add considerable value to the SuDS option through environmental and social benefits over and above what underground drainage systems can provide (e.g. Ellis, 2013). There may also be additional benefits, apart from water quantity and quality, arising from other SuDS measures or schemes that are structurally based and do not use green measures. Table 3.1 lists the green and other SuDS options. Grey entries indicate SuDS which would not or frequently do not, have the opportunity to be/create a green space, or have only limited potential for this.

Table 3.1 SuDS and green measures (adapted from Ashley et al, 2011)

Component	Description	Opportunities for using green areas
Water butts, drainage layout and property house-keeping	• Stormwater management at property level and the immediate curtilage. • Source control to promote avoidance of adding waste, chemicals etc.to surface water runoff (pollution prevention)	• To direct excess water on to garden areas, store for irrigation and other uses. Can maintain lawns, horticulture and be used for e.g. indoor plant watering • Increasing proportion of permeable surfaces
Rainwater harvesting	Direct collection other than the above for toilet flushing or other purposes	May detract from green areas if used for purposes other than irrigation
Green roofs	Variety of options – may promote growth of plants (e.g. Castleton et al, 2010)	Roof surface demonstrably green, or with vegetation and suitable substrate depth. Water retention on roof may influence other water uses as above.
Filter drains	• Linear drains/trenches filled with permeable material. • Remove pollutants.	Infiltrates runoff but may be an opportunity to plant trees or shrubs on the surface.
Filter strips	Vegetated strips of sloping ground taking runoff away from paved areas and filtering solids	Usually comprises grassed surfaces and as gently sloping can be considered to be useful green areas, although solids capture may

Component	Description	Opportunities for using green areas
		result in muddy areas
Swales	Shallow vegetated channels that convey or retain runoff and may infiltrate. Also filters solids in vegetation.	As filter strips and filter drains above and may include shrubs
Ponds or retention areas	Usually contain standing water but have bankside and marginal vegetation. Remove pollutants by settlement.	A key green component with attractive marginal and bankside areas. Aquatic ecology is the most significant.
Wetlands	As ponds, but with shallow standing water and different types of vegetation. Remove pollutants by a range of mechanisms.	Also a key component, but wetlands are less common in urban areas due to the land take requirements although recent designs mean these can be used at much smaller size than in the past. When established they are the most rich SuDS for biodiversity.
Detention basin	A combination of the two above, may have permanent but very shallow water as for wetlands, or may be dry until it rains. Usually retains some solids.	Also a key component that may be more readily installed than the above in recreational areas or other grassed areas not normally used during rainfall and supporting biodiversity.
Soakaways	Sub-surface structures that store and infiltrate runoff. Remove pollutants.	Useful in greening terms only for maintaining soil moisture, although it may be possible to plant bushes and shrubs on the surface. More commonly comprise gravelled surfaces that may have limited aesthetic value (e.g. Japanese Garden)
Infiltration trenches	As filter drains but wider and allows infiltration through the trench sides	Infiltrates runoff but may be an opportunity to plant trees or shrubs on the surface such as willow coppices. But may be as above.
Infiltration basins	As for detention basins but stored runoff can also infiltrate	A key component that may be more readily installed than some of the above, but not in recreational areas or other grassed areas and not normally used during rainfall unless the permeability is high.
Permeable surfaces	As for infiltration systems but with porous paving. Remove pollutants, retaining them in upper soil layers.	Some porous paving has openings (e.g. concrete lattice) that allow grass to grow creating a green area that is usually visually attractive. Otherwise as for soakaways. An added value is that these surfaces are better at managing frost coverage at low temperatures
Bioretention areas (including rain gardens)	Vegetated areas that collect and temporarily store runoff with the express purpose of treating it.	May be amenable to high quality planting. Typically very good at removing solids, nutrients and metals from runoff
Sand filters	Treatment devices (usually proprietary) for removing pollutants from runoff	Not normally green as often located below ground. However, some sand filters do have surface foliage.
Silt removal devices	As above, although may be in the inlets to ponds and basins	Where located with ponds and basins may be amenable to planting, although frequent de-sludging may damage planting. Otherwise as above.
Trench-troughs (also known as WADIs in the Netherlands)	A combination of infiltration trenches and under-drained conveyance swales used where infiltration capacity is low	Can be valuable means of adding green into an area where infiltration capacity is low as surfaces are usually grassed.

3.1.1 Sustainability, place making, liveability and surface water management

Concepts for urban environments and ways of living, densifying (urban compaction) or not, all influence the long-term survival of cities. Sustainability is about the long-term survival, whereas liveability is about the here and now and the quality of urban environments as experienced by citizens (de Chazal, 2010; Johnstone et al, 2012). Despite more people living in urban areas, expectations about the quality of those areas are high in Europe and place-making agendas are aimed at making urban areas as pleasant as possible (e.g. Digman et al, 2012; GreenSpace Scotland, 2013). The drive to densify urban areas on sustainability grounds; 'the new urbanism' is misguided where water, energy and land use are concerned as shown in the Engineering and Physical Sciences Research Council (EPSRC) funded SOLUTIONS project[9] when considering the South East of England (Echenique et al, 2013). This has significance for using SuDS as options are more limited in compact developments when compared with less dense developments (Kellagher & Lauchlan, 2006).

On a large scale the EU has a Blueprint to Safeguard Europe's Water which is aimed primarily at water resources[10]. This has established that most citizens understand issues around water but that the delivery of EU policies related to water is far from certain (van Leeuwen et al, 2012). The inter-relationship between green urban areas and the water cycle in Europe is increasingly being recognised as important, not only for biodiversity, but for quality of life and the opportunity to use water and green infrastructure synergistically (EC, 2011). The Green City index[11] has defined a number of criteria that contextualise how green or otherwise a city will be. These include: governance; the need to take a holistic approach; the importance of wealth; civic engagement; technology; having a green and brown agenda; and dealing with informal settlements. This interpretation of how cities may increase their 'sustainability', becoming attractive and to some extent self-sustaining shows how city planning and functioning have to be seen to operate hand in hand. Such visions are key elements in the task of ensuring sustainability, whatever it may mean.

Despite being contested, the concept of sustainability is still used widely. Recently there have been proposals to link it to wealth (e.g. Arrow et al. 2012; 2013). These claim the "wealth measure is unusually comprehensive, capturing not only reproducible and human capital but also natural capital, health improvements and technological change." It is considered in relation to wellbeing of the current and also future generations (e.g. Self & Randall, 2013).

The National Planning Policy Framework (NPPF) for England (DCLG, 2012) utilises some of these ideas and has sustainable development clearly defined:

"So sustainable development is about positive growth – making economic, environmental and social progress for this and future generations…pursuing sustainable development involves seeking positive improvements in the quality of the built, natural and historic environment, as well as in people's quality of life..

[9] http://www.suburbansolutions.ac.uk/ accessed 01-08-13
[10] WISE: http://ec.europa.eu/environment/water/blueprint/index_en.htm accessed 01-08-13
[11] http://www.siemens.com/entry/cc/en/greencityindex.htm accessed 01-08-13

> *…so that it is clear that development which is sustainable can be approved without delay".*

Given that globally there is no consensus as to how to define development that is sustainable, nor what the term means, nor how to achieve development that is sustainable, this aspiration is naïve and may be unhelpful. Such locally defined versions of 'sustainable development' are being used especially in urban planning processes, despite their lack of clarity and definition. Although often misleading, they can nevertheless be helpful in narratives between the professionals involved in surface water management despite the uncertain nature of the concept (Cettner et al, 2013).

In the private sector there are a number of on-going initiatives relating to 'sustainable' business processes (e.g. Baxter, 2012; Grantham Research Institute et al, 2012) and Corporate Social Responsibility (CSR) (Lindgreen & Swaen, 2010) that may provide a platform on which to engage enterprises in any business case for using SuDS and the derived benefits therefrom. Given the reduction in size / expenditure of the public sector, private enterprise interest in sustainable development as a marketing tool may well be valuable. Significantly, many call for the identification of "further co-benefits" and "social externalities that private providers will not take on board" (Grantham Research Institute et al, 2012).

Wellbeing is increasingly being used to define how people feel about their lives. For example the Natural Capital Committee (2013) define it as: "the degree of happiness, health and prosperity of an individual or society". The concept of wellbeing now and for future generations is used as a sustainability measure by Arrow et al (2012) in relation to wealth.

Like 'sustainability', the term 'liveability' describes an essentially contested concept (Gallie, 1956) in that it signifies some valued achievement that is internally complex, variously describable and modifiable in the light of changing circumstances which cannot be prescribed or predicted in advance; i.e. liveability is dependent on the viewpoint of the person describing it at a given point in time. Adamowicz and Johnstone (2011) & Johnstone et al, (2012) describe liveability as: 'how well the needs of a community are met' and mix the definition with 'quality of life' (e.g. Fujiwara & Campbell, 2011).

The CRC for water sensitive cities has taken a societal needs approach to liveability (Johnstone et al, 2012): "Humans require that their basic needs be satisfied in order to ensure their continued survival from both the physiological (the needs of the body: breathing, food, water) and security stances (the basic need for a perception of safety: of the body, health security and the continuity of necessary resources). In addition, humans also have 'wants' that are thought to enhance their quality of life." Hence in determining the liveability of a city, the citizens needs and wants need to be considered. The needs and wants beyond what is necessary for survival are a reflection of the values and ambitions of the community; i.e. "a liveable city should be one that meets the needs and wants of its present inhabitants without compromising the ability of its' future inhabitants to meet their needs." (ibid).

It can be considered that while sustainability describes the ever-changing process of maintaining functioning environmental and human systems across generations, liveability is concerned more with present circumstances, i.e. the 'now' of the wellbeing continuum of Arrow et al (2012). In the definition of liveability above from the Australian CRC, it uses very narrowly defined boundaries: the 'inhabitants' i.e., it seems not to include those who may use but not inhabit the city; and the wider rural, environmental and urban context within which the city operates and relies upon to function.

From their definitions above, Johnstone et al (2012) develop a vision as to how urban water systems can meet aspects of societal needs using the tripartite E.R.G. 'needs' theory of Alderfer (1969). This is shown adapted in Table 3.2 to include the potential contribution of SuDS in contributing to this vision of liveability.

Table 3.2 urban water societal needs and the contribution that SuDS can provide (adapted from Johnstone et al, 2012)

Needs category		Urban water societal need	Description	SuDS potential Contribution
Existence	Physical and material needs	Potable water	Safe, secure supply of water for consumption	Harvesting from source or storage units; replenishing groundwater
		Non-potable water	As above for all other purposes	As above, but lower levels of treatment
		Public health	Protection from contaminated water, controlled microclimates, public places promoting physical and mental health	Water quality improvements; greening and heat reduction; parks and green infrastructure benefits
		Public safety	Protection of people from hazards such as flooding	A primary function of all SuDS; GI SuDS also reduce crime levels.
		Property protection	As above for property	As above
		Economic activity	Industries and jobs that rely on water and related services	GI SuDS create and sustain jobs, tourism etc.; source controls make water available near places of need
Relatedness	Social interaction and inter-personal relationships	Recreation	Places for play, sport and leisure	Many SuDS provide green or blue areas that facilitate these activities
		Social cohesion	Safe and secure places for social interaction and human connectedness with people and nature	Local and or source control SuDS especially can be community managed; GI SuDS can connect people with ecosystems
	Societal environmental inter-relationships	Beauty	Aesthetic urban environments	GI & blue SuDS are aesthetically attractive
		Comfort	Pleasant micro-climate and landscape for thermal comfort	GI and blue SuDS reduce urban heat and also absorb greenhouse gases
		Ecological health	Clean and healthy ecosystems with no negative impact on other	GI and blue SuDS create new ecosystems and sustain these; by providing treatment

Needs category		Urban water societal need	Description	SuDS potential Contribution
			ecosystems	pollutants are managed
Growth	Societal self-esteem and self-actualisation	Identity	Harmony with culture and tradition; belonging. Proud association with urban water systems	Not an attribute typically found in the UK other than for industrial or commercial developments.
		Purpose and ambition	Progress towards a shared vision of a water sensitive future	Not a significant consideration or development for the majority of the UK, although Scotland has Hydro-Nation aspirations
		Control and independence	Choice and influence on decision-making about water infrastructure and services	The WFD is bringing a new approach in this regard for communities and in England the new outcome focus for the WaSCs appears to put more emphasis on communities (customers)
		Equity and social justice	Equal opportunities to access the benefits of urban water systems	GI and blue SuDS, where on public land provide this
		Intergenerational equity	Preserve the ability of future generations to meet their water needs	SuDS are more flexible and adaptable to future changes and can therefore be modified easily if needed.

Howley et al. (2009) demonstrate that while a developer may perceive that they have created an environment within the principles of sustainability, the experience of living in that environment may test that claim. Individual values and underlying contextual attributes can constrain or support change (de Chazal, 2010). Thus what is more sustainable or contributing more to liveability in terms of water management is 'in the eye of the beholder', and is often where conflicts lie in practice, especially between competing 'insiders' and 'outsiders'[12]. Despite, this, liveability is growing in use for defining the nature of urban environments in particular and has been used to consider the place of water systems and how best to exploit their value within the interconnected network of urban systems and services (de Haan et al, *in press*).

In summary, the concepts of sustainability, wellbeing and liveability are all potentially useful for evaluating the benefits and values from SuDS measures.

3.1.2 Green Infrastructure

Many planners and others call for an increase in green spaces in Cities and the EU express the view that GI enhances Europe's natural capital (EC, 2013a). However,

[12] These terms are referenced in the transitions to sustainability literature and 'insiders' are those who define, use and practice particular ways of doing things, such as the professionals bringing SuDS into use or those resisting the change to SuDS. Whereas 'outsiders' are those who are not a party to these changes as they are not a part of the governance, institutional, professional domains of practice communities. Outsiders may generally hold uninformed views or hold views contrary to the incumbents who control the normal practice domain. Therefore proponents of SuDS are in certain contexts, 'outsiders'; and in others – where change in practice is happening they are 'insiders'.

many GI proponents fail to connect the need for irrigation of these green areas (eg. Natural England et al (2013). This is especially notable in the succession of reports and documents related to green spaces in London over the last few years (the most recent is BOP, 2013). Few if any mention SuDS and invariably the need for irrigation water is ignored and where the water source will come from. If it is to come from potable mains water supply it will lead to even greater water stress in parts of the UK.

Green, grassed or planted surface areas are not necessarily classifiable as green infrastructure (GI) and the concept is contested in planning terms (Wright, 2011; Mell, 2013). Nevertheless GI has a classical definition. For example, BOP (2013) in reviewing the benefits of green spaces in the City of London, concentrates on the green spaces and is parsimonious in the use of the term GI; this could be because green infrastructure *planning* is about the enhancement of green resources (Mell, 2013). Nevertheless, green spaces are seen as providing significant value to the lives of Londoners through a range of benefits. Wright (2011) and Mell (2012) argue that the ambiguity between GI and GI planning is significant in both delivery of new resource terms and also in attempts to evaluate the added value benefits in the UK. This potential disparity in perspective also causes practical difficulties and illustrates how the perspective on GI and related aspects like SuDS can vary depending on the stakeholder. Future reconciliation of such ambiguities and different framings of perspective will be required if the most is to be made of GI opportunities in urban areas.

In terms of benefits from GI and frameworks for assessment, these without exception adopt a 'GI perspective'. This means that frequently water, drainage or SuDS are not considered other than in a minor way as the planning of GI is considered to be the driver for these (e.g. Natural England et al, 2013). Conversely, SuDS, water and drainage benefits appraisal frameworks often fail to consider the value of GI fully. Even the GI frameworks are considered deficient in regard to involving the wider community and organisations beyond the lead local authority; allowing them to shape the places in which they live and identifying the best type and mix of green infrastructure for 'maximum performance' (ibid).

The benefit potential from GI is examined below, following a description of GI. CIRIA project RP944 demonstrates the delivery of biodiversity benefits using GI and how this can be linked to and maximised in construction and new developments (Dale et al, 2011) as does BS42020: 2013. The former includes reference to adding value and economic benefits, although it is very limited in how it addresses SuDS.

The term 'green infrastructure' (GI) emerged in the USA in the 1990s (e.g. Walmsley, 1995) and is a concept that has been developed independently of its' uses for managing stormwater. Benedict & McMahon (2006) are cited as the primary originators of GI. For them, GI is both a concept and a process. The GI concept influences urban planning and layouts to maximise the inclusion of green space hubs and corridors, but the GI process also attempts to maximise the benefits of such green spaces, identifying their potential change in ecosystem services (Center for Neighborhood Technology, 2010).

The complexity of the urban area and the structure of the green space, its temporal dynamics, constraints on ecosystem flows (Section 3.1.3), large numbers of land managers, conflicting goals, differences in perceptions and frames of the many players compared with reality mean that managing GI and ecosystem services is a ‘wicked’ problem (Gaston et al, 2013), ie. there is no ‘right’ approach, but many options and schemes that might deliver the best outcomes. SuDS are but one potential part of this wider complexity, as ES and GI are but small parts of the entirety that is the flow of services, utilities and living organisms in urban areas.

Among the services provided by GI is its’ potential usage to assist stormwater management. This was realised by the US Environmental Protection Agency (USEPA) (2012) and others and now the term is often used interchangeably with BMPs and LID, when referring to the management of stormwater and combined sewer overflows (Struck et al, 2010) (Section 2.1.1). In the USA the green infrastructure approach has recently been endorsed at the highest level: “the White House is placing a higher priority on stormwater and the establishment of green infrastructure to address it…” (Brzowozki, 2012).

Green Infrastructure (GI) is defined variously in the US stormwater management literature as: *“a network of decentralized stormwater management practices, such as green roofs, trees, rain gardens and permeable pavement, that can capture and infiltrate rain where it falls, thus reducing stormwater runoff and improving the health of surrounding waterways”* and is now *“more often related to environmental or sustainability goals that cities are trying to achieve through a mix of natural approaches”* (Foster et al., 2011). In Seattle, ‘GSI’ ‘Green Stormwater Infrastructure’ is the term used in design codes which specify its use to the ‘maximum extent feasible’ (MEF) – which means GI is to be fully implemented, constrained by the opportunities and physical limitations of the site, practical considerations of engineering design, and reasonable considerations of financial costs and environmental impacts (Tackett, 2008).

The term GI is increasingly being used in the stormwater literature in a way that is almost synonymous with LID, as exemplified by the small number of papers at the 2008 LID conference in Seattle compared with the use of GI as a stormwater management term at the 2010 LID conference in San Francisco. Now: “Green infrastructure is an approach that communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities. Unlike single-purpose grey stormwater infrastructure, which uses pipes to dispose of rainwater, green infrastructure uses vegetation and soil to manage rainwater where it falls. By weaving natural processes into the built environment, green infrastructure provides not only stormwater management, but also flood mitigation, air quality management, and much more” (USEPA, 2012). This overlap perhaps shows the degree of “reinvention of the wheel” that occurs within disciplines, in order to generate interest and engage stakeholders.

There are numerous GI initiatives in the UK mainly from environmental based groups such as Natural England (2009) (e.g. Eftec et al, 2013). Few consider surface water as anything other than a means to irrigate the GI or ignore the place of water completely in the ‘planning with nature’ process (e.g. RSPB et al, 2013). Although professional bodies such as the Landscape Institute (2013), CIWEM (2010) and Royal Town Planning Institute (RTPI) (2013) take a more coherent view on the potential of GI as synergistic with surface water management. A national 'Green Infrastructure Partnership'[13] has been coordinating understanding and the further development for potential uptake of GI in England. Recently the EU issued a consultation document request (EC, 2013a) on the place of GI in enhancing Europe's natural capital. This defines the components of GI in these terms:

- **Physical Building Blocks**: the network of green spaces in which and through which natural functions and processes are sustained.
- **Projects**: interventions designed to conserve, improve or restore nature, natural functions and processes to secure multiple ecosystem services for human society.
- **Planning**: Integrating the conservation, improvement and restoration of nature, natural functions and processes into spatial planning and territorial development and sustainably delivering the associated benefits for human society.
- **Tools**: Methodologies and techniques that help us understand the value of the benefits nature provides to human society and mobilise the investments necessary to sustain and enhance those benefits.

EC (2013a) also provides an overview of GI benefits, as indicated Table 3.3, together with examples of costs and benefits from GI projects around the EU. Notable by its absence in Table 3.3 is the potential for GI to provide stormwater drainage functions. The potential is shown in Table 3.3 and in Table 3.4 from Ashley et al (2011).

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Table 3.3 Key Benefits of GI (EC, 2013a)

Benefits group	Specific Green Infrastructure benefits
Enhanced efficiency of natural resources	Maintenance of soil fertility
	Biological control
	Pollination
	Storage of freshwater resources
Climate change mitigation and adaptation	Carbon storage and sequestration
	Temperature control
	Storm damage control
Disaster prevention	Erosion control
	Reduction of the risk of forest fires
	Flood hazard reduction
Water management	Regulation of water flows
	Water purification
	Water provisioning
Land and soil management	Reduction of soil erosion
	Maintaining/enhancing soil's organic matter
	Increasing soil fertility and productivity
	Mitigating land take, fragmentation and soil sealing
	Improving land quality and making land more attractive
	Higher property values
Conservation benefits	Existence value of habitat, species and genetic diversity
	Bequest and altruist value of habitat, species and genetic diversity for future generations
Agriculture and forestry	Multifunctional resilient agriculture and forestry
	Enhancing pollination
	Enhancing pest control
Low-carbon transport and energy	Better integrated, less fragmented transport solutions
	Innovative energy solutions
Investment and employment	Better image
	More investment
	More employment
	Labour productivity
Health and well-being	Air quality and noise regulation
	Accessibility for exercise and amenity
	Better health and social conditions
Tourism and recreation	Destinations made more attractive
	Range and capacity of recreational opportunities
Education	Teaching resource and 'natural laboratory'
Resilience	Resilience of ecosystem services

Table 3.4 potential stormwater benefits related to using GI (adapted from Wise et al, 2010)

GI Measures	Benefits from GI
Urban trees	Stormwater detention
	Reduced energy for heating or cooling in urban areas
	Reduced health impacts from extreme heat events
	Air quality improvements in urban area
	CO_2 reductions (both avoided and sequestered)
Permeable pavements (Seen as part of GI in the USA)	Increased stormwater retention
	Reduced energy use, air pollution and greenhouse gas emissions
	Reduced ground conductivity (urban heat island and use of salting in winter)
	Reduced air pollution
	Reduced noise pollution
Water harvesting	Reduced potable water use
	Increasing available water supply
	Improved biodiversity
	Public education
Green roofs	Storm water retention
	Reduced building energy use
	Carbon sequestration
	Greenhouse gas emission reduction
	Urban heat island mitigation
	Improved air quality
	Noise reduction
	Biodiversity and habitat
	Longer roof life
Other infiltration practices including rain gardens, bioswales, constructed wetlands	Stormwater retention and pollutant removal and many of the other benefits above
Other general benefits from GI	Increased property values
	Recreation space value
	Avoided conventional infrastructure costs
	Reduced wastewater treatment costs
	Reduced flood risk damage
	Increased groundwater recharge
	Societal benefits such as crime reduction

There are a number of EU commissioned reports covering many examples of the multiple benefits of using GI (e.g. IEEP, 2011; Ecologic, 2011), most of which are linked to ecosystem services (Section 3.1.3). DG Environment (2012) has produced a summary document dealing with the multifunctional value of GI, suggesting the use of a Total Economic Value (TEV) approach.

Box 3.2 shows a case example of retrofitting SuDS in Augustenborg, Malmo in Sweden where GI was linked with SuDS to enhance the quality of a socially deprived neighbourhood (Stahre, 2008) and an extract from DG Environment (2012) related to the reduced use of grey infrastructure via GI.

Box 3.2 DG Environment (2012)

Retrofitting SuDS in Augustenborg – costs and benefits

Augustenborg was the target of this project after having experienced socio-economic decline and floods from overflowing drainage. The key aim of the initiative was to create a more sustainable neighbourhood by focusing on combating flooding, waste management and enhancing biodiversity. A system was created to collect rainwater from rooftops and other impervious surfaces and channel it through canals, ditches, ponds and wetlands before finally draining into a traditional closed sub-surface storm water system or SUDS. Biodiversity was addressed through the creation of new wetland habitats.

Table 2: Estimated Costs from 1998 (Naumann *et al.*, 2011b)

One off costs	Project planning	€666,000
	Investment in infrastructure (pumping station and stormwater pipes)	€1,900,000
Recurrent costs	Maintenance	€17,000 per year for 14 years: €238,000
OVERALL TOTAL COSTS		**€2,804,000**

No opportunity costs related to foregone land use were reported but there may have been foregone recreational uses in terms of large open fields used for sports that were to be used for retention ponds.

Identified benefits (Naumann *et al.*, 2011b)

- Improved water regulation and surface runoff and protection from flooding
- Improved water quality
- Reduced carbon emissions
- Reduced pluvial and sewer risk
- Aquifer recharge (relieving stress in water scarce areas)
- Enhancement of urban spaces
- Increased biodiversity
- Increased aesthetic and amenity values of landscape and increased eco-tourism

Less grey infrastructure – more funding

"The strategic placement of GI reduces the need for grey infrastructure and the community's susceptibility to floods, fires, and other natural disasters. Prime examples are green roofs, which not only reduce the need for expensive water treatment facilities but also improve energy efficiency. By saving on the installation of grey infrastructure there is a freeing up of funds for other community needs, which in turn helps to improve its economic state. As Benedict & McMahon (2002) point out, this can create a healthy cycle in that initially we need to actively promote GI systems to free up funding, but this can then be used to build further GI which in turn releases further funding. As such the funding cycle should hopefully sustain itself. GI can also contribute to the economy through mitigating impacts of flooding and other natural disasters."

Box 3.2 illustrates a list of perceived benefits related to water and liveability from the SuDS scheme, but without any attempt to quantify all of these. However, according to EC (2013a) in Augustenborg, "Rainwater run-off rates have decreased by half. The image of the area has improved. Biodiversity has increased by 50% (green roofs have attracted birds and insects and an open stormwater system provides a better environment for the local plants and wildlife). The impact on the environment has decreased by 20%. Unemployment has fallen from 30% to 6%. The turnover of tenancies has also decreased by 50%."

A case example from Nijmegen in the Netherlands is also quoted: *"Comparing reference scenario with grey scenario (paved area) and Green Infrastructure scenario (whole area planted with trees). Capital and maintenance costs of different options. Estimation of the health impacts of particulate matter and NOx, noise impacts, flooding impacts, water treatment costs, enjoyment of the environment, recreation, climate regulation, reduced energy costs due to wind shelter effects, impacts on travel time, carbon sequestration. Net present values: loss of €275m for the grey scenario, with a gain of €230m for the Green Infrastructure scenario."*

In the USA, the emphasis is on GI rather than Ecosystem Services in considering the multiple benefit values of methods for stormwater management. Stormwater management in the USA has been successfully transformed in some areas in part by the ability to 'sell' these benefits of innovation from grey to green to practitioners. The 'triple bottom line' of economy, environment and society is acknowledged but is defined in monetary terms for the value of 'green infrastructure' and is becoming the norm (e.g. American Rivers et al, 2012; Foster et al, 2011; Thurston, 2012; USEPA, 2012). For example the City of Cuyoga Falls, Ohio USA where four flood-damaged properties have been demolished and a GI flood storage area created in their place that has multi-functional value as a park as illustrated in Figure 3.2[14].

Figure 3.2 multifunctional park in Cuyoga Falls, USA

Other examples of the use of GI for stormwater management from around the world are given in Ashley et al (2011) and Digman et al (2012).

Table 3.5 shows the potential role of GI and surface water systems in helping adapt to climate change (Ashley et al, 2011).

[14] http://planning.co.cuyahoga.oh.us/infrastructure/pdf/raingarden.pdf accessed 01-08-13

Table 3.5 The potential role of GI in helping adapt urban areas to climate change (Ashley et al, 2011)

Water related phenomena	Adaptation needs	How and why GI can help
Flooding	Managing surface water runoff	Urban development results in faster runoff of surface water, and higher rates and volumes of runoff, because the capacity for local retention/infiltration is diminished. An increase in green areas (GI) to reduce the rate at which rainwater runs off and increasing infiltration can help to better manage intra-urban flood risk.
	Managing overland pathways	An option to better manage intra-urban flood risk is to direct peak flood flows along green links where the risk to infrastructure, buildings and people is minimal.
	Managing fluvial pathways	GI can provide water storage and retention areas, reducing and slowing down peak flows, and thereby helping to alleviate flooding from rivers and urban watercourses.
Droughts	Maintaining water quantity.	GI can provide a permeable surface which helps to sustain infiltration to aquifers, recharge groundwater and maintain base flow in rivers.
	Maintaining water quality.	GI catches sediment and can remove other pollutants from the surface water, thereby ensuring that water quality is maintained; this is especially important in the UK where the quality of water sources from uplands is deteriorating ostensibly due to a changing climate.
	Maintaining the source	GI can assist with the provision and management of healthy and biodiverse catchments as a whole; reducing the stress on flora and fauna.
Heat	Managing high temperatures	Urban areas are at increased risk of heat waves due to the urban heat island (UHI) effect. UHI arises because materials used in cities (asphalt, concrete, bricks) store heat and release it slowly during the night, keeping urban temperatures higher than rural temperatures. GI can counteract the heat island effect of cities by providing shading and/or cooling through evapo-transpiration.
	Providing recreation	GI provides recreation services, so that people can enjoy positive consequences of climate change like warmer summers.

In a desktop study looking at land use in Manchester, Gill et al (2007) found that increasing green spaces by 10% in urban residential areas can reduce runoff from these areas from a 28 mm total volume rainfall event by 4.9% (such an event is expected to occur in the 2080s under the High Emissions climate change Scenario given by UKCIP at the time) . Increasing the tree cover by 10% reduced the runoff by 5.7%.

The economic downturn has concentrated HM Governments' interest on economic growth. The place of GI in this has recently been assessed (Saraev, 2012; Eftec et al, 2013). The latter develop a list of economic benefit indicators arising from GI, including the ‘amount (of) absorbed or abstracted from conventional stormwater drainage system, heavy metal, oil and fertiliser pollution reduction from using GI for stormwater’.

Few references or studies have linked water (and even fewer drainage) management with GI and benefits, other than for main river flooding.

> *“While the potential of greenspace and woodland in particular to reduce stormwater run-off and reduce flood risk by slowing water flows is often acknowledged, economic estimates are scarce and tentative. The only study, at Pickering, that provides economic estimates of the benefits of woodlands for flood management and erosion reduction reports a present value for these over 100 years of about £180 000 for 85 ha of woodland created.”* (quoted in Saraev, 2012 from Nisbet et al, 2011).

These estimates also included the ecosystem services benefits (see Section 3.1.3).

Elsewhere in the world attempts have been made to directly value the water related benefits of GI. e.g. The Trust for Public Land in the USA published a series of reports between 2008 and 2011 where the value of parks has been assessed and the contribution of these parks to water uses was assessed. In one study, the annual value of the absorption of (54% of the 42 inches of rainfall) stormwater by the parks in Mecklenburg County was found to be some $19M (US) per year (The Trust for Public Land, 2010). In a study commissioned by American Rivers (2012), an in-depth review of US experiences demonstrates conclusively that synergies between SuDS for stormwater management and GI are likely to save costs and bring multiple benefits under virtually all conditions. This money saving conclusion is reinforced in a recent review of thirteen case studies (USEPA, 2013).

3.1.3 Ecosystem services

Some of the benefits discussed in 3.1.2 are more correctly derived from ecosystem service provision. Ecosystem Services (ES) provide support to humanity (help sustain) and in turn humanity needs to provide support to ensure that ecosystem services can themselves be sustained (e.g. Sukhdev et al, 2010). The development of ideas as to how best to value the functions, goods and services provided by ecosystems has accelerated recently, moving on from early classical texts (eg. de Groot et al, 2002 to Smith et al, 2013).

These approaches now allow much more detailed assessments of ecosystem related benefits derived by society of changing systems and services, such as water, to be made than has previously been possible and also to consider how best to support and provide these benefits expressed in transnationally agreed monetary and other terms (e.g. Everard, 2011; Bateman et al, 2010). Linking ES with monetary and other non-financial indicators has provided a means now to develop accounts that include the value of ES and also to encourage a formalised system of Payments for Ecosystem Services (PES) by beneficiaries of these services (Defra, 2013).

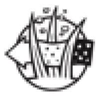
There are many environment related targets especially in European countries, such as for biodiversity (Defra, 2013a; BS 42020: 2013) and for water, in the over-arching Water Framework Directive (WFD) (Vlachopoulou et al, 2013). ES and GI are means of contributing to many of these, helping to offset failing trajectories as indicated for England in the latter report. For this to happen, however, a more consistent and coherent integration of the various threads of ES, GI and surface water management is required.

According to Mell (2013) SuDS and *"water resources should properly be considered as part of the broader management of Green Infrastructure resources as they provide ecological, economic and social benefits if planned and managed innovatively. The value of this process is in highlighting how engineered water management does not have to be viewed as standalone, but can be reconsidered as Green Infrastructure if the form of the infrastructure is modified. What we define as Green Infrastructure in terms of water management can thus be seen as variable or ambiguous, but by using the grey – green approach to assessments, this selectivity can be addressed."*

The following outline of ES is taken from Ashley et al (2012). The global Millennium Ecosystem Assessment (Bateman et al, 2010; Sukhdev, et al 2010) provided the means to take an ecosystem services approach, whereby the natural environment is seen as of financial value to humanity and in turn, can be affected by human behaviour, although the economic values themselves are understood to have no absolute meaning. They are most useful when considering marginal values of altered conditions (i.e. an improved condition compared with now) and whether these are likely to be significantly positive. This has provided for the first time a globally accepted approach to monetise many of the beneficial criteria and indicators relevant to an ES assessment, especially those related to the natural environment. Table 3.6 provides the principal categories and specification for the ecosystem services criteria taken from the *The Economics of Ecosystems and Biodiversity* (TEEB) Manual for Cities: Ecosystem Services in Urban Management (Sukhdev, et al 2010).

Table 3.6 Ecosystem categories and types

Ecosystem service	International icon	Service description
Provisioning services: Ecosystem services that describe the material or energy outputs from ecosystems that can be used to support human needs		
FOOD		Ecosystems provide the conditions for growing food. Food comes principally from managed agro-ecosystems, but marine and freshwater systems, forests and urban horticulture also provide food for human consumption
RAW MATERIALS		Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species
FRESH WATER		Ecosystems play a vital role in providing cities with drinking water, as they ensure the flow, storage and purification of water. Vegetation and forests influence the quantity of water available locally
MEDICINAL RESOURCES		Biodiverse ecosystems provide many plants used as traditional medicines as well as providing raw materials for the pharmaceutical industry. All ecosystems are a potential source of medicinal resources.

Ecosystem service	International icon	Service description
Regulating services: The services that ecosystems provide by regulating the quality of air and soil or providing flood and disease control, etc.		
LOCAL CLIMATE AND AIR QUALITY REGULATION		Trees and green space lower the temperature in cities whilst forests influence rainfall and water availability both locally and regionally. Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere
CARBON SEQUESTRATION AND STORAGE		Ecosystems regulate the global climate by storing greenhouse gases. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues; thus acting as carbon stores.
MODERATION OF EXTREME EVENTS		Ecosystems and living organisms create buffers against natural disasters, thereby preventing or reducing damage from extreme weather events or natural hazards including floods, storms, tsunamis, avalanches and landslides. For example, plants stabilize slopes, while coral reefs and mangroves help protect coastlines from storm damage
WASTEWATER TREATMENT		Ecosystems such as wetlands filter effluents. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced
EROSION PREVENTION AND MAINTENANCE OF SOIL FERTILITY		Soil erosion is a key factor in the process of land degradation, desertification and hydroelectric capacity. Vegetation cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and agriculture and well-functioning ecosystems supply soil with nutrients required to support plant growth
POLLINATION		Insects and wind pollinate plants, which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats
BIOLOGICAL CONTROL		Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls.
Habitat or Supporting services: These services underpin almost all other services but do not necessarily have direct economic worth. Ecosystems provide living spaces for plants or animals: they also maintain a diversity of plants and animals and support the other ecosystem services		
HABITATS FOR SPECIES		Habitats provide everything that an individual plant or animal needs to survive: food, water, and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle. Migratory species including birds, fish, mammals and insects all depend upon different ecosystems during their movements
MAINTENANCE OF GENETIC DIVERSITY		Genetic diversity (the variety of genes between, and within, species populations) distinguishes different breeds or races from each other, providing the basis for locally well-adapted

Ecosystem service	International icon	Service description
		cultivars and a gene pool for developing commercial crops and livestock. Some habitats have an exceptionally high number of species which makes them more genetically diverse than others and are known as 'biodiversity hotspots'
Cultural services: These include the non-material benefits people obtain from contact with ecosystems. They include aesthetic, spiritual and psychological benefits.		
RECREATION AND MENTAL AND PHYSICAL HEALTH		Walking and playing sports in green space is a good form of physical exercise and helps people to relax. The role that green space plays in maintaining mental and physical health is increasingly becoming recognized, despite difficulties of measurement
TOURISM		Ecosystems and biodiversity play an important role for many kinds of tourism, which in turn provides considerable economic benefits and is a vital source of income for many countries. In 2008 global earnings from tourism summed up to US$944 billion. Cultural and eco-tourism can also educate people about the importance of biological diversity
AESTHETIC APPRECIATION AND INSPIRATION FOR CULTURE, ART AND DESIGN		Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.
SPIRITUAL EXPERIENCE AND SENSE OF PLACE		In many parts of the world natural features such as specific forests, caves or mountains are considered sacred or have a religious meaning. Nature is a common element of all major religions and traditional knowledge, and associated customs are important for creating a sense of belonging

ES are shown in terms of their role in contributing to the 'sustainable management and protection of water' in tables in (Vlachopoulou et al, 2013). ES and related SuDS benefits have a significant potential contribution to WFD Article 1 (prevention and mitigation), Article 4 (surface, ground water and protected areas), Article 7 related to drinking water, Article 9 (cost recovery) as well as certain repealed but still relevant directives..

The monetary value of these services may be assessed using standardised national accounting estimates, agreed databases, local data or other methodologies. This should be added to the traditional value of any infrastructure investments; normally expressed in terms of benefit-cost ratios (Figure 3.3).

For a comprehensive assessment, discounted costs and benefits need to be included over a specified time horizon and accounting needs to be taken of future scenarios. Ideas about Payments for Ecosystem Services (PES) are evolving into accounting processes for buying and selling ES as outlined in Section 5.4.

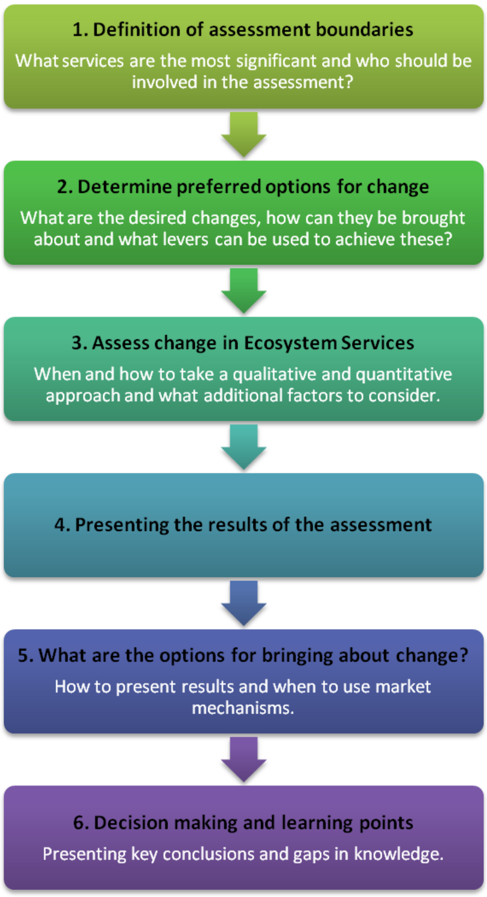


Figure 3.3 Using ecosystem services in the assessment process for valuation of benefits (Ashley et al, 2012)

Some attempts have been made to estimate the benefits to ES provided by using SuDS or their equivalent in a number of studies, although no credible UK studies so far exist (Lundy & Wade, 2011). In a US study, Moore & Hunt (2012) consider how SCMs (Stormwater Control Measures) comprising 20 constructed stormwater ponds and 20 constructed wetlands also provide ES benefits in a study in North Carolina. The study defined 'additional' ES categories of: carbon sequestration; biodiversity; and cultural services in the analysis. These categories are already included in standard lists and definitions of ES (Table 3.6) and another study related to SuDS in Manchester (Scholz & Uzomah, 2013) also claimed to have defined additional ES categories. Such studies only serve to confuse ES assessments as the defined standard lists of ES (Table 3.6) are comprehensive if interpreted appropriately.

An important conclusion from the US study was that neither of the SuDS investigated 'could entirely bridge the gap' between constructed and natural systems in terms of the provision of ES. The paper also suggested a number of design implications for SuDS when trying to maximise ES benefits. These included *inter alia*: ensuring that ponds have littoral edge areas; incorporating SuDS into otherwise green recreational areas.

Various studies have set out to establish a universal framework for how best to evaluate ES contributions from system changes. Virtually without exception such studies have been applied to rural or upland ecosystems and developments outside urban areas. Both quantitative and qualitative approaches are used despite the drive for monetisation of results (e.g. Busch et al, 2012) and each has a place in the analysis.

Manchester seems to have been the subject of many ES studies and also considered in various EU funded blue-green and flood risk management projects[15] all of which have considered the place of GI and ES. In a separate study Radford & James (2013) considered a rural-urban transect through the city and used a non-economic evaluation tool to show how ES deteriorate as urbanisation densifies. They call for a shift in priorities so that high value green space can be introduced into the most dense urban areas in the future.

The reality of trying to apply an ES approach to the water environment as opposed to the potential of ES, is illustrated in Table 3.7 taken from Lundy & Wade (2011). The need for data and information from a wide variety of sources and disciplines prompted the conclusion that there is a need for a transdisciplinary approach to be taken to this area of developing ideas. This is also borne out by the occurrence of ES relevant papers in journals from virtually all discipline areas (e.g. Gaston et al, 2013).

Table 3.7 potential for the restoration of the River Brent in London to contribute to ecosystem services

		Types of urban water component in Tokyngton Park					
		Channelized watercourse		Vegetated filters		Natural and restored watercourse	
Category of ecosystem service	Type of ecosystem service	Potential	Actual	Potential	Actual	Potential	Actual
Supporting	Primary production	✗	✗	✓	✓	✓	✓
	Oxygen production	✗	✗	✓	✓	✓	✓
	Soil formation	✗	✗	✗	✗	✓	✓
	Water cycle	✓	✓	✓	✓	✓	✓
	Habitat	✓	✓	✓	✓	✓	✓
Provisioning	Food	✓	✗	✗	✗	✓	✗
	Water	✓	✗	✗	✗	✓	✗
	Renewable energy	✓	✗	✗	✗	✓	✗
	Genetic resource	✓	✗	✓	✗	✓	✗
Regulating	Climate regulation.	✓	✓	✓	✓	✓	✓
	Water regulation	✓	✓	✓	✓	✓	✓
	Erosion control	✓	✓	✓	✓	✗	✗
	Water purification	✗	✗	✓	✓	✗	✗
Cultural	Spiritual value	✗	✗	✗	✗	✓	✓
	Educational value	✗	✗	✓	✗	✓	✗
	Aesthetics	✗	✗	✓	✓	✓	✓
	Recreation	✗	✗	✗	✗	✓	✓

In Table 3.7 the grey shaded cells had data to support their evaluation, whereas the data for all of the other cells was informed from literature sources. The 'potential' columns with ticks were identified as possibly likely to contribute to ES, whereas the 'actual' columns with ticks were those found to really be contributing to ES.

[15] e.g GRaBS: http://www.grabs-eu.org/; SmarTEST: http://www.floodresilience.eu/ both accessed 20-08-13

Table 3.7 demonstrates the complexity and difficulties of conceptualising and actually achieving and assessing ES.

There is by no means universal agreement about the accounting processes being applied to ecosystems. There are many different perspectives on ES, and in a review of academic sources in which the majority were found to have been published in landscape and urban planning journals, Hubaceck & Kronenburg, (2013) say:

> *"There has been some uneasiness with the economic dominance in the ecosystem service discourse when translating different qualities of services into one super-numeraire, i.e. translating every ecosystem service into monetary values. It is argued that lots of useful information is being lost, especially when dealing with tradeoffs amongst different services."*

> *"The uptake of the concept of ecosystem services in urban planning research could be one of the measures of the concept's success, but the adoption of this concept by urban planners would be even more important. Nevertheless, urban planners also have to be aware of the diversity of perspectives on ecosystem services and their value, and they have to take that diversity into account when making or facilitating relevant decisions. As a result, any decision that aims at managing urban ecosystem services needs to be based on a careful analysis and management of the different perspectives on the value of those services. As argued by Pincetl et al. (2012), such decisions "should be arrived at through public, transparent and democratic processes".*

From a layperson's perspective, Monbiot (2012) questioned the entire premise of "putting a value on the rivers and rain" and especially on the monetisation of ecosystems – shifting perspective from "values to value" will "cede the natural world to the (very) forces wrecking it". The main counter-argument to this is that, in any decision with impacts on ecosystem services, failing to account for and value these impacts lead to them implicitly being treated as having zero value, and therefore being ignored.

Recently reports on 'Common Cause for Nature Conservation' by Blackmore & Holmes (2013) and Blackmore et al (2013) point out the contradictions in values held by the UK's population when it comes to nature. They are also critical of linking nature conservation with business cases, claiming this to be counter-productive in the longer term. Figure 3.4 illustrates the 60 commonly held values across human cultures (Blackmore et al, 2013) within 'intrinsic' behaviours that "benefit the environment and society" and 'extrinsic' values that "make people more self-interested and reduce their willingness to act on behalf of the environment."

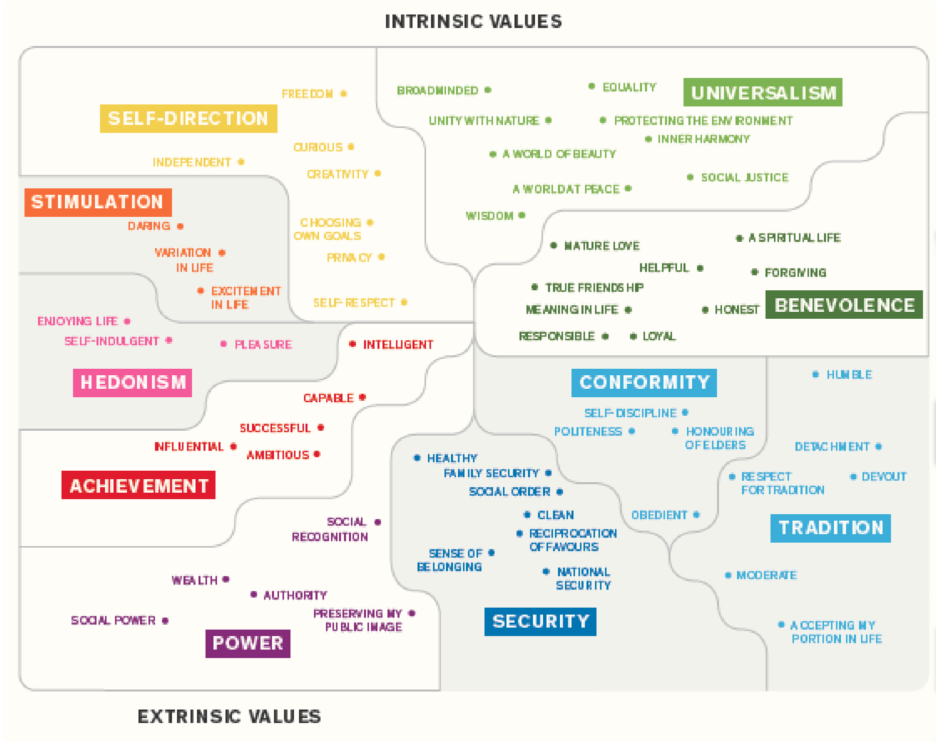


Figure 3.4 The human values that "seem to recur across cultures - held to varying degrees" (Blackmore et al, 2013)

The report's authors demonstrate that there is a need to link any exhortations for people to change their behaviours and to encourage them to develop conservation attitudes to a clearer understanding of the seeming contradictions in human attitudes and value systems illustrated in Figure 3.4. Some people hold views and behave in ways more aligned with different parts of Figure 3.4. Thus those with a more 'universalism' value set will be more understanding, appreciative, tolerant and protective for the welfare of all people and for nature (Blackmore & Holmes, 2013).

Inappropriate value framing is also highlighted and the example of the current 'red tape challenge' is used to illustrate an already loaded (framed in a way that implies legislation and regulation is overly constraining) consultation that promotes responses to reinforce implicit values already held by Government. There are in-built presumptions for example, that regulations reducing freedom for industry and commerce for environmental protection are 'red-tape' and need to be reformed. An alternative framing would be less pre-judgemental and would simply ask respondents to consider whether current regulations were effective and fit-for-purpose.

In attempting to define a way forward for conservation, Blackmore & Holmes (2013) highlight the frustration of practitioners:

> *"For some in conservation an understanding of the ineffectiveness of… a fact-based approach has meant turning to business and marketing for solutions."*
>
> *"This new approach has been a miscalculation for two distinct reasons. Firstly, conservation is not a product: although products can be sold to support its work, ultimately it is a pursuit that is driven by a strong moral imperative.*

> *Secondly, research increasingly suggests that messages appealing to self-interest are likely to impede our wider environmental objectives by decreasing people's motivations to act."*

They go on to make a recommendation:

> *"Fostering values such as self-acceptance, care for others, and concern for the natural world can have real and lasting benefits in conservation. By using this understanding to identify new areas for policies and campaigning, and by working together to cultivate these intrinsic values, we can create a society that is more compassionate, more connected to nature, and more motivated to protect our environment for generations to come."*

These ideas correlate well with those discussed briefly in Section 2, especially those expressed by Adam Smith in his Theory of Moral sentiments in the 18th Century. Box 3.3 gives an extract from the recommendations made by Blackmore and Holmes (2013).

Box 3.3 Recommendations for communicating about conservation (Blackmore & Holmes (2013)

Try to:

- Show how amazing nature is and share the experience of wildlife;
- Talk about people, society and compassion as well as the natural world;
- Explain where and why things are going wrong;
- Encourage active participation: exploration, enjoyment, and creativity.

Avoid:

- Relying on messages that emphasise threat and loss;
- Appeals to competition or status or money, or frames that imply a transaction between an NGO and its supporters;
- Economic frames;
- Attempts to motivate people with conflicting values;
- Segmenting audiences based on values.

For the purposes of this review, the considerations above and in Box 3.3 are important not only when trying to define some means of valuing the wider benefits of SuDS however that may be done, but also in understanding the value frame(s) within which such a valuation needs to be set. If we are to 'sell' the benefits of SuDS, then we need to properly understand how these benefits can be made accessible and to appeal to those who might wish to 'buy' them. Notably, Box 3.3 suggests that appeals to … money… transactions and economic frames should be avoided. These are all characteristics of many of the current approaches to valuing ES and other services (e.g. Defra, 2010).

CIWEM (2013) also consider the moral and ethical issues around monetisation of environmental and ecological services and despite reservations: "CIWEM warns that putting a price on nature is highly contentious with a number of unanswered moral and ethical questions"; they broadly support engagement in this approach as being necessary and pragmatic in the modern world, although they do call for more research and evidence.

Reports such as that by Blackmore & Holmes (2013), together with other recent studies concerning the way in which SuDS are 'seen' or framed by both the public and the wide platform of relevant professionals, policy and decision makers are vital to inform the way in which the wider benefits of SuDS can be valued to ensure engagement and acceptability by users (e.g. Lems et al, 2011; Cettner et al, 2013).

3.1.4 Surface water management planning & multiple benefits

Since 1981 when the Wallingford Procedure was published (Section 2.1.1) there have been considerable advances in understanding and in tools and techniques for assessing benefits from any investment and particularly in flood risk management. Even the ways in which environmental and social benefits are assessed have advanced to a point at which many of these are confidently being monetised. However, not all such benefits are amenable to monetisation and it is still necessary to provide subjective descriptions that indicate whether one project proposal is expected to provide greater benefits than another (e.g. Ashley et al, 2012; Pötz & Bleuzé, 2012).

In the water domain considerable advances have been made in conjoining the economic assessment of flood and coastal erosion risk management (FCERM) with the wider social and environmental benefits (EA, 2010; Defra, 2011a). The latter states:

> *"To achieve wider environmental objectives and other benefits, the measures used to manage all flood risks (including local sources of flooding) and coastal erosion will work with natural processes wherever possible and be based on partnership working with local communities. Working with natural processes can include taking action to manage flood and coastal erosion risk by protecting, restoring the natural function of catchments, rivers, floodplains and coasts…. The maintenance and restoration of a range of ecosystem services, or natural functions of the environment, can provide valuable additional benefits including:*
>
> - *water quality improvements through reductions in run-off and diffuse pollution;*
> - *water resource provision through aquifer recharge;*
> - *mitigation of and adaptation to climate change through measures such as wetland creation and coastal and fluvial realignment, and*
> - *the provision of urban biodiversity and amenity green spaces through sustainable drainage systems (SuDS).*
>
> *FCERM projects should minimise damage to and, where possible improve, the local natural, cultural and built environment*."

In the recent guidance related to outcome measures in relation to Grant-in-Aid (GiA) funding (EA, 2013c), the use of 'benefits' is tightly prescribed and double counting has to be avoided.

Table 3.8 illustrates where some of the added-value benefits from the above could be considered to be included in benefit-cost assessment over and above the traditional way in which flood risk management infrastructure is traditionally evaluated, from Defra/EA (2011). In this, green infrastructure may comprise all or any green surface; existing or that can be created as part of good urban design.

Table 3.8 Linking sustainable development and wider considerations in addressing flood risk management in England and Wales

Government themes for tackling sustainable development	Examples beyond the traditional flood and coastal erosion risk management (FCERM) technical appraisal processes
1. Actions to tackle climate change & protecting and enhancing the natural environment	• Greater use of working with natural processes to reduce flood and coastal erosion risk. • Greater use of sustainable drainage systems. • Carbon counting and setting carbon budgets, with the aim of decreasing greenhouse gas emissions. • Use of an environmental management system to monitor and report on resource consumption and process efficiencies. • Use of a recognised environmental performance tool • Reducing flood and coastal erosion risk in ways which create and link habitats and promote green infrastructure, thus adding to the total stock of biodiversity, as well as conserving important wildlife sites, and the ecosystem services this provides.
2. Fairness, improving wellbeing & building communities	• Promoting flood resilience and resistance measures at property and community level. • Involving local people and community groups in risk assessment to raise awareness of risk from all local sources of flooding and coastal erosion and empowering them to manage those risks. • Giving local communities a greater stake in project design and delivery at an early stage. • Using FCERM projects and activities to increase community health and well-being. For example, by providing access to pleasant open green spaces. • Using good design (such as promoted by Commission for Architecture and the Built Environment) to improve the look and feel of FCERM infrastructure, enhance river, wetland and coastal landscapes and respect the setting of historic buildings. • Seeking opportunities through FCERM to reduce inequalities and support less well-off communities. • Creating a 'sense of place' to help to promote sustainability. • Making use of multiple sustainability benefits through, for example, use of open areas as both storage capacity and amenity areas.
3. Green economy & operations and procurement commitments	• Using whole life cycle analysis and eco-footprinting in the procurement of FCERM services. • Seeking to reduce product miles when sourcing goods and services. • Using sustainable local low carbon energy supplies. • Working with partners on flood defence and coast protection schemes with multiple benefits, this could help reduce flood risk where it would otherwise be difficult to secure funds from traditional sources. • Use FCERM projects and activities to enhance local economies, for example increasing local tourism through improved public access and habitat creation.

Government themes for tackling sustainable development	Examples beyond the traditional flood and coastal erosion risk management (FCERM) technical appraisal processes
	• Ensuring inter-generational equity, for example avoiding complex, expensive flood defences that future generations may struggle to maintain and replace.
4. Use of sound science	• Using environmental impact assessment techniques (including sustainability appraisal and strategic environmental assessments where appropriate) to assess the environmental impacts of management options. • Using ecosystem services valuation in project appraisal to better understand the value of the natural environment to society and the economy.
5. Transparency and public accountability	• Being open about the costs and the benefits (and the distribution of those cost and benefits across social groups, generations and geographical areas) of different ways of managing risk. • Setting relevant local objectives, which local people clearly understand, and publishing clear reports on progress towards sustainability. • Working with the community to encourage innovation in defences that achieve multiple objectives. • Working closely with planning authorities and ensuring FCERM and planning are effectively linked. • Working with insurance companies prior to building so that developers are aware of the insurance assessment of the flooding 'risk' prior to building.

The benefits arising from the additional considerations shown in Table 3.8 over and above those of providing flood risk management alone (i.e. multiple benefits) are difficult to value. However, there are now many guidance documents and tools providing ideas and the means to begin to do this with some scientific credibility, including the aforementioned valuation of ecosystem services. A number of these are outlined in this review in Section 4.2. In England FCERM schemes have utilised multi-value concepts and the ecosystems services valuation outlined above in more detail to define transferrable value to support and justify flood risk management investment that delivers more than simply reductions in flood risk (Eftec, 2010).

Detailed and costed examples are provided mainly for coastal flood risk and erosion protection, including schemes that allow for managed set-back of defences and flooding of previously defended land by (Eftec, 2010). The Eftec handbook is extremely detailed and contains cost and benefit data that may be used widely. Further UK reviews have looked at river and urban drainage schemes that include multi-objectives and hence attracted multi-funding sources with partnership delivery (Babbs, 2011).

When it comes to surface water management, there is an inconsistent approach in England. Despite the world-leading benefit assessment guidance for FCERM schemes as outlined above, no such comprehensive perspective is applied, with the draft national SuDS standards (Defra, 2011) being interested in costs alone, ignoring benefit value.

The water industry has a considerable interest in the more effective management of CSO spills, given the extent of combined sewerage in the UK. The implications of managing storm water alongside foul flows are also a challenge for potentially disrupting wastewater treatment plant performance (Ashley et al, 2002; Meyer et al, 2012). UK standards and guidance for managing the pollution from wet weather discharges – both from CSO spills and effluents is defined in the Urban Pollution Management Manual which has been recently updated (FWR, 2012) although the principles remain the same as in the earlier guidance produced in 1995 and there is only scant reference to 'source controls'; mainly related to keeping pollutants out of drainage systems.

CSO spills are intended to be managed to control their frequency and volumes as is under consideration for the Thames Tideway Tunnel (e.g. Ashley et al, 2010). A significant means for doing this is to remove surface water at source from the combined sewer system via SuDS (eg. Stovin et al, 2013). A UKWIR study (Wade et al, 2009) considered the costs and benefits of doing this for the water industry and developed a spreadsheet tool for the evaluation of using SuDS and other measures. Table 3.9 shows a summary of the benefits potentially accruing from different types of intervention measures in regard to combined sewerage systems.

The benefits were categorised in terms of sewer flooding: quantifying the reduction in flood risk; quantifying the contribution from intervention measures; and monetising the benefit of reduction in flood risk.

Also environmental quality improvements, for which the monetisable benefits associated with (scheme-specific) potential key areas of water quality benefit were categorised as:

- Direct economic benefits to commercial fisheries and shellfisheries
- Public health benefits (e.g. at Bathing Waters)
- Recreational benefits (e.g. contact water sports, angling)
- Aquatic ecology benefits (e.g. increased biodiversity, reduced fish kills).

The guidance includes a decision support tool and worked case studies are given. Table 3.10 provides a breakdown of the benefits considered. None of the case studies provides any benefit values other than for those related to reduction in wastewater treatment costs or pumping as a result of retrofitting SuDS. There is provision in the spreadsheet for all of the benefits in Table 3.10. It also has guidance notes and details as to how to determine the values.

There are examples where the WaSCs are considering multiple benefits of SuDS in studies. Utilising a risk based partnership approach, Northumbrian Water Limited (NWL), five Lead Local Flood Authorities and the Environmental Agency (EA) investigated the opportunities for SuDS and surface water management in the Tyneside Sustainable Sewerage Study. One area of focus has been in Killingworth and Longbenton where NWL, EA and North Tyneside Council progressed the identified opportunities to a feasibility stage. The study used a hydraulic integrated urban drainage model of the drainage area to identify SuDS measures that can be built to provide a range of benefits across the community including:

- reducing flooding,

- improving water quality,
- reducing flows to treatment
- facilitating growth
- increasing recreational opportunities
- enhancing habitat and bio-diversity
- enhancing amenity
- cultivating public education opportunities

An initial benefit assessment using the ‘multi-coloured’ manual and considering only flooding resulted in a benefit cost ratio of approximately 2:1. An ecosystem services assessment was then applied to value those multiple benefits, not considered in the initial assessment. This resulted in a benefit cost ratio of approximately 3:1. The wider benefits demonstrated are sufficient to support the project progressing the partners are now agreeing the next steps.

In Yorkshire unsatisfactory intermittent discharges to the Upper Lake in Roundhay Park and the un-named tributary that extends upstream of Roundhay Park contribute to poor water quality and may be impacting on the ability of Native White Clawed Crayfish (a priority species under the UK Biodiversity Action Plan) to survive in the area. Overflows from storm events also have a number of other impacts, including increased flood risk and reduced recreational enjoyment. In addition, low water levels in the Upper Lake and in Waterloo Lake have been an issue in the past, affecting recreational activities, water quality and biodiversity.

To address the issues described above, Yorkshire Water identified a number of potential options, many of which incorporate SuDS features. These options would, to a greater or lesser extent, help to address the water quality and flow issues in the area, and subsequently result in a range of different benefits, to people and the environment.

A notional traditional solution and three SuDS scenarios were considered with the Ecosystem Services approach (UK NEA, 2011) being used to provide a framework for identifying and assessing the likely benefits associated with each of the four scenarios. Consideration was given to promoting either the proposed solution, or the approach, for investment for PR14.

Table 3.9 Summary of the potential benefits from implementation of each of the intervention measures (Wade et al, 2009)

Intervention measure			Reduction in sewer flooding risk	Water quality improvement[1]	Other environmental benefits[2]
Conventional intervention measures			Y		
Alternative measures based on disconnection	Realigning surface water connections	Foul/ surface separation	Y		
		Land drainage separation	Y		
		Highway runoff separation	Y		
		Surface sewer separation	Y		
		Watercourse separation	Y		
		River restoration	Y	+	Y
	Runoff attenuation measure	Green roofs	Y	Y	Y
		Bio-retention areas	Y	Y	Y
		Swales	Y	Y	+
		Balancing Ponds	Y	Y	Y
		Detention basins	Y	Y	+
		Soakaways	Y	Y	
		Infiltration Basin	Y	Y	+
		Filter strips	Y	Y	+
		Filter drains	Y	Y	
		Sand filters	Y	Y	
		Rainwater harvesting	Y		
		Constructed wetlands	Y	Y	Y
		Pervious surfaces	Y	Y	+
Source reduction measure		Domestic demand management	Y		+
		Industrial water efficiency	Y		+

Key:
Y= primary benefit, + = secondary benefit
[1] Excluding water quality benefits associated with a reduction in inflow or increase in capacity in the sewerage network, common to all intervention measures.
[2] Categorised as amenity, aesthetics and ecology benefits (CIRIA, 2007); excluding water quality benefits

Table 3.10 benefits check list for storm water removal from combined sewers (adapted from Wade et al, 2009)

Potential benefit	Sensitive receptors	Action to develop benefit value
Reduction in flood risk	Properties at risk of flooding?	**Review scale of benefit (number of properties and nature of flooding (internal or external)**
Environmental quality: public health benefits	Designated Bathing Waters?	**Identify number of Bathing Waters improved and the step-change in quality (e.g from Mandatory to Guideline)**
Environmental quality: aquatic ecology (rivers)	Rivers with reduced water quality?	**Identify length of river improved and the step-change in quality (e.g from GQA Class C to B)**
Direct economic benefits	Designated Shellfish Waters? Recreational benefits?	**Develop bespoke benefit**
Operational cost savings	High operating cost base?	**Identify reduction in sewage pumping or wastewater volume treated and cost of pumping/treatment**
Carbon footprint reduction	High carbon emissions?	**Identify reduction in sewage pumping or wastewater volume treated**
Other monetisable benefits?	e.g. Highway flooding, biodiversity.	**Develop bespoke benefit**
Non-monetisable benefits	**e.g. Community quality of life increase in headroom, social inclusion, visual amenity.**	**No monetisable benefit value currently available**

Surface water management planning (SWMP) spans flood risk management and local catchment management, using SuDS (Halcrow, 2010). With the advent of surface based SuDS measures, there is now much greater interaction with land uses, planning and urban design and layout processes than where piped drainage systems were buried and largely 'out-of-sight-out-of-mind' (NAO, 2004).

The benefits listed in the SWMP technical guidance are:

- Reduced surface water flood risk to properties, businesses, and critical infrastructure
- Reduced social and health impacts of flooding
- Reduced emergency costs of responding to flood incidents
- Reduced risk to life due to improvements in surface water flood risk management
- Contribution to meeting the requirements of the Water Framework Directive (WFD) through reducing pollution entering watercourses
- Contribution to meeting objectives of green infrastructure plans
- Contribution to creating or enhancing biodiversity and amenity

- Adaptability to climate change – the benefit could be the reduced use of carbon through the use of lower energy options, and greater adaptability of an option to future climate change

The guidance suggests first calculating the benefits which are to be monetised (and discount) for comparison with the costs using Net Present Value (NPV) and/or Benefit Cost Ratio (BCR). This is followed by a sensitivity and uncertainty analysis to review the ranking of options. 'Unvalued' social and environmental benefits should be included using a benefit transfer approach[16]. Comparing options can then be made using both the costed results and a scoring system where financial assessment cannot be made. A similar process is recommended in Digman et al (2012) for retrofitting surface water measures and the example from Leeds first edition SWMP is referred to in both the SWMP document and the latter. In this, the option with the greatest BCR was ultimately rejected due to uncertainty in the outcomes of the analysis. Elsewhere, significant decisions have been made based on multiple benefit valuations of surface water management measures, described in Digman et al (2012). In Philadelphia, the CNT (2010) methodology was used to assess the multiple benefits of disconnecting 50% of the stormwater inputs to the combined sewer networks compared with constructing a large tunnel. This found that the sum of the multiple benefits yielded some $2.8bn of added value for the SuDS hybrid option compared with $122m for the sewer tunnel (Stratus Consulting, 2009).

Local Authorities (LAs) often neglect to consider their opportunities and duties in delivery of the WFD requirements, yet especially those who have a lead local flood authority (LLFA) role, their contribution is crucial (in England e.g. EA & Sustainability West Midlands, 2012). For example, the latter quotes the Localism Act 2011 power that can compel LAs and others to make payments if by their actions there has been an infraction of EU Law. How this applies to deteriorations in water body status due e.g. to urban diffuse runoff pollution is not yet clear. However, LAs have a major role in ensuring such runoff from their assets, such as roads, and those they also have permissive and other powers to deal with is within prescribed standards. The cooperation duty is also important, although this may be harder to comply with for the private sewerage undertakers.

LAs also have the lead role in community engagement, community health and safety and localism support. The new public health responsibilities in England[17] also need to be considered in the light of integration across all services and functions of a LA, seeing these collectively rather than traditionally as in the past in a disconnected way. SuDS offer considerable potential benefits and the forthcoming responsibilities in regard to SABs and longer term operation of SuDS provide a once-in-a-generation opportunity to benefit from the synergies and efficiencies that this joining up can provide (e.g. Burrage, 2011; Miller et al, 2012).

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[16] A benefit (or value) transfer approach essentially takes values derived for another project/study/location, and transfers them (either unadjusted or adjusted for factors such as socio-demographic attributes of affected populations and inflation) to the project in question. It is a well-established means of helping to value non-market impacts and the government has published guidelines for its use (Defra, 2009). Benefits transfer is discussed in more detail in Section 4.2.

[17] under The Health and Social Care Act 2012

Department of Health (2012) point out:

> *"Shapers of place: Since local government holds many of the levers for promoting wellbeing it makes sense to give it greater responsibility and power to shape the locality in a healthy direction.*
>
> *Every day of the year local councils have direct contact with many of their residents. A fully integrated public health function in local government at both strategic and delivery levels offers exciting opportunities to make every contact count for health and wellbeing.*
>
> *Local authorities should embed these new public health functions into all their activities, tailoring local solutions to local problems, and using all the levers at their disposal to improve health and reduce inequalities."*

Table 3.11 is taken from EA & Sustainability West Midlands (2012) and illustrates how and where LAs can contribute to the delivery of the WFD. What is now needed is additional guidance to join this with the land use planning strategy, SWMP process, the localism agenda and the public health, recreational and environmental functions not only of LAs, but of all the players involved in societal services. This of course also means managing LA assets as sustainably as possible and 'practising-what-you-preach' by setting examples that others' can follow for example in regards to using SuDS. The related SuDS benefits are shown in Table 3.12.

Table 3.11 key local authority functions that can affect causes of poor water body status (from EA & Sustainability West Midlands, 2012)

Table 1: Key Local Authority Functions which can affect causes of poor water body status

Local authority functions and services:	Point source pollution	Urban diffuse pollution						Rural diffuse pollution e.g. from agriculture, septic tanks etc.	Physical man-made modifications to water bodies	Low flows in water bodies	Habitat degradation e.g. Invasive non-native species
		Polluted runoff from impermeable urban surfaces	Drainage/sewerage – e.g. misconnections, surface water connections to combined sewers etc.	Sediment runoff from land, e.g. during construction	Spillages, poor storage or handling, pollution down surface water drains	Littering, dumping and general neglect of watercourses	Pollution from contaminated land, including disturbance during development				
Local planning policies	◇	◆	◇	◇			◆		◆	◇	◇
Determination of planning applications and Building Control inspections	◇	◆	◆	◆		◇	◆	◇	◆	◇	◇
Local authority drainage and flood risk management functions, and future SuDS Approval Body role	◇	◆	◆	◆	◇			◇	◆	◇	◇
Environmental health and pollution control functions	◇		◆		◆	◆	◇	◇			
Managing local authority buildings and assets	◇	◆	◆		◆	◇				◇	◇
Openspace and green infrastructure, ecology and recreation		◆		◆		◆		◇	◇		◆
Highways design, maintenance and cleansing operations		◆	◇		◇	◇			◇		◇
Local authority community leadership & advocacy roles, including education		◆	◆	◇	◆	◆		◇	◇	◇	◇

◆ = significant potential effect on causes of poor water body status ◇ = less significant potential effect on causes of poor water body status

Note: The influence of local authority functions on water bodies will also vary depending on whether it is a unitary, district or county council, and the type and nature of the issues affecting local water bodies.

Table 3.12 SuDS for water quality, environmental and quantity benefits (adapted from EA & Sustainability West Midlands, 2012)

SuDS techniques for generating water quality, environmental and water quantity benefits

SuDS techniques:	Water quality improvements	Environmental benefits			Water quantity benefits			
		Aesthetics	Amenity	Ecology	Conveyance	Detention	Infiltration	Water harvesting
Water butts, site layout & management	◇	◇	◇	◇	◇	◇	◆	◇
Permeable pavements	◆	◇	◇	◇		◆	◆	◇
Filter drain	◆				◆	◆		
Filter strips	◆	◇	◇	◇	◇	◇	◇	
Swales	◆	◇	◇	◇	◆	◆	◇	
Ponds	◆	◆	◆	◆		◆	◇	◆
Wetlands	◆	◆	◆	◆	◇	◆		◆
Detention basin	◆	◇	◇	◇		◆		
Soakaways	◆						◆	
Infiltration trenches	◆				◇	◆	◆	
Infiltration basins	◆	◇	◇	◇		◆	◆	
Green roofs	◆	◆	◇	◆		◆		
Bio-retention areas	◆	◆	◆	◆		◆	◆	
Sand filters	◆					◆	◇	
Silt removal devices	◆							
Pipes, subsurface storage	◇				◆	◆		

Key: ◆ Significant potential benefits ◇ Some potential benefits subject to design

(Source: adapted from the CIRIA SuDS Manual, Table 1.7 and the Peterborough City Council draft Flood and Water Management SPD).

The Local Authority functions in Tables 3.11 and the use of SuDS shown in Table 3.12 has now to fit with the other missions of LAs eg. to be ‘brilliant’ (KPMG, 2011) and the new public health duties (Department of Health, 2012) in England and also the localism focus. Surface water and the WFD is only one of many considerations the ‘brilliant local authority’ has to juggle and helps in understanding why it is not a priority for many.

In Coventry and Birmingham AECOM & Severn Trent Water (2013) assessed the benefits from retrofitting SuDS to green streets. Box 3.4 shows an extract from the study report that lists the financial benefits. Many of the benefits have been assessed using locally provided data, although international research has also been used to define much of the performance of the green infrastructure. Some of the assumptions are contestable, e.g. the creation of 48 jobs through the provision of GI may be at the expense of jobs lost at STW as there are lower flows into the sewer systems; there may be added sewer blockages in the combined system (Butler & Parkinson, 1997). Even the creation of green jobs may not come about as the Council may compel existing staff to take on a heavier workload.

Box 3.4 ***Summary of the Severn Trent Water Ripple Effect investigation*** **: benefits of retrofitting SuDS to create green streets in Coventry (AECOM & Severn Trent Water, 2013).**

Sewer flooding – During heavy rainfall, the sewer system can be overwhelmed, flooding properties. Retrofitting with SuDS would reduce and slow surface water runoff to sewers. Severn Trent Water (STW) and Coventry City Council suggest that in an average year, city wide sewer flooding compensation costs amount to £3.6-million, or £83-million over 40 years. Reducing this will create financial benefits in terms of damage avoided.

Improved river water quality – Diffuse pollution from urban runoff and CSOs affects the quality of urban rivers. By using SuDS, this will significantly reduce. Currently, the EA consider the Quality of the River Sherbourne to be of 'poor 'quality. Improving the River to 'moderate' quality is worth £17,900 per km per year. Assuming the delivery of SuDS could significantly improve the water quality along the full length of the Sherbourne (10km), the potential benefit would be approximately £4.1-million over 40 years.

Reduction in surface water runoff – STW allows customers to claim back surface water drainage charges, if they disconnect. This is £30-£90 depending on property type. If all households in Coventry were to do this, there would be a total benefit of more than £5.7-million in bill reductions for householders. Over a 40 year lifetime, this equates to approximately £131-million.

Reduced wastewater pumping and treatment costs – Much of Coventry has combined sewers. By removing surface water it reduces pumping and treatment costs. Rainfall in Coventry is approximately 600mm per year. For a 60m^2 roof the surface water runoff would be 36m^3 per year. Using costs for pumping and treating wastewater estimated by STW, and assuming half of Coventry is served by combined sewers, the total value is calculated to be as high as £296,000 per year, or £6.9- million over 40 years.

Property values – Worldwide research has found uplifts in property values from treelined streets, of 3-15%. With the lower uplift in areas where there is already plentiful amounts of greenery. An average value of 7% has been assumed here, as Coventry does not have a high proportion of greenery in streets. Average homes on Stoney Road are valued at approximately £230,000; this is a £16,100 uplift per property. Rain garden tree pits will deliver two street trees every 33m on Stoney Road (one on either side of the road) with a combined value of £805,000 for the uplift for the 50 properties. For Coventry as a whole this would be £1.2-billion, with more than 66,000 trees. However, if all streets in Coventry were retrofitted as green streets, the high demand might prevent this figure from being achieved.

Box 3.4 continued

Reduced energy costs – The energy savings per tree from wind protection in the winter and shade in the summer as £32 per tree. The benefit in Stoney Road could be £800 per year or £18,500 over 40 years (not accounting for likely increases in energy costs). Across Coventry as a whole this gives £2.1 million per year, or more than £48.8-million over 40 years.

Carbon dioxide sequestration – Assuming 132,000 properties in Coventry, and one tree for every two properties, some 66,000 trees would be planted. Approximately 1.5 tonnes of CO_2 is sequestered for every hectare of trees. With 1,000 trees per ha, some 66 ha of sequestration value is delivered. Using a carbon offset value of £46 per tonne of CO_2, the value of carbon dioxide sequestration is up to £4,550 or more than £100,000 over 40 years.

Air quality improvements –for every m^2 of tree canopy, some 10 - 14 g of pollution are avoided annually (particulate matter, ozone, sulphur dioxide, nitrogen dioxide, and carbon monoxide). The damage of air pollution has been estimated in the UK for SOx (£1,633/tonne), NOx (£955/tonne) and particulate matter (117,900/tonne); this equates to £0.03/g of pollution (excluding the proportions for ozone and carbon monoxide which could not be monetised). With 66,000 trees planted, each with a 2.5m radius canopy, 15.8 tonnes of pollutants worth nearly £517,000/yr would be removed. This is worth £12 million over 40 years and over £4,500 for the retrofitted section of Stoney Road alone.

Local job creation – Creating green streets would require maintenance and care of the landscaped areas. One job is equivalent to eliminating job-seekers allowance for one person. At £65.45 per week for a year, this is £3,403.40. If the value of housing benefit is included of £63/week this would be an additional annual cost saving of £3,276. Combined, this is £6,679. Scaled across Coventry this is equivalent to 48 jobs created, or roughly £320,592 benefit to the city. Over 40 years these jobs are worth more than £7.4 million.

Biodiversity – When street trees are planted on a citywide scale, functional ecological corridors can be established, improving habitats.

Pedestrian movement and recreation – Greener streets could be combined with home zone initiatives and the creation of more pedestrian friendly streets to improve the walkability of Coventry. One study found that residents that live in walkable neighbourhoods do 30-45 minutes more of activity per week and are less likely to be obese or overweight.

Urban heat island – There are an estimated 15 heat wave days in Coventry by 2080, resulting in a predicted 6.4 lives lost. A 10% increase in tree canopy would reduce expected surface temperatures in the urban area by 2.5^{o}C.

Groundwater recharge and water re-use – SuDS can be designed to recharge local aquifers or be stored and used locally as an alternative water supply. As new water sources are scarce in the catchment, the cost of developing a new source is significant. By either replenishing groundwater supplies for re-extraction or extracting a portion of treated runoff for reuse, a new water source could be created. By retrofitting SuDS to capture and treat runoff from the roofs and roads, significant amounts of water would be available as a water supply. Assuming 15% is lost to evaporation and plant uptake and if only 50% of the available runoff is used as a water supply, the value of that water source could be up to £6.7-billion over 40 years based on the offset of the cost of developing new sources elsewhere in the area. Storage tanks, final treatment and pipework have not been costed in the case study and would need to be included to gain this benefit.

In total, from the quantifiable benefits above (not including the benefits relating to heat-related deaths, biodiversity and health), the city-wide benefits of retrofitting green SuDS is valued at in excess of £1.5-billion over 40 years. For the site at Stoney Road, there is a benefit of over £906,000 or 7.5 times the site costs of £121,000. If water reuse infrastructure was added to store and recycle runoff locally for irrigation and toilet flushing, the benefits would increase dramatically to nearly £8.3-billion across the city and nearly £3-million at the site scale.

Combining greener streets with home zone initiatives will not work as home zones discourage green infrastructure in order to not impair the sight lines of car drivers (Department for Transport, 2007). Although with sight lines of only some 20m, it is recommended that additional traffic calming measures are used in home zone streets. Ironically in the Westleigh home zone, which is generally liked by residents, it includes some bright green parking spaces which some residents dislike (Biddulph, 2010). This is the closest to green infrastructure that such areas come. The additional traffic calming could easily be provided by rain gardens or 'bump-outs' as they are known in Australia that would serve multiple purposes.

The example in Box 3.4 does not include any benefits classified as ES, although there are overlaps between the classical ES and some of the benefit categories considered.

3.1.5 Dealing with uncertainty and being resilient

Where possible all uncertainties need to be managed. Despite some calls to obtain more climate data and better models to more effectively manage climate change uncertainty (Dyke et al, 2012), uncertainties are pervasive and here to stay in each aspect of the management of surface water (Milly et al, 2008; Rance et al, 2012). There is a need to be proportionate about what information and how much data can realistically be collated to offset these uncertainties before being comfortable with making a decision, as recognised in the EA (2010) FCERM guidance. As regards SuDS, they are much more effective at coping with uncertainties in estimates of rainfall, runoff and future hydrological process changes than piped drainage systems. They also provide a wider range of benefits that can help with other uncertainties, such as changes in the urban heat island (e.g. CWSC, 2013).

In London the Borough of Islington's promotion of the use of SuDS[18] has in part been due to a perceived need to provide buffering against the uncertainties of future climate change in the Borough:

> *"SUDS manage runoff from development in an integrated way to reduce the quantity of water entering drains and therefore to reduce surface water flood risk – an important consideration in a dense urban area like Islington, particularly given the increase in heavy rainfall likely as a result of climate change. SUDS also improve the quality of runoff from development, bringing clean water back into use in our urban environment to create attractive places for people and wildlife."*

The study illustrated in Box 3.4 for Coventry was undertaken in part to enhance the resilience of the areas to climate change. Deculverting, retrofitting SuDS and WSUD were proposed components that were seen as enhancing resilience of these urban areas. The assumptions regarding valuation of the benefits are in many cases highly specious and lack robustness. This is because of a lack of evidence and data for many of the presumed benefits. Even the quantifiable chemical data (e.g. tonnes of CO_2) estimates may be challenged. Yet, despite these limitations, such studies are

[18] http://www.islington.gov.uk/services/parks-environment/sustainability/sus_water/Pages/SUDS.aspx accessed 19-08-13

not normally reported in terms of ranges of or the uncertainty related to the estimates of potential benefits, with the notable exception of Everard et al (2011a). Any standard assessment process to quantify the benefits as has been done above should have a formalised uncertainty statement.

Kellagher (2003) considered the effects of climate change on the hydraulic design of sewers. The report suggested that the use of SuDS "can be beneficial in the management of the rainfall effects of climate change." This was within the context of concluding that the implications of climate for changes in sewerage system performance are large if they are addressed only by modifying the infrastructure. A risk-based approach to design is recommended in view of the uncertainties and there needs to be a move away from using spill frequency analysis for CSO performance to one that considers the receiving water impacts. It was also indicated that new modelling tools were required for SuDS and overland flow. CSOs, and the use of SuDS to reduce their spill frequency is also highlighted by Rance et al (2012) in the national review of climate and water systems.

Many examples of studies of climate change adaptation related to SuDS exist. In the UK the Adaptation Sub Committee on Climate (ASC, 2012) sees SuDS as a major way to provide adaptation capacity mainly aimed at flood risk management. They identify that

> *"sewers have fixed capacity, they still overflow when the intensity of rainfall exceeds this capacity. Maintaining and refurbishing conventional drainage is necessary but can be expensive and does not produce a particularly high return."*

The report recommends greater use of SuDS in new developments to slow flows, but that by itself, is unlikely to provide sufficient attenuation to prevent the growing risk from flooding in urban areas. In addition to SuDS, the committee suggests that urban design can play a role in managing the flow of surface water and flood risk and that:

> *"Using roads and paths as emergency flood channels can help keep surface water away from vulnerable people and property during extreme downpours…and designating low value land for temporary (flood) storage can keep water away from people and property"*

The report also suggests that property-level protection can work alongside structural flood defences to manage risks.

Designing and managing SuDS in the light of climate change has been considered in Auckland New Zealand. Semadeni-Davies (2012) concludes that ponds can be incrementally adapted over time to keep pace with increased rainfall provided land was earmarked for future expansion, whereas raingardens that directly serve impervious runoff, occupying for example road space, can only be adapted economically by adding to their numbers rather than expanding. The added life cycle costs of this adaptation potential are indicated to be some 8.7-12.3% for ponds and 8.5% for rain gardens in the New Zealand context (Semadeni-Davies et al, 2013). This study used a life of 100 years and a discount rate of 3.5%.

It is incumbent now for decision makers to be reflexive. This is because decisions made today may need to be revisited tomorrow in a non-stationary world (Milly et al, 2008; CWSC, 2013). Flexibility is a valuable characteristic of any asset, measure or service. SuDS are inherently more flexible than underground drainage systems, but measuring the value of this is not straightforward (Eckert et al, 2012).

Being better placed to deal with future uncertainties is a theme addressed in the Stern (2006) report and recently highlighted in EU strategy which has laid out ways to make investments climate resilient (EC, 2013). Flexible and 'no regret' measures are preferred whereby it is relatively straightforward to abandon or alter schemes as knowledge advances about climate and other societal changes. Accounting procedures, such as 'Real Options' and 'Real in Options' (RIO)[19] (Defra, 2009; de Neufville & Scholtes, 2011; Woodward et al, 2011; Gersonius et al, 2013) can provide estimates of the value of leaving decisions open and of taking a staged implementation approach as recommended for adaptation.

There are a number of studies now that have considered the benefits that using surface based SuDS can bring to adaptation and resilience as regards climate change and other future uncertainties. In the SWITCH[20] project it is formalised via a set of utility functions developed to assess the comparative benefits of using piped compared with surface-based drainage systems (Peters et al, 2005). An analytical tool, 'Comparing the Flexibility of Alternative Solutions' (COFAS), has been developed from this to compare the flexibility[21] of alternative options (e.g. for stormwater management) regarding their adaptiveness to future changes. It was found that decentralized solutions like stormwater infiltration are more flexible than conventional drainage systems (Sieker et al, 2008).

The COFAS approach uses 4 'metrics' to assess flexibility.

- **Capability of change** - indicates the range of future developments for which a change of the system is possible. A high flexibility is assigned when a wide range of future states can be managed by a particular flexibility option – this corresponds to the robustness measure in scenario analysis e.g. Ashley & Saul (2007).
- **Costs of change** & **duration of change** – the effort of change represented by the costs of change as well as the duration of the change process. The lower the effort to change the system during operation, the higher the flexibility of the system.

[19] 'Real Options' is a mechanism for evaluating flexibility in an investment decision and is founded in the analysis of financial decision making (Woodward et al, 2011); whereas Gersonius (2012) defines: Real Option as "The right—but not the obligation to adjust a system or a component of the system to future uncertainties as these unfold" and a Real In Option: "A Real Option created by changing the engineering system (re)design".

[20] http://www.switchurbanwater.eu/ accessed 19-08-13

[21] defined as: "*the ability of urban drainage systems, to use their active capacity to act, to respond to relevant alterations in a performance-efficient, timely and cost-effective way*"

- **Performance of system** - the performance of the system for different future states described as regret. The regret is the difference between the value of benefit of the assessed alternative solution for different future states and the maximal possible benefits if other alternatives are chosen. The lower the regret of the alternative for different future states, the higher the flexibility.

The metrics are integrated into a framework for the measurement of flexibility. The internal homogeneity of performance is used as a measure of the flexibility, internal homogeneity and the total utility value results in the development of a “multi-dimensional Degree of Target Achievement”.

A system with a high internal homogeneity is more robust against future changes e.g. changing conditions associated with climate change, than a system with a low internal homogeneity, because it shows equally good performance against all criteria Eckart et al, (2012).

When considering the relative flexibility of SuDS to climate change adaptation, it is intuitively obvious that surface based systems are easier to modify than below ground piped systems. In a follow-on study to a Defra IUD pilot study in West Garforth Yorkshire, Gersonius et al (2012 & 2013) demonstrated that a staged adaptation process was the most cost beneficial to adapt the existing piped drainage system to cope both with current annual flooding and with the future likely changes in flood risk due to climate change. Using a ‘Real in Options’ appraisal[22], the following (managed adaptive) staged implementation was determined (Gersonius et al, 2012):

- System configuration A1 – the core strategy is to build this in the first 30-year time period. It includes enlarging sewer conduits, with the removal of adverse gradients, and building six new SuDS storage areas.
- System configuration A2 – this is built if the intensity of the design storm has gone up by 13% in either the second or third 30-year time periods. It involves building two new SuDS storage areas, expanding four already-built SuDS storage areas and disconnecting stormwater from 213 back roofs (source control).
- System configuration A3 – this is built only when the rainfall intensity has increased by 28% in the third 30-year time period. It includes building one new SuDS storage area, expanding three already built storage areas and disconnecting storm water from a further 137 back roofs (source control).

This strategy gave the economic value of the estimated maximum regret avoided with respect to maladaptation errors (equal to the net present costs of the traditional static/robust strategy minus the initial capital costs of the managed/adaptive strategy) as some £0.47 million (22% of the costs of the static/robust strategy) (Gersonius et al, 2013). This is the economic value of the flexibility.

There were a number of caveats, *inter alia*:

- The adaptation options identified remain available in the future and perform as expected when implemented.

[22] see above

- The actors remain committed to the active learning process even though the individual and institutional actors may be different over time.

Clearly the ability to expand the footprint of an existing SuDS measure in the future will depend on land use and on policies for this at the time and the trajectories for this in the intervening period. In this respect, modifying below ground systems may often be easier as it may be possible to enlarge a pipe irrespective of the land use above it.

Taking advantage of flexibility and adaptive potential depend substantially on the willingness of the decision maker to revisit ‘old’ decisions. With continuous change due to climate and other effects such as creeping urbanisation, no decisions regarding surface water management can be considered made and remaining effective for all time. Hence the decision making needs to keep on top of developments in knowledge and understanding and will need to verify and modify old decisions as time passes to ensure performance is maintained; this is a process known as active learning.

A recent report for Defra, VividEconomics (2013), suggests that the benefits of adaptability in one sector like water may go beyond that sector and benefit others. It calls for some means of calculating in aggregate the overall benefits including across sectors. GI and ES in relation to surface water management and the techniques outlined above, may go some way to doing this, but there may be a need to re-appraise the boundaries of analysis.

3.1.5.1 Summary of ways for dealing with uncertainty

There are a number of important aspects related to uncertainty that are relevant for surface water management and pertinent for the valuation of SuDS:

- Uncertainties exist in all of the environmental, economic and social aspects of SuDS and other surface water drainage systems.
- The presence and nature of the various uncertainties needs to be acknowledged and accepted by decision makers; any advisers need to ensure that uncertainty is explicit and presented in a way in which all stakeholders can understand and accept that it is an inevitable part of decision making
- In decision making in relation to actions that will be affected by climate change, as in surface water management measures, the minimisation of uncertainties is only possible within a limited domain – such as for the performance of a SuDS measure. Uncertainties regarding climate change and how this may affect surface water systems will not diminish within the short to medium term.
- Some uncertainties are definable whereas many are not. Hence probabilistic techniques are required to define the scale and sources of uncertainties.
- An adaptive, flexible and no-regrets approach is most likely to lead to the selection of measures that will provide the most robust required levels of performance despite the uncertainties.

- Making a decision to utilise a hard infrastructure measure that is costly and complex to adapt, will lead to 'locked-in' infrastructure and potentially stranded assets (eg. Walker, 2000).

In the flooding and water resources domains a lot of progress has been made in dealing with future uncertainty in relation to climate and other changes. Much of this has focused on ensuring the flexibility and adaptability of measures (e.g. Gersonius, 2012; Haasnoot, 2013**;** Korteling et al, 2013). Techniques using 'tipping point' analysis, 'real options' and 'real in options' are being further developed from origins in the financial sector (de Neufville & Scholtes, 2011).

Haasnoot et al (2013) define a 'dynamic adaptation policy pathway' approach as illustrated in Figure 3.5 for the management of future climate change uncertainty.

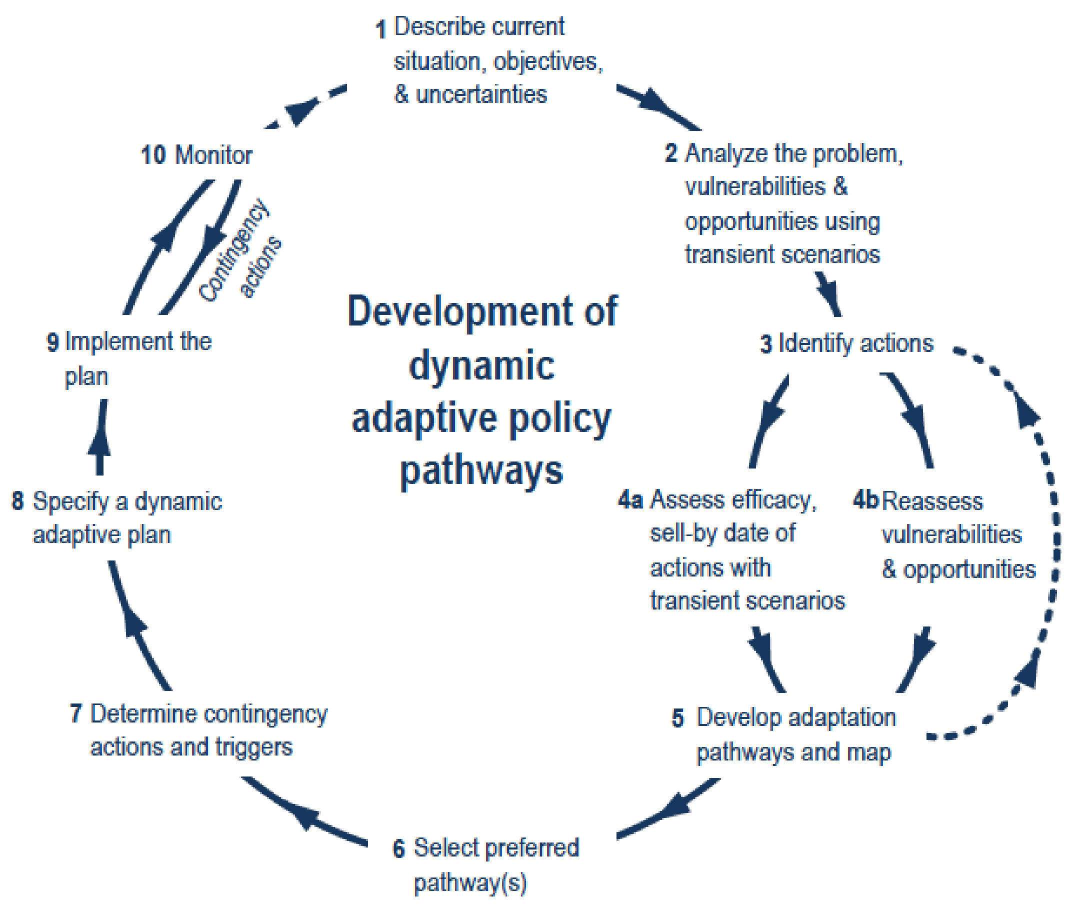

Figure 3.5 Dynamic Adaptive Policy Pathways for managing climate change and related uncertainties (Haasnoot et al, 2013).

This approach has now been taken up by the National Government in the Netherlands as the baseline for managing uncertainties in relation to flood risk management. It combines adaptation pathways with adaptation policies and provides a framework for utilising adaptation tipping points, real in options and other techniques that define where, when and how best to make system changes.

It can be concluded from this brief introduction that in view of the changed landscape regarding uncertainties that has become apparent in the last decade or so, when dealing with water systems (eg. Milly et al, 2008) a multiple approach is needed:

1. A dynamic adaptive approach is required to ensure that any investments are robust and fit to continue to deliver expected outcomes into the future over the lifetime of any hard or soft assets
2. Use 'traditional' tools such as probabilistic tools like Monte-Carlo simulation to explore the ranges of uncertainties in the parameters used in these approaches to inform the decision maker and build confidence
3. Educate decision makers and others so that their traditional expectations that once designed and built, assets will continue to perform for their expected lifetime without adaptation, is no longer a valid assumption and that a different, and dynamic approach to decision making is now needed

The above outline is important for valuing the multiple benefits of SuDS as the benefits will accrue not only from the initial construction stage, but through cycles of adaptation over the SuDS lifetime; more (or less) and different benefits may arise. Due to the more than 20 year lifetime of SuDS, there may be many interventions and adaptations and there may be many and different decision makers; each with their own understandings and investment priorities. It is likely also that knowledge about climate change and other phenomena, including SuDS performance will also grow. Analysing how the benefits will unfold over time is therefore not straightforward and in the short term, needs to include assumptions about how decisions will be made in the future and the place that uncertainties will play in this process.

4 VALUING THE BENEFITS OF SUDS

4.1 Frameworks for Economic Evaluation

There are many potential frameworks for economic evaluation. The varied organisations involved in water, SuDS management and implementing have in many cases, differing approaches. The main and overarching guidance document in the UK is the Treasury Green Book (4.1.1). However, this has to be fed into and supplement other frameworks and processes. For example, in the water industry in England and Wales there is a need to manage assets as part of the five year review, through the ‘asset management planning’ process regulated by Ofwat. It is likely that the management of SuDS by the water and sewerage undertakers in the UK will follow the common framework for capital asset maintenance (Heywood et al 2002) and develop new ideas to comply with the new resilience duty (Conroy et al, 2013) as considered in Section 4.1.5.

4.1.1 UK- Treasury green book

The Green Book (HM Treasury, 2011) provides a central and well-established approach to economic appraisal. Although it is primarily aimed at public sector projects, it is widely used to help assess projects involving the private and third sectors, but with ‘external’ social and environmental impacts.

It specifies that wherever feasible, all costs and benefits of a proposed activity, including those relating to the environment, should be valued and monetised within a cost-benefit analysis. However, it also allows for other decision-making tools, such as multi-criteria decision analysis, where there is a mix of monetary values, quantified data and qualitative considerations.

The Green Book discusses particular aspects of appraisal, including sensitivity analysis and discounting, where the social time preference rate (the rate at which society would trade a unit of a benefit between the present and the future) of 3.5% is generally recommended.

There is supplementary guidance on accounting for environmental impacts (Dunn, 2012).

4.1.2 Ecosystem service approaches

This framework, discussed in Section 3.1.3, is now widely used for assessing the goods and services provided by ecosystems. Under this approach, environmental impacts relate to a loss or gain of one, a group, or all of the services of the ecosystems. The categorisation of ecosystem services used is often based on the Millennium Ecosystem Assessment (MEA, 2005) and features provisioning, regulating, supporting and cultural services.

4.1.3 Social Return on Investment and Health considerations

4.1.3.1 Social considerations

Social Return on Investment (SROI, 2012) is a framework based on generally accepted accounting principles that can be used to help manage and understand the social, economic and environmental outcomes created by an activity or organisation. It is particularly appropriate for not-for-profit organisations and social enterprises, enabling them to improve performance, inform expenditure and highlight added value.

SROI is based on seven principles:

1. **Involve stakeholders**
   Understand the way in which the organisation creates change through a dialogue with stakeholders
2. **Understand what changes**
   Acknowledge and articulate all the values, objectives and stakeholders of the organisation before agreeing which aspects are to be included in the scope; and determine what must be included in the account in order that stakeholders can make reasonable decisions
3. **Value the things that matter**
   Use financial proxies for indicators in order to include the values of those excluded from markets in same terms as used in markets
4. **Only include what is material**
   Articulate clearly how activities create change and evaluate this through the evidence gathered
5. **Do not over-claim**
   Make comparisons of performance and impact using appropriate benchmarks, targets and external standards
6. **Be transparent**
   Demonstrate the basis on which the findings may be considered accurate and honest; and showing that they will be reported to and discussed with stakeholders
7. **Verify the result**
   Ensure appropriate independent verification of the account

4.1.3.2 Health considerations

Many health related benefits claimed for green infrastructure and ecosystem services also include health components (shown under cultural services in Table 3.6). Blue infrastructure is also beneficial to health (Miller et al, 2012), although the latter warn that:

> "we found little empirical evidence and many gaps in the literature on the links between blue space and health".

Tzoulas et al (2007) reviewed the many benefits to human health that GI can bring:

> "Ecosystem services provided by a GI can provide healthy environments and physical and psychological health benefits to the people residing within them. Healthy environments can contribute to improved socio-economic benefits for those communities as well".

In stating this and setting out a conceptual framework for delivery, there is a call that the many and diverse professionals and others involved need to work together in a more integrated way than traditionally if these benefits are to be realised. With their new public health duties, local authorities in England need to ensure that this happens if they are to deliver services in the most efficient and effective way.

Most of the tools being used to assess the benefits of GI and SuDS outlined in Section 4.2 include aspects of public health in their assessments. However, there are few UK publications that have linked public health with surface water management. The majority of public health linkages are made with the environment and water is mentioned rarely, typically in relation to supply, wastewater disposal and flooding. For example, Haines (2012) in an editorial about health and climate change does not mention water or green spaces at all as being part of policy needs.

There are many perceived benefits to health from green spaces and other open spaces. Many of these are in parks in urban areas in the UK. Ideally these should be 'natural environments' as far as practicable and 'tranquil' (Watts et al, 2011). Without access to these spaces in childhood, evidence shows there can be 'nature-deficit-disorder'. These spaces contribute to overall feelings of well-being (see also Section 3.1.1) and reduce human stress levels. New ideas are now emerging as to how to positively design such places in urban areas, but there is still some way to go in this endeavour, although there is evidence that 'water-generated' sounds are part of the tranquillity of an area and by positively managing these significant benefits can occur (Watts et al, 2009). Clearly SuDS can be designed to incorporate the sounds of running or cascading water that are found to be beneficial.

Changes in service provision and moves toward greener living are coming about through the support of the transition towns movement. Studies have looked at the positive health benefits from these transitions. Richardson et al, (2012) used a health impact assessment (HIA) template to demonstrate positive benefits in which criteria were developed. Although water and drainage were not considered, public access to green spaces was considered important drawing on mental health guidance to its' value (Mind, 2007). A HIA approach seems to be commonly used for assessing how environment and human health are linked (eg. Negev et al, 2012) and may be an approach that should be incorporated into any SuDS benefit tool.

There are health risks associated with any change in practice and traditional surface water management proponents often claim that alternatives are likely to compromise human health and lead to new and less well understood risks. As an example, climate change related health risks have been defined for the UK by Vardoulakis & Heaviside, (2013) for the Health Protection Agency. This report calls for reductions in greenhouse gas emissions and also in air pollution for health improvements, both of which can be supported by SuDS. While generally supportive of the move to using greener infrastructure, the report is cautious about the implications for buildings that use more green components, such as green roofs. There is concern about the opportunities for mould growth and the easier spread of micro-organisms that may impact on health and may be supported by more green building components. Externally to buildings there are also concerns that by using more water on the surface there may be opportunities for more disease spreading vectors such as ticks and mosquitos to breed and even concerns about the greater ease with which larger mammals such as deer, can pass through densely populated urban areas and attendant health risks from this.

To counter the concerns above, CWSC (2011) considered the Health and Risk aspects of Stormwater Harvesting and Reuse. This review concluded that there were a number of knowledge gaps:

"The gaps in our knowledge on the health risks associated with stormwater harvesting and reuse are related to hazard identification (i.e. knowledge of the contaminants actually in stormwater); human health risk assessment (exposure and effect); and human health guidelines (risk mitigation)" and provided a detailed table of what these were in 2011. None were considered to be a serious impediment to stormwater harvesting and reuse in Australian practice,

World Health Organisation (WHO, 2013) have developed an economic analysis tool to support health adaptation planning in relation to climate change that also includes the need to protect water and wastewater systems and the utilisation of more green spaces in urban areas. Both direct (eg. deaths) and indirect (eg mental) health benefits are considered. The approach takes a 'health damage avoided' stance, rather than looking for opportunities and benefit maximisation.

Safety is also a primary consideration in promoting and ensuring that maximum benefits are obtained from any surface water management measures. Designing and constructing green infrastructure requires due diligence in this regard both during the construction phase and in operation. In the UK, Health & Safety regulations need to be adhered to and understood by all promoting eg. biodiversity. For example, under Annex F Biodiversity and the Construction (Design and Management) Regulations 2007, BS 42020: 2013 specifically refers to SuDS, stating that

"An ecologist, working as part of a multidisciplinary team, ought not take overall responsibility for the design of any engineered structure, such as a pond, although they may input into the design by, for example, suggesting suitable depths, type of planting to be supplied. Other examples include green roof design, sustainable urban drainage systems (SuDS) design".

4.1.4 Total Economic Value

The Total Economic Value (TEV) framework (DG Environment, 2012) is a well-recognised method for identifying the different aspects of monetary value, and can be applied to help value different aspects of ecosystem services. The TEV shows that for any given product or resource, the total value is the sum of use value and non-use value.

Use value involves some interaction with the resource, either directly or indirectly:

- Direct use value: The use of the area in either a consumptive manner, e.g. industrial water abstraction or in a non-consumptive manner, e.g. tourism;
- Indirect use value: The role of the area in providing or supporting key (ecosystem) services, e.g. nutrient cycling, habitat provision, climate regulation; and
- Option value: Not associated with current use of the area but the benefit of keeping open the option to make use of the area's resources in the future. A related concept is quasi-option value, which arises through avoiding or

delaying irreversible decisions, where technological and knowledge improvements can alter the optimal management of a natural resource. Although quasi-option value lies outside the TEV framework, it represents the value/benefit of better decision-making where there is potential to learn by delaying a decision. The OECD‟s review, Cost-Benefit Analysis and the Environment: Recent Developments (OECD, 2006) shows that quasi-option value is particularly relevant in the context of ecosystems – there is uncertainty, irreversibility and a major chance to learn through scientific progress in understanding better what ecosystems do and how they behave.

Non-use value is associated with benefits derived simply from the knowledge that the natural resources and aspects of the natural environment are maintained, i.e., it is not associated with any use of a resource. For example, individuals place a value on knowing that certain areas will be protected even though they may have no intention to visit or make any other direct or indirect use. Non-use value can be split into three parts:

- Altruistic value: Derived from knowing that contemporaries can enjoy the goods and services related to the area;
- Bequest value: Associated with the knowledge that the area as a resource will be passed on to future generations; and
- Existence value: Derived simply from the satisfaction of knowing that the area continues to exist, regardless of use made of it by oneself or others now or in the future.

The TEV framework is summarized in Figure 4.1

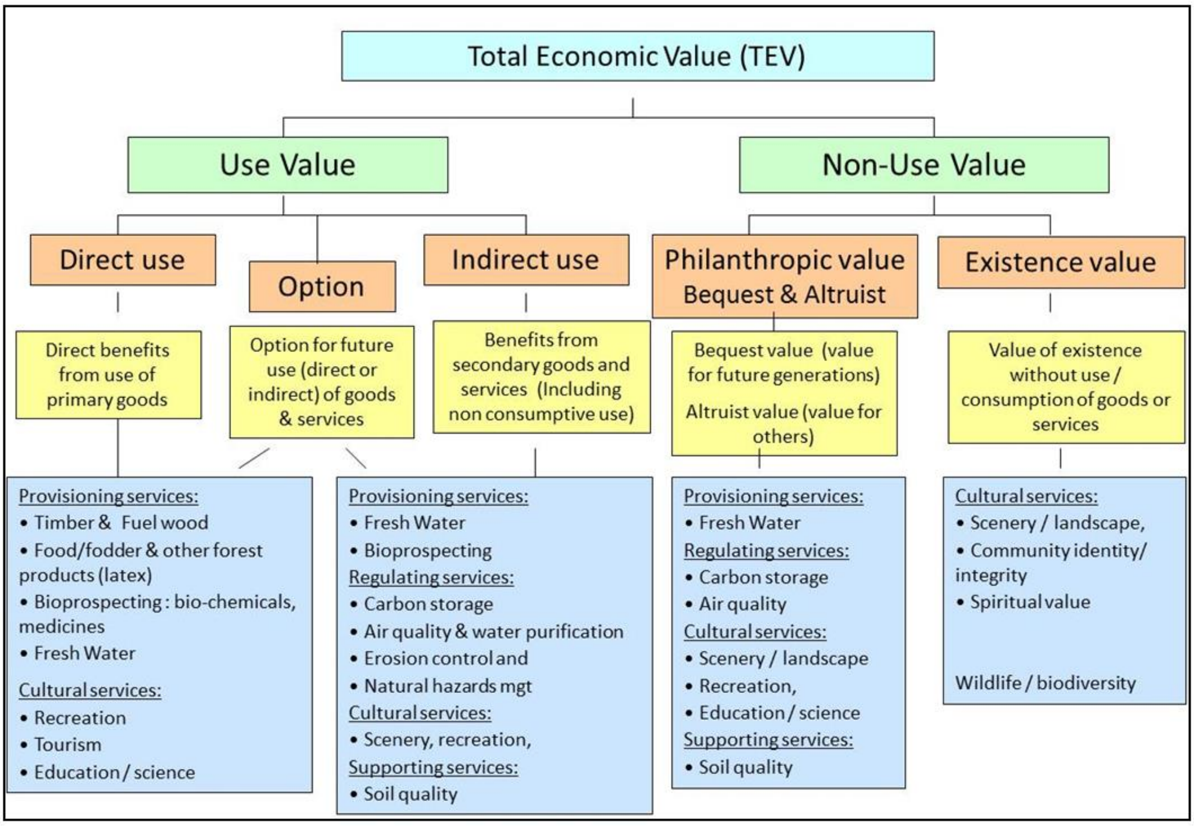

Figure 4.1 Total Economic Framework (TEV) from ten Brink et al, 2011

This same framework is used in Marlow et al (in print) in relation to water asset management, although 'altruistic' is replaced by 'option' values. Also 'direct' use value is divided into 'marketed outputs' such as water supply and consumption and 'unpriced benefits' like recreational and aesthetic uses of water. Figure 4.2 illustrates the importance of 'marginal' changes in TEV, net benefits minus costs.

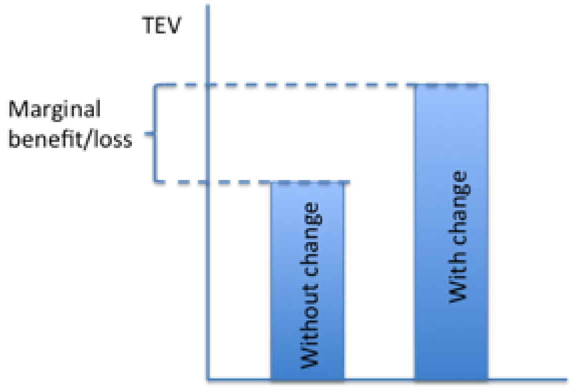

Figure 4.2 Marginal change in TEV (Marlow et al, in print)

4.1.4 Environment Agency Water Appraisal Guidance

This recent suite of guidance (Environment Agency, 2013b) has been designed primarily for Environment Agency staff engaged in River Basin Management Planning. It has been developed to assist in the assessment of benefits for economic appraisal for projects, policies and programmes which affect the water environment (both surface water and groundwater). The guidance comprises a number of tools, including:

- A guidance document to lead users through the process of economic appraisal and valuation;
- A Water Appraisal Summary Table (AST), which provides users with a flexible step by step process by which to assess benefits qualitatively and quantitatively and gives users a common format to work from;
- A Stage 1 Valuation sheet, which helps to monetise benefits and can be used to estimate a ballpark cost benefit ratio for projects, policies and programmes which affect the river environment; and
- A Stage 2 Valuation template and Review of Benefits for Value Transfer document, which can be used where a more detailed Stage 2 level monetisation of benefits is necessary.

In this, the benefits are categorised only in terms of ecosystem services – acting as a 'comprehensive list of impacts'. Seemingly no other benefits are considered.

The stage 1 valuation uses a simple "toolkit" approach with standard values of benefits that allows an analysis at the national, river basin management or catchment scale, to prioritise a programme or where a high level estimate is fit for purpose at a local scale. Overall the methodology is similar in nature and philosophy to the Benefits Assessment Guidance (BAG) (Environment Agency, 2003) which is still recommended for use at the 'stage 2 valuation' stage. Similar to the 2003 BAG, low levels of confidence in the results of a stage 1 valuation can be inferred from the guidance on the results where benefit cost ratios between 0.5 and 1.5 are deemed to be not clear and therefore require a Stage 2 Study.

A useful addition since the 2003 BAG is clearer guidance in a table to assist in decisions in benefits transfers as reproduced in Table 4.1 from EA (2013b). The table summarises valuation evidence which has been derived through studies using the valuation methods outlined in Section 4.2.3 of this report. This includes the use of drop down boxes to filter the studies to enable the user to review a manageable amount of information. The example in the table raises concerns on validity of the data for useful benefit transfer in terms of its age, typically a decade old. Overall the 2013 guidance suggest that there has only been limited progress in benefit valuation since the 1996 FWR (Foundation for Water Research) methodology.

Table 4.1 Extract from the Review of Benefits for Value Transfer table (EA, 2013b)

The physical characteristics of the goods: e.g. the impact, pollutant, habitat, species, resources, etc	Unit Value (£s)	Parameter (e.g. per household per annum	Value year	Source
Inland Marsh	~£1300, with range £200-£4300	per ha per annum	2008	EVEE guidance table 2.2.
Salt Marsh	~£1400 with range £200-£4500	per ha per annum	2008	EVEE guidance table 2.2.
Intertidal Mudflat	~£1300, with range £200-£4300	per ha per annum	2008	EVEE guidance table 2.2.
Peat Bog	~ £300 with range £0-£1000	per ha per annum	2008	EVEE guidance table 2.2.
Commercial fisheries; trout fingerlings	£170	per tonne restocking rate.	2002	Nix (2002) as summarised in table 4.3 in BAG part 2
Commercial fisheries; trout fry	£210	per tonne restocking rate.	2001	ABC (2001) as summarised in table 4.3 in BAG part 2
Commercial fisheries; Grisle (young) salmon	£2,200	per tonne restocking rate.	2001	ABC (2001) as summarised in table 4.3 in BAG part 2
Commercial fisheries; pre-salmon	£2,300	per tonne restocking rate.	2001	ABC (2001) as summarised in table 4.3 in BAG part 2
Commercial fisheries; salmon	£2,400	per tonne restocking rate.	2001	ABC (2001) as summarised in table 4.3 in BAG part 2
Commercial fisheries; Carp (fry, 2 to 3 inches long, 700 to 800 per acre)	25p	per fish restocking rate	2001	ABC (2001) as summarised in table 4.3 in BAG part 2

The water appraisal guidance recommends sensitivity analysis to show the uncertainties in the outcomes of the assessment.

4.1.5 Asset management

Globally the concept of asset management is growing. For example, in the US, Water Environment Research Foundation (WERF) has recently commissioned two guidance documents for asset management (Marlow et al 2013; 2013a) setting out definitions of the various costs and benefits and assessment tools and providing examples of application[23]. They define "Benefits as increases in 'welfare', which is termed as 'utility' in economics" based on and UKWIR review by Bateman et al (2010). Although the US reports are aimed at sewered drainage systems, the concepts are also applicable to SuDS.

The Institution of Civil Engineers (2013) has also issued 'guiding principles' for asset management which calls for "whole-organisation alignment with asset management". It also takes the 'customer' stance in stating: "defining the levels of performance provided by the assets to customers". Whereas, as far as SuDS are concerned, the term 'customer' may be counter-productive as it distances water users, consumers and others making them simply 'customers' who purchase a product rather than part of the community that collectively manages and engages in the use of a precious resource. A more engaging term is required; especially as many 'customers' will be required to manage their own assets in regard to surface water in the future (Wong & Sharp, 2009).

SuDS provide multiple services and benefits and there may be more than one asset beneficiary. However, unless partnerships are set up, ownership and hence liability for the asset will fall on one party alone who might be the property owner who has limited understanding about asset maintenance; a problem identified in London when retrofit SuDS were being considered (e.g. Ashley et al, 2010). In Scotland the provision of SuDS in the front gardens of individual properties often requires special wayleaves[24] to facilitate access and maintenance by the SuDS owner, usually the local authority.

In England, the Common Framework for Capital Asset Maintenance (CFCAM) Heywood et al (2002) defines capital maintenance as the renewal or refurbishment of capital assets in order to provide continuing service to customers and the environment consistent with current regulatory obligations (Royce, undated). The process is in three stages: considering historical records of asset performance; identify what this means for future capital maintenance and predict expenditure; justify the forward projection based on historical trends. Figure 4.3 illustrates the process (ibid).

This approach is applied to all capital assets held by the water companies in England and Wales and is growing in application elsewhere in the world. Data is needed covering:

- Asset deterioration rates
- Likely changes in asset performance, and resulting impact on service
- The costs of replacing assets, compared with the costs of maintaining deteriorating assets

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[23] there is also an online benefit-cost tool for asset management but it is only available to members of WERF: http://simple.werf.org/Books/Contents/What-is-SIMPLE-/Overview accessed 21-08-13

[24] "Although the law does not define the word "wayleave", it is a conventional term to describe the arrangement that exist, with rights and obligations, when powers are taken to construct, use and maintain apparatus, such as pipes and cables, in, on or over land." Scottish Land & Estates: http://www.scottishlandandestates.co.uk/index.php?option=com_content&view=category&layout=blog&id=88&Itemid=197 accessed 14-08-13

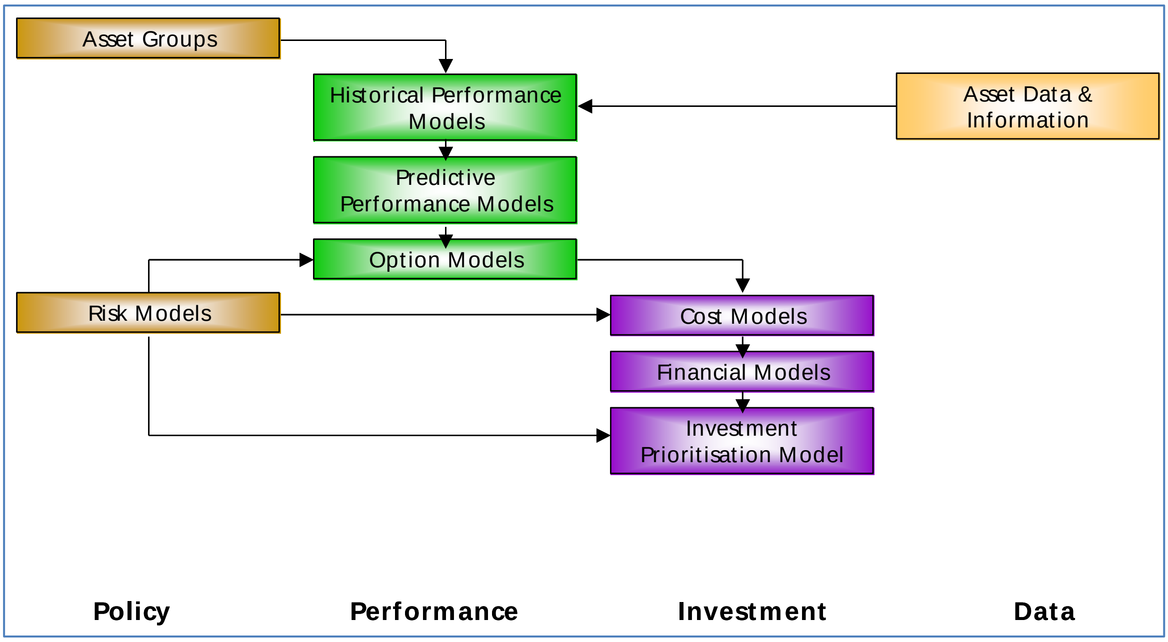

Figure 4.3: Components of models and tools for CFCAM planning (Royce, undated)

There is a class on 'non-infrastructure' which is above ground assets but this does not include surface water management. Investments are made on balancing cost and performance risks – of not delivering a service. The serviceability of the asset has now also to be included, ie just delivering the service is not good enough; the asset *al*so has to be serviceable in itself.

How amenable is the CFCAM to the use of SuDS in the water industry? In principle, a risk based perspective is sensible and attainable. However, a number of issues need to be considered before SuDS become part of the routine CFCAM process as outlined in Table 4.2.

A recent UKWIR asset management study (Dyke *et al*, 2012) has considered how climate change may impact on asset management planning in the UK water industry. This makes the erroneous statement that 'uncertainties regarding climate change projections will reduce over time' which is misleading and unlikely within the next 25 years at least and hence will confuse decision makers. There is a need for WaSCs to concentrate on managing assets (including future SuDS) in an adaptive and flexible way so that uncertainties can be less of a concern. Whatever the future climate conditions, sensible adaptive approaches can handle them if applied appropriately (Section 3.1.5.1) (de Neufville & Scholtes, 2011).

UKWIR reports by Bateman *et al* (2010) and Newton & Reid (2007) cover Cost Benefit Analysis and its use in regard to sewer flooding respectively. The former reviews the use of CBA in PR09 and considered how it needed to be revised for PR14. It is suggested that the scope be applied to all types of company investments and not to a narrow view of investment types. Importantly it provides guidance on eliciting customer preferences and recommends that more effort be put into sensitivity analysis.

Table 4.2: The common framework for capital asset maintenance and SuDS (with reference to Figure 4.3

CFCAMP aspect	Relevance and application to SuDS assets
Asset groups: Definition of asset	The distinction between infrastructure/non-infrastructure and above and below ground asset in regard to SuDS needs to be clarified
Asset data and information	There is a need for standardised SuDS typology of symbols and terms to use in data bases. As many SuDS will be assets owned by others, but may interact with WaSC assets, this needs to be agreed nationally. Descriptive information and attributes also need to be defined nationally.
Historical performance models	So far there is still limited historical data about SuDS performance and even less about SuDS as WaSC assets in the UK. For the immediate future extant models will need to be used from international studies and the limited UK work so far done. Performance needs primarily to cover water quantity and quality aspects of SuDS; however, others' may also be interested in other performance aspects related to amenity, aesthetics etc. there is a need for an agreed national research protocol for this.
Predictive performance models	This is essentially about both design and operational performance. There is even less information about long-term performance of SuDS than short-term for which some data exist. The future climate change, adaptation potential and resilience requirements also need to be included here.
Option models	It will be impossible for WaSCs to confine options to direct service considerations alone. Partnering will be needed to ensure the options provide opportunities to deliver multiple benefits.
Risk models	The economic and performance risk models developed by the water industry may be amenable to accommodate surface water drainage systems as there are already models related to flood risk management. These will need to be adapted for routine surface water drainage situations, ie. for when flooding is not being considered, rather the multiple benefits of SuDS are being promoted and realised.
Cost models	The WERF/UKWIR models are so far the only UK based models available for this. However, these do not include inter alia: water quality; amenity; biodiversity etc.
Financial models	These will need to include the wider range of benefits, above.
Investment prioritisation model	Where confined to customer charges, there needs to be a strict focus only on the outcomes related to water supply, wastewater management and effectual drainage. This needs to be considered also in terms of environmental protection requirements. Otherwise there will need to be clearly defined cost allocations, as in Scotland between Scottish water and the local authorities there.

In England and Wales there has been a move from an Overall Performance Assessment (OPA) as a means whereby the regulator can incentivise water company performance to one that uses a Service Incentive Mechanism (SIM). The initial form of SIM was developed collaboratively with key stakeholders such as CC Water (Bryan *et al*, 2012) to focus on the overall quality of the response to customers. It is intended to promote innovation and also address some of the Cave and Walker[25] review recommendations. The report (ibid) made recommendations as to what the quantitative and qualitative aspects of a revised SIM should comprise. It

[25] Defra. (2009). Sir Michael Cave's Independent Review of Competition and Innovation in Water Markets: Final report. & Anna Walker - The Independent Review of Charging for Household Water and Sewerage Services

is unclear how this will impact on company's ability to value SuDS as assets and interact with 'customers'.

There are a number of potential liabilities for the sewerage undertakers in the UK associated with SuDS as part of an asset portfolio (adapted from Bamford *et al*, 2006):

1. The need to accept output flows from others' SuDS assets and the consequences thereof
2. Own owned SuDS assets – the entire portfolio of potential liabilities incurred from any infrastructure *inter alia*:
    a. Health and safety of both the public and workers involved
    b. Nuisance issues
    c. Pollution risks
    d. Management and maintenance of the asset
3. Design issues especially related to use of software and knowledge

Addressing these, a protocol has been developed to minimise the ownership costs and liabilities for sewerage undertakers as regards SuDS by Bamford *et al* (2006). However, much of this pertains to increasing knowledge and as yet, adhering to 'best practice' appears to be the most useful risk mitigation approach.

This fits with the most recent approach to evaluating the benefits and costs of SuDS and surface water measures, not only in Surface Water Management Plans (SWMP) (Defra, 2010) but also when considering the wider benefits (Ashley *et al*, 2012). The theme of customer preferences is also considered extensively in Newton & Reid (2007) and in Bryan et al, (2012); where stated preferences approaches are recommended to cover both use and non-use values. Although these include consideration of 'altruistic values', ie by customers willing to support others' impacted by flooding, there are no other benefit considerations such as added-value from multiple land uses of eg flooding recreational areas. This is important for SuDS and it may be that advances in thinking since Newton & Reid's 2007 report have moved on especially as the water industry now has a slightly different focus on 'outcomes' defined in terms of customer expectations (Ofwat, 2012).

4.1.6 Cost Benefit Analysis

The practical application of Cost-Benefit analysis (CBA) has been attributed to water development projects in the United States since the 1930s (Pearce, 1972). In these studies the principle of comparing social benefits accrued from a project to the costs associated with its development, in terms of a common monetary unit, was established. However, the first application of the method in the United Kingdom was on the first M1 motorway project. The technique has continued to be widely used in the transport sector and it is incorporated as a standard tool in Volume 13 of the Highways Agency Design Manual for Roads and Bridges (HMSO, 2004).

In England, the Environment Agency (2012) gives guidance on partnerships and Defra (2012) has produced a funding options interactive document which also provides links to all of the other relevant guidance and specification documents to ease the process of funding proposals[26]; although a number of the links are now defunct. This is intended primarily for use by LLFAs, but as they require partnerships, the information is also able to assist other key stakeholders. In general some form of CBA is required as for SWMPs (Defra, 2010). Many SWMPs will include SuDS in their measures. Both valued (monetised) and unvalued benefits need to be evaluated in the CBA, however, a multi-criteria analysis is recommended based on Defra's PAG to ensure that the non-monetised impacts are accounted for.

4.1.6.1 Benefit Analysis in Scotland

SEPA is working on cost benefit guidance in relation to the Flood Risk Management (Scotland) Act 2009 (the FRM Act). All cost benefit guidance in relation to the FRM Act will be in line with the HM Treasury Green Book (2003) and in line with Scottish Government policy on FRM Act cost benefit analysis.

The Scottish Government have a policy on cost benefit analysis for the FRM Act – Sustainable flood risk management - principles of appraisal: a policy statement (2011) available on the Scottish Government website[27]. This sets out high level principles, including appraisal and cost benefit analysis carried out at different levels of detail (from strategic to detail appraisal), and assessment of economic, social and environmental impacts and assessing non-monetary impacts.

The Scottish Government also has more detailed guidance on appraisal / cost benefit analysis: Project Appraisal for Flood Protection Schemes – Guidance (also available on the same website as above. This is detailed guidance on how to apply the policy and this is currently being updated. At present it focuses on detailed appraisal of structural measures and the update will include guidance on strategic level appraisals and provide overarching guidance on all types of appraisal for the FRM Act. It is estimated that the updated version will be available early 2014.

A group consisting of SEPA, local authorities and Scottish Water is developing equivalent guidance on the strategic cost benefit analysis of surface water flooding measures that will inform the Local Authority Surface Water Management Plans. This will include measures such as SuDS. This is in development at the moment and is expected to be available early 2014, (this will be in line with the above government policies). The strategic appraisal of measures for the SWMPs will not replace detailed project appraisal when measures are implemented. This will still have to take place at the detailed design stage.

In Scotland as elsewhere, one of the major challenges in any economic evaluation remains in the determination of the value of the benefits.

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26 http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17085 accessed 19-08-13

27 http://www.scotland.gov.uk/Topics/Environment/Water/Flooding/FRMAct/guidance

4.2 Benefit Valuation Methods

There are three general approaches to benefit valuation that can be considered relevant here.

1. Benefit Transfer
2. The application of benefit evaluation toolkits
3. Primary benefit assessment methods

4.2.1 Benefit Transfer

This process involves the transfer of valuations of benefits that were undertaken at a specific study site and then applying these values to a study in another context or at another location. The simplest form of transfer is to use the average estimated value from studies if it can be assumed that there is broad similarity between the previous studies and the new study. This is often not the case so adjustment may be necessary using either a functional relationship of differences between the sites e.g. size, distance from centres of population or following a meta-analysis of a set of data to explain variations in the values. This approach was reviewed and recommended in the EU AQUAMONEY project[28] and applied to the Humber river basin catchment when considering the value of rivers (Watkins et al, 2007).

The benefit transfer process is attractive because it reduces the time and cost required to obtain and apply values. Consequently, the literature (e.g. Digman et al, 2012; Chow et al, 2013; Eftec, 2010; 2013) consistently identifies the necessity for benefit transfer whilst paradoxically noting the paucity of useful data. This would enable only the use of an average value or single value benefit transfer methods.

4.2.2 The application of benefit evaluation toolkits

Eftec (2013) provide a comprehensive review of toolkits that could “provide ready-made green infrastructure valuation tools that can be used by those who do not have specialist environmental or economics training or familiarity with the relevant literature”. This report assessed the following nine of these tools “in terms of their adherence to the principles of scientific and economic analysis, and applicability to the UK”

- CAVAT: Capital Asset Value for Amenity Trees;
- Green Infrastructure North West’s Green Infrastructure Valuation Toolkit
- Guide to valuing Green Infrastructure from the Centre for Neighbourhood Technology Chicago;
- Health Economic Assessment Tool for Walking and cycling (HEAT);
- Helliwell;
- i-Tree Design;
- i-Tree Eco;
- i-Tree Streets, and
- InVEST: Integrated Valuation of Environmental Services and Tradeoffs.

[28] Economic Assessment of the Environmental and Resource Costs and Benefits of Water Use and Water Services - http://www.wise-rtd.info/en/info/development-and-testing-practical-guidelines-assessment-environmental-and-resource-costs-and-9 [accessed 04-10-13]

The report includes a headline summary of the appraisal as shown in Table 4.3 below which suggest that only two of the toolkits (HEAT and CNT) are based on a robust benefit valuation approaches and these cover only a limited range of benefits

There are a number of other less pervasive tools for either greening urban areas or designing SuDS. Examples include the Washington DC 'Green up' toolkit[29], the USEPA's national stormwater calculator[30] and the uksuds[31] online design tool. Of these only the first considers benefits other than water quantity and quality as its focus is on GI. This also deals with energy and carbon and is applicable from the rain barrel (water butt) scale upwards.

4.2.3 Primary Valuation methods

Benefit transfer is a secondary valuation process. The literature highlights the expertise, time and costs that are required to carry out robust case specific valuations of benefits using primary valuation. However, primary valuation can be tailored to the study in question and provides more robust and reliable results. Since the 1990s the UK water industry cost-benefit assessment methods have recommended the following primary approaches to benefit valuation.[32]

4.2.3.1 Contingent Valuation Method

The contingent valuation (CV) method involves directly asking people, in a survey, how much they would be willing to pay for specific environmental benefits. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental Benefits. The term "contingent" valuation reflects that people are asked to state their willingness to pay, contingent on a specific hypothetical scenario and description of the environmental service.

The contingent valuation method is a "stated preference" method, because it asks people to directly state their values, rather than inferring values from actual choices, as is the case in the "revealed preference" methods such as travel costs and hedonic pricing. Contingent valuation is based on what people say they would do, as opposed to what people are observed to do and this is the source of its main strengths and its weakness. For example contingent valuation can assign currency values to non-use values of the environment—values that do not involve market purchases and may not involve direct participation. However, the fact that the contingent valuation method is based on asking people questions, as opposed to observing their actual behaviour, present methodological challenges and the transfer of resulting benefit values must be treated with caution. The results of contingent valuation surveys are often highly sensitive to what people believe they are being asked to value, as well as the context that is described in the survey.

[29] http://greenup.dc.gov/ accessed 20-08-13
[30] http://www.epa.gov/nrmrl/wswrd/wq/models/swc/ accessed 20-08-13
[31] http://geoservergisweb2.hrwallingford.co.uk/uksd/ accessed 20-08-13
[32] These are discussed in more detail in various places, see for example European Commission et al (2013)

Table 4.3: Headline summaries of valuation toolkits

Valuation toolkit name	Q1. Is the tool recommended for use in the UK? Head line answer	Science assessment	Economics assessment	Q2. Which GI features?	Q3. Which ecosystem services?	Q4. In which context?
Capital Asset Value for Amenity Trees (CAVAT)	Not recommended for economic valuation.	No. Assessments dependent on expert judgement.	No. Measures cost of replanting and maintenance, not the value of ecosystem services	Trees	Does not value ecosystem services	Can be recommended for financial compensation for tree damage.
Green Infrastructure Valuation Toolkit (GIVT)	Not recommended for economic valuation without input from expert economists.	Not clear. Biophysical analysis is either side-stepped or quantification of benefits is left to the user	No*. Welfare and economic impact estimates are mixed, unit values are not always substantiated based on literature, there is a high risk of double counting	Any that can provide the ecosystem services covered	Amongst the 11 benefits covered the following correspond to ecosystem services: Climate change adaptation and mitigation; Water and flood management; Place and communities; Health and wellbeing; Tourism and Recreation and leisure.	The tool is a mix of benefits, value evidence and assumptions. While the format of the calculator is easy to use, it should not be used without expert economics input to determine robust unit values and disentangle different types of value to avoid double counting.
Guide to Valuing Green Infrastructure by Centre for Neighbourhood Technology (CNT)	Yes. Prepared for the USA so input data and assumptions will need to be replaced with UK specific data (energy price, shadow cost of carbon)	Yes. Based on currently available research	Yes. Measures economic value using valuation methods	Green roofs Trees Rain gardens (bioretention and infiltration) Permeable pavements Water harvesting	Regulating services: climate regulation (inc air pollution), water regulation Cultural services: recreation and ecotourism	Investments in new GI feature or improvements to existing ones. Consult scientific and economic experts, where necessary.

Valuation toolkit name	Q1. Is the tool recommended for use in the UK? Head line answer	Science assessment	Economics assessment	Q2. Which GI features?	Q3. Which ecosystem services?	Q4. In which context?
Health Economic Assessment Tools (HEAT) for walking and cycling	Yes. Should replace the default values with UK specific data.	Yes. Based on review of published scientific research and the tool itself is peer reviewed and tested.	Yes. Measures value of statistical life	Any feature that provides recreational (walking and cycling) opportunity	Health (reduced mortality risk) benefit of recreation	To estimate the mortality risk reduction benefits of regular exercise (walking and cycling) opportunities provided.
Heliwell (H)	Not recommend ed for economic valuation	Original paper is from a peer reviewed journal but scaling factors[33] to use in the tool are based entirely on expert opinion.	There is no economic basis for the unit economic value used.	Individual trees woodland	Visual amenity (aesthetics)	The user may find the scoring process and factors taken into account useful for other purposes such as qualitative and quantitative descriptions of costs and benefits.
Integrated Valuation of Environmental Sciences and Tradeoffs **(InVEST)**	Yes, though the intention of the tool is to be used for spatial planning.	Yes, the model uses methods that are scientifically tested and peer reviewed publications.	Yes, but depends on the type and robustness of the value data inputted to the model. The tool designed to use market prices, cost of treatment and welfare estimates.	None specifically, but will generally cover GI features which cover area (e.g. a park or woodland rather than a single tree, ponds).	Biodiversity*; Regulating services: carbon storage and sequestration, water purification, sediment retention; Provisioning services: managed timber production, and Supporting services: crop pollination* *: not valued in monetary terms	Examples of the types of green infrastructure questions the tool could help to answer are:: Where would reforestation or protection achieve the greatest downstream water quality benefits?

[33] *The tool scales the value of a tree depending on the following factors: tree size, life expectancy, suitability to setting, importance in landscape, presence of other trees and form.*

Valuation toolkit name	Q1. Is the tool recommended for use in the UK? Head line answer	Science assessment	Economics assessment	Q2. Which GI features?	Q3. Which ecosystem services?	Q4. In which context?
						Which parts of a watershed provide the greatest carbon sequestration, biodiversity, and tourism values?
i-Tree Design	Unclear on its applicability to the UK	The tool states that it is based on peer reviewed sources. But as it is a closed tool, it has not been possible for this study to assess its underlying data and assumptions.		Individual trees around a given property which can be marked on Google Maps™ for the USA and Canada	Regulating services: Carbon dioxide reduction, storm water capture, also Air pollution and Energy conservation due to tree shade	The annual and over project lifetime value of the selected ecosystem services of trees around a single given property.
i-Tree eco	Yes, but with adjustments of the parameters to the UK.	The tool states that it is based on peer reviewed sources. But as it is a closed tool, it has not been possible for this study to assess the background. If applied to the UK, peer reviewed data should be inputted.		Individual trees or any size urban forest sizes	Regulating services: Carbon dioxide reduction, storm water capture, also Air pollution, Energy conservation due to tree shade and public health and several biophysical data results that support these services	Selected ecosystem services of a single tree or any size tree population in an urban setting.
i-Tree Streets	No. Not applicable to the UK	The tool states that it is based on peer reviewed sources. But as it is a closed tool, it has not been possible for this study to assess the background. The tool advises international users to use i-Tree Eco instead.		Street trees	Regulating services: Carbon dioxide reduction, storm water reduction Cultural services: Aesthetics as captured by increase in property values Energy conservation due to tree shade	To estimate the economic benefits of ecosystem services covered by the tool and management needs and costs.

As an example, Bastein et al (2012) use a CV approach to ascertain via a questionnaire the value assigned by Scottish residents to a number of SuDS ponds when they were living in close proximity. The quality of the pond was found to be immaterial in the valuation; it was simply the presence nearby that gave it value in the eyes of the residents. It is claimed from this study that developers should therefore be more willing to accept such SuDS as the added-value assigned by the residents is translated into greater willingness to pay more for properties.

4.2.3.2 Travel Cost Method

This method assumes that the value of a site or its recreational services is reflected in how much people are willing to pay to get there. The basic premise of the travel cost method is that the time and travel cost expenses that people incur to visit a site represent the "price" of access to the site. An advantage of the travel cost method is that it uses information on actual behaviour rather than verbal responses to hypothetical scenario and of all the techniques it is relative inexpensive to apply. However the results may be site specific and may again lead to problems in benefit transfer.

4.2.3.3 Hedonic Pricing

Many of the methods and examples used to promote the added benefit value of SuDS utilise house and property price values. For example, the GINW GI valuation tool was used to estimate the benefits of GI for a scheme in Liverpool (Digman et al, 2012). The uplift in land and property values was estimated as applying to some 6000 properties and to be between £1.7M and £6.7M. As the total added value from the study was some £29.3M – £45M, the property value contribution was significant.

The hedonic pricing method is used to assess these types of benefit and relies on information provided by households when they make their location decisions (e.g. Bradon & Ando, 2012; Zhou et al, 2013). Its theoretical basis is that the demand for housing increases the supply of labour in the more desirable locations. This influences the demand for land and housing increases and as the supply of workers increases the market wage rate falls. The higher housing prices and lower wages reveal how much people are willing to pay for the amenities in desirable locations.

For example the housing market could be considered by comparing the housing market areas with high amenity SuDS with that in areas with low amenities. Data on housing sales can be evaluated and used to compare the prices of similar houses in the two locations and account must be taken of the characteristics of the houses (e.g., number of bedrooms, baths, etc.) and neighbourhoods (e.g., school district, parks, etc.). The difference in housing prices is one component of an estimate of the value of SuDS amenity. The labour market in the two areas should also be considered, using data on incomes to compare the wages of similar people and jobs in the two locations. Account must be taken of the characteristics of the workers' education and experience and jobs. Then the residual difference in wages also helps estimate of the value of SuDS amenity. The full impact of the SuDS amenity is the sum of the value of air quality in the housing and labour markets.

The application of hedonic pricing requires a considerable investment in expertise and it may also be very difficult to find comparative locations where, for example

SuDS amenity are the dominant difference. It can also provide contradictory results regarding how people value e.g. proximity to a park or grassed areas even in a single city (e.g. Larson & Perrings, 2013).

Other examples from the USA are given by Bradon & Ando (2012). Table 4.4 shows recent studies of economic benefits assessed using hedonic pricing and engineering based approaches.

Table 4.4 Examples of hedonic priced and other economic benefits from use of SuDS equivalent in USA (Bradon & Ando, 2012)

Source	Study for	Type of benefit	Underlying methodology	Estimated benefits - $ at 2000 prices
Braden & Johnstone (2004)	Offsite value of stormwater (SW) management	Water quality	Hedonic property value (Benefits transfer BT)	5% for undeveloped riverside properties; 10-15% for developed riverside residential inc. sediment benefits
Johnstone et al (2006)	Comparison of offsite SW management with piped system	Downstream flooding and offsite cost of drainage infrastructure	Hedonic property value, flood insurance costs etc. BT and engineering design	PV = $110-158 per developed acre PV = $340 per developed acre
Hansen & Hellerstein (2007)	Partial value of soil conservation programmes	Opportunity cost of water storage	Sediment removal costs (engineering design)	PV = $0.24 up to $1.38 per ton of sediment kept out

Bradon & Ando (2012) also point out that the use of SuDS equivalents in new housing developments in the USA are ‘benign’ in that they reduce construction costs to such an extent that they can help to “reduce house prices”. They claim that this increases the net sum of “total societal welfare” as both developers and those seeking houses are better off.

Open Urban Drainage Systems (OUDS), are defined as open to the air and to the general public and may provide a range of recreational services (Zhou et al, 2013). These are equivalent to the UK’s regional controls. This Danish study considered the value of the additional recreational amenities from the potential of retrofit OUDS using hedonic house price valuation and also capturing the value of the surrounding neighbourhood. When implementing this strategy, it was necessary to convert some private properties into green spaces to provide room for OUDS. This meant there were additional costs for obtaining the overall benefits. It was pointed out that the hedonic method related to the new construction could only measure values as perceived by house owners. There may be other users of the recreational areas provided by OUDS, which also obtain a welfare gain or loss. The case study considered the entire extent of the city of Aarhus and 12,339 properties sold between 2000 and April 2010. The additional benefits considered were only for the increase in property values and taxes due to the recreational design of the OUDS systems. Six new small ponds and three new (floodable) green spaces were considered for retrofit within the survey area. Thirty-five family houses were removed to accommodate these. The spatial extent of the green areas established was small compared with the overall supply of larger green recreational areas in and around Aarhus. Two OUDS options were considered as shown in Table 4.4.

Table 4.5 comparison of options for retrofitting GI based SuDS in Aarhus - The average benefit in MDKK (million DKK) from OUDS 1 and OUDS 2 based on welfare estimated from the estimated hedonic price function using a robust spatial error model (Zhou et al, 2013)

Source of welfare economic loss/gain	OUDS 1	OUDS 2
Loss of property		−179.61
Loss of garden	−22.28	
Increased access to lakes	86.11	144.63
Loss of unattractive recreational area	0.22	0.22
Increased access to recreational areas with lake	141.39	169.87
Increase in size of nearest recreational area	17.64	18.86
A: Sum of direct increase in property prices	*223.09*	*153.97*
Total property value of affected properties	15071.60	14960.48
B: Tax revenue	*177.16*	*122.23*
Total	400.25	276.24

In Table 4.5 the numbers in italics show the added economic benefits due to increased property values in the area and the resulting increase in property taxes. The EAD decreases to 6.3 MDKK per year with implementation costs of 54.5 MDKK in the present value The estimated net benefits from the CBA are 157 MDKK. OUDS 1 provides a potential welfare increase of 223.1 MDKK and OUDS 2 provides a potential welfare increase of 154.0 MDKK, which account for a 1.48 and 1.03 % increase in the value of affected properties respectively. In total, 3,450 properties would be affected by the changes in OUDS 1 and OUDS 2. The hedonic method only included the benefit of these areas as experienced by the local homeowners who were affected directly.

The Aarhus property tax is 2.458 % of the property value. Therefore the additional income acquired by the municipality over a 100-year period with a discount rate of 3% is some 177 MDKK for OUDS 1 and 122 MDKK for OUDS 2.

In conclusion the authors state:

> *"A traditional framing approach would be to consider only the urban drainage sector in the analysis, leading to the result that pipe enlargements and open basins are equally suitable as adaptation measures against increased risk of flooding. When framing the analysis to include potential benefits of the OUDS; however, this solution turns out to be very likely best solution of the options considered. However, the value of the added recreational benefits is estimated under the assumption that only this part of the city will implement OUDS, and hence the change in environmental amenities is marginal in relation to the overall housing market captured in the hedonic function. If the entire city chooses to implement OUDS, the benefits are likely to be smaller than those estimated here, and the estimates should, therefore, also for this reason be considered an upper bound. This is because a widespread*

implementation of OUDS may affect the housing market's marginal pricing of the environmental benefits offered by OUDS, as supply change is no longer marginal."

So, although the methodology presented may be valid, provided the appropriate uncertainties are taken into account in the analysis, it is suggested that were SuDS to be implemented widely, then the hedonic pricing valuation would inevitably show that because 'everyone has green or blue' the advantage now to those few who do have green, expressed in elevated property values, would diminish and eventually disappear.

In a review of SuDS and their effects on property values Petrova (2011) showed that amenity (in terms of property values) can easily contribute to overestimation of ecosystem benefits, thus skewing the results towards more favourable NPV for SuDS. There were also a number of opportunities for double-counting of benefits in the study looking at a housing development in Ashford Kent.

4.2.3.4 Avertive Expenditure Approach

The Avertive Expenditure approach considers the expenditure incurred by household or firms to avoid or reduce the risk of environmental hazards. The theoretical basis is that individuals have already undertaken and implicit CBA of their financial resources and will spend only when the benefits of the actions exceed the cost. The limitations of this method are that it is expensive to implement through surveys and interviews and is restricted to instances where there is clear link between environmental hazards and expenditure. In a SuDS context this may be limited to water quantity (flooding) risks rather than water quality risks.

A similar range and classification of tools are identified by Defra (2007) in the context of Ecosystem valuation.

4.3 CBA for urban pollution management in the UK

In the water sector, the Foundation for Water Research (FWR, 1996) published a manual entitled "Assessing the Benefits of Surface Water Improvements" to provide water industry staff and associated regulatory agencies with a means of evaluating the benefits from improvements in surface water quality in response to emerging EU legislation. The manual provides guidance on the application of CBA and includes tables of standard values of benefits, including "non-use" benefits (the intrinsic value of water improvements as posed to directly derived economic benefit, that could be used to inform a desktop assessment of the viability of a scheme in terms of cost benefit ratio. The viability assessment had three possible outcomes:

(i) the scheme appears to be viable – benefit-cost ratio >3;
(ii) the assessment is ambiguous and no firm conclusions can be drawn benefit-cost ratio 0.3 – 3.0; and
(iii) the scheme appears not to be viable - benefit-cost ratio <0.3.

These criteria suggest limited confidence in the general applicability of the standard values and the manual listed the following limitations:

- a serious scarcity of general data;
- where available, data did not cover a full range of possible water quality improvements;
- limited local (UK) data and a need to rely on international valuations of benefits;
- poor degree of integration between scientific and economic literature, particularly on the definition of degrees on water quality improvement;
- most literature focused on general economic valuation of unit benefits and did not address the extent of use of the potential benefits.

Furthermore, practical applications of the methodology can be dominated by single factors. This was demonstrated by considering non-use values (ENDS Report, 1988) where the major element in the economic valuation of a watercourse's benefits was the public's "willingness to pay" for "non-use" benefits. Thames Water and the Environment Agency's evaluation of present value of the non-use benefits in an evaluation of a water abstraction scheme for the same watercourse were £0.3m and £13m respectively, demonstrating issues with setting boundaries for the beneficiaries (ibid).

Full guidance was given in the FWR manual on the derivation of the standard benefits values which allowed its' use to make an informed decision on accuracy and on their appropriateness for benefit transfer to specific locations. The standard benefits provided in the manual were themselves developed using benefit transfer, drawn from a range of literature. The manual also includes useful guidance on the benefit valuation approaches:

The Environment Agency (2003) produced a revised method "Guidance assessment of benefits for water quality and water resources schemes in the PR04 environment programme" that retained most of the features of the FWR method." This was also used for Section 25 of The SUDS manual (CIRIA, 2007) where it considers the cost and benefits of SuDS and suggests a benefits transfer approach where the assessed value of benefits from other studies are used to support the evaluation of benefits in a SuDS scheme or component. The manual suggests that benefit valuations from other studies can be used and proposes that the Environment Agency (2003) method above provides a possible source of benefit valuations. Surprisingly, the SUDS manual suggests only Contingent Valuation as a method of benefit appraisal, notwithstanding the range of valuation techniques used to support the Environmental Agency method. The manual provides a simplistic example of valuation of recreation and amenity benefits that requires a number of unsubstantiated assumptions due to the limitations in benefit valuations previously identified in the FWR (1996) method. The SUDS manual notes additional difficulties in assessing the benefit values for biodiversity and water quality improvement and concludes that no attempt would be made to value these in the example provided.

There is no evidence of any development of benefit valuation methodologies within the later SUDS for Roads guidance which was commissioned and guided by SCOTS and SUDS Working Party and authored by WSP, (SCOTS, 2009). Section 6.6.4 of the guide suggests again that the estimation of values of environmental benefits may be calculated using the Contingent Valuation Method and the supporting reference is the SuDS Manual 2007

4.4 Valuing surface water management in the UK

A comprehensive review of UK benefit-cost guidance was provided by (Digman et al, 2012). Table 4.6 summarises the features of the methods but it only identifies the available benefit evaluation data in a limited range of cases. A fuller analysis of the guidance is required to ascertain the data availability for SuDS Benefit evaluation.

Table 4.6 adapted from Digman et al (2012)

Name of guidance	What it includes	Other comments
SWMP guidance (Defra, 2010)	Guidance on the monetisation of costs and benefits and uncosted benefits and costs. Provides information on Net Present Value (NPV) and Benefit-Cost Ratio (BCR) assessments and dealing with uncertainty.	Straightforward introduction to benefit cost assessment. Limited actual data for value and cost of SuDS.
Flood and Coastal Resilience Partnership Funding Defra policy statement on an outcome-focused, partnership approach to funding flood and coastal erosion risk management (Defra May 2011)	Links outcome measures to present values and whole life benefits for grant-in-aid support.	Encourages direct community funding and consideration of wider outcome measures than just flood risk reduction in benefits
Understanding the risks, empowering communities, building resilience. The national flood and coastal erosion risk management strategy for England. (Defra/EA, 2011)	The strategy and principles that underpin the above and the delivery of many aspects of the Flood and Water Management Act 2010	As above
Preliminary Framework to assist the development of the Local Strategy for Flood Risk Management (Local Government Group, 2011)	Guidance and information about engaging communities and in assisting them to contribute directly to managing their local flood risk. Stresses the multi-benefit approach and provides information about alternative sources of funding	A living document.
Delivering biodiversity benefits through green infrastructure (CIRIA, 2011)	Provides guidance on assessing and including biodiversity benefits in schemes at the design, construction and operational stages.	Adaptive management linked to the construction cycle. Outlines the ‘accessible natural greenspace standard (ANGSt)
Valuing ecosystem services (Defra, 2007)	Guidance on valuing the natural environment. Usually applied to larger schemes.	Useful where there are significant environmental and ecological considerations.
Treasury Green Book (HM Treasury, 2003) and supplementary guidance Accounting for Climate	The primary guidance for many assessments including the economic assessment for flood and coastal erosion risk investment (EA, 2010).	Useful where there are significant flood risk reduction benefits.

Name of guidance	What it includes	Other comments
Change (Defra, 2009)	The supplement explains how to evaluate benefits and costs for adaptation and flexibility. These are usually applied to larger schemes.	
The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques - 2010 (Penning Rowsell et al, 2010)	Provides guidance on assessing the benefits of flood risk management options and the impacts resulting from flooding. It enables the practitioner to assess the relationship between costs and benefits.	The handbook is appropriate for most schemes. However, where the scheme is complex, use the more extensive Multi-Coloured Manual (Penning Rowsell et al, 2005).
Exploring the cost benefit of separating surface water from combined sewers (UKWIR, 2009)	Guidance for cost benefit of separating stormwater from combined sewers to reduce overflows. Asset based investment water industry criteria are used in the assessments which are from a sewerage undertakers' perspective.	Applicable mainly to sewerage undertakers and does not include many of the wider benefits potentially accruing to other stakeholders.
Sewer flood risk asset investment (UKWIR, 2007a and UKWIR, 2007b))	Methodology for cost benefit analysis for sewer flood risk asset investment. Complemented by Ofwat (2009) which deals with the use of NPV in asset investments.	Applicable mainly to sewerage undertakers.
Cost-benefit of SuDS retrofit (EA, 2007) Carbon related aspects of source control & related costs and benefits (EA, 2009)	Benefit cost assessment information for a reduced range of SuDS measures. Includes only a limited range of non-monetisable benefits. Relates costs to carbon abatement and sequestration for green SuDS.	The benefit cost assessment boundaries are limited in the analysis.
SuDS manual (CIRIA, 2007)	Provides guidance on SuDS design, and whole life costing.	The primary source for SuDS related cost data in the UK but would benefit from more recent data.
Cost-benefit of SuDS retrofit (Environment Agency, 2007) Carbon related aspects of source control & related costs and benefits (Environment Agency, 2009). **Rainwater harvesting (RWH) and SuDS – Carbon Implications for Wales (Environment Agency Wales and Arup, 2011).**	2007 report has benefit cost assessment information for a reduced range of SuDS measures. Includes only a limited range of non-monetisable benefits. Relates costs to carbon abatement and sequestration for green SuDS. The 2011 report updates this assessment and shows when and where retrofit RWH can be beneficial in terms of both carbon and downstream flood risk reduction	The benefit cost assessment boundaries are limited in the analysis in the 2009 report. The 2011 report links the analysis to the DCWW' surface water management strategy and the use of small scale (200litre) RWH.
BS42020: 2013 Biodiversity — Code of practice for planning and development **& CIRIA report C711 (Dale et al, 2011) on Delivering biodiversity benefits through green infrastructure**	2013 British Standard gives "recommendations and guidance for those in the planning and development and land use sectors whose work might affect or have implications for the conservation or enhancement of biodiversity. As such it is applicable to professionals working in the fields of ecology, land use planning, land management, architecture, civil engineering,	Although the BS 42020 does not explicitly include costs and benefits, it deals with 'significance': In general terms, a "significant impact" is an effect which is important, notable, or of consequence, having regard to its context. Whether an action is likely to have a "significant" impact depends upon the "sensitivity"

Name of guidance	What it includes	Other comments
	landscape architecture, forestry, arboriculture, surveying, building and construction."	of the resource that is affected (including consideration of such factors as its scientific and social value, its status, condition and quality), and upon the "magnitude"."
Scottish Water retrofit SuDS project (Atkins, 2004)	Provides a discussion of benefits to be considered and costed examples.	Current thinking has advanced but still a very useful source of information.
Sustainable drainage Cambridge design and adoption guide (Wilson et al, 2009)	Data on the maintenance costs of SuDS which, although set up for new build may also be applicable to retrofit.	A typical example of Local Authority guidance for developers.

4.5 Summary of existing valuation studies

A number of existing studies have sought to value some (or all) of the benefits of SuDS. Table 4.7 summarises those that are those likely to be the most relevant to the current study. A total of 25 sources, including site-specific SuDS projects, general studies and toolkits, were reviewed in detail, with particular attention paid to:

- Description/driver
- Benefits identified
- Indication of values derived
- Data confidence
- Applicability to project

It is worth noting that the majority of studies consider costs in much greater depth than benefits (e.g. Royal Haskoning, 2012).

Table 4.7 Economic benefits of surface water drainage systems - Summary of studies reviewed

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
Ashley et al (2012) **(See also Appendix A of this review which provides a detailed inventory of the benefits identified)**	Considers use and application of benefits assessments around the world, and the applicability of these to the SKINT project within ecosystem services approach. Main driver is stormwater management and wider benefits.	• Reduced water treatment needs • Improved water quality • Reduced grey infrastructure needs • Reduced flooding • Increased available water supply • Increased groundwater recharge • Reduced salt use (on roads in winter) • Reduced energy use • Improved air quality • Reduced atmospheric CO2 • Reduced urban heat island • Improved aesthetics • Increased recreational opportunities • Reduced noise pollution • Improved community cohesion • Urban agriculture • Improved habitat • Education opportunities	**CNT** (Centre for Neighbourhood Technology) • Reduced air pollution $0.181 per tree • Carbon sequestration $0.12 per tree per year • Compensatory value of trees $632 per tree • Groundwater replenishment $86.42 per acre-foot infiltrated • Reduced energy use $0.18 per sq ft of green roof per year, 5-10% energy savings from shading & wind blocking per 10% increase in tree cover • Reduced treatment costs $29.94 per acre-foot of reduced runoff **Other** • $1,100 to $12,938 per waterfront for one meter change in water clarity (turbidity reduction) • 5,000 sq ft green roof, avoided infrastructure cost saving of $7,588 • SEA Streets in Seattle 15–25%, or $100,000–$235,000 per block • GINW - WtP of £0.41–£1.14 per household per year for preserving a SSSI • £0.33–£0.90 per household per year to increase an area of commercial woodland by 12,000 ha • Recreation - £951.40 per year for each additional vegetated acre • Improved aesthetics - property values of 2-10% from new street tree plantings (CNT: 3.5%) • Annual property value gains per tree over 40-yr average in the Midwest US region range from $4.50–$23.44 in residential yards depending on size of tree, compared to £5.32–£27.69 for public space, depending on size of tree.	Medium (comprehensi ve review, but wide range of studies, values, units)	Medium (some values may be useful)
American Rivers (2012)	Compendium of current experiences, analysis and Knowledge, driven by	Wide range of financial, social and env	Very few generic benefit estimates provided, since report cites cost savings from GI measures implemented in schemes across North America. However, some values potentially useful, e.g. Canadian study which found green roofs reduce indoor energy consumption by 7–10% per year	Medium (broad review of studies brought together and critically	Low (all US based and applicable to specific schemes, so difficult to

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
	stormwater management			appraised)	apply
Bastien et al (2011)	Considers potential value to residents of living in close proximity to a SuDS pond.	Amenity (mainly encompassing safety, proximity, visual impact, green space; although may have captured aspects of biodiversity, recreation, education)	£10.95 per month per dwelling for the residents living in close proximity (5 mins walk or 400m) to ponds	High (detailed questionnaire based study)	Medium (reliable estimate but likely to result in double counting if combined with other estimates)
CAVAT (2012)	Tool to estimate financial cost of replanting a tree for use in compensation claims	Trees - cost can be adjusted for location, relative contribution to amenity value, and assessment of functionality and life expectancy.	None	Low (no values presented and assessments dependent on expert judgement)	Low (measures cost of replanting and maintenance, not value of ecosystem services)
CNT (2010)	Wide ranging review of benefits associated with non-traditional means of stormwater management	• Regulating services: climate regulation (inc air pollution), water regulation • Cultural services: recreation and ecotourism	See Ashley et al (2012) above)	High (comprehensive review, wide range of studies, values, units)	Medium (US based, so input data/assumptions will need to be replaced with UK specific data
CIRIA (2013)	Broader engagement in WSUD	Wide range of financial, social and environmental benefits	Very few generic benefit estimates. However, some values potentially useful, e.g. water butt saves £33 on water bill	Medium (but little quantification)	Low (sparse values)
City of Portland (2010)	Stormwater management best management practices (BMPs) (eco-roofs, green streets, trees, invasive removal and	• Health • Energy and carbon sequestration • community liveability • Air quality improvement (PM10, respiratory symptoms)	Most benefits not monetised. However, study does suggest • 3.5 - 5% increase in home values with green streets + swales + culvert removal • $7,953 Increase in home value per tree in front of house.	Low (benefits estimates cited are from secondary	Low (old study, distant location)

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
	revegetation, culvert removal, land purchase and planting in natural areas). Benefits assessed using ecosystem services approach	• Increased greenness (physical and mental health) • Energy savings (electricity usage) • Greenhouse gas reduction (carbon sequestration and emissions) • Amenity/aesthetic improvements (property values) • Community cohesion (social capital, crime) • Access to nature (number of people affected by BMPs) • Environmental equity (relative share of BMPs in minority/low income neighbourhoods)	Benefits to neighbouring home values $7,098 per tree (ref Donovan and Butry, 2008) • Homes within 600-800 ft of natural parks had 17% price premium, from 800-1,000 ft had 13.6% premium (ref Lutzenhiser and Netusil) • Residents willing to pay 3-13% of house price for streambank restoration program (Steiner, 1996).	data)	
Defra (2011c)	Comparative costing information of conventional drainage solutions and SuDS, from various UK case studies, compiled in series of technical reports.	• Amenity • Biodiversity • Others mentioned (e.g. avoided car journeys)	• No benefit values provided	N/A (no values provided)	Low (no values presented)
Eftec (2013a)	Assesses robustness, usefulness and applicability to the UK of a number of green infrastructure (GI) valuation tools, using ecosystem services framework	No specific	• None	Medium - concludes that estimates produced by GI tools are appropriate for appraisal of small scale GI projects, or to make an initial case at outline stage of project	Low (no values presented)
Eftec (2013b)	Considers extent to which investment in Green Infrastructure increases economic growth, and evidence to support this	• Change in economic activity as measured by gross domestic product (GDP)	• Cites values from series of UK and international case studies. • For example. park improvement in Glasgow led to: 47% increase in Council Tax receipts; 28% increase in the number of employees in area; 230 jobs supported; 15% increase in rateable value from business. • Canal and canal-side improvements in Birmingham led to 30 FTE jobs created plus 77-96 jobs supported through visitor expenditure; 25.7 – 57.1 million property value uplift.	Medium (paper notes some concerns about additionality – extent to which the improvements	High (some UK evidence relating to different economic and social changes that might be expected

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
				would have happened anyway)	from SuDS measures)
Environment Agency (2007)	Compares the costs and benefits of replacing traditional systems with SUDS	• Avoided flooding • Demand reduction for water • Avoided pollution	• Benefit of avoiding flooding incident - £39,000 per incident • Reduced demand – water bill saving of £2.01/m^3 • Benefit of avoiding CSO - £51,000 per CSO	Low (contribution of SuDS measure to cost savings not clear)	Low (mainly assumed cost savings, rather than benefits)
Environment Agency (2009)	Whole-life (capital and operational) greenhouse gas emissions and costs of range of SuDS measures, with measures evaluated using multi-criteria analysis and marginal abatement cost curves	• Greenhouse gas emissions • Energy savings	In a situation where SUDS are installed in an existing development over a one hectare permeable area, and this results in all of the surface runoff being diverted away from the STW, the avoided cost of pumping (energy and CRC costs) to the water company is up to £88 per annum, and potential carbon savings of 0.5 tonnes per year.	High (detailed study of single benefit type)	Medium (useful for benefit types referred to)
Environment Agency (2013a)	Economic valuation based on stated preference survey, for use in river basin management planning	Recreation, amenity & non-use benefits from improving the water environment Values are provided per catchment and are per km (rivers) or per km^2 (lakes), and align with WFD improvements	Central estimate (Eng & Wales) • £17,400 (bad to poor) • £20,000 (poor to mod) • £23,200 (mod to good)	High (large sample extensively tested and reviewed)	High (but only where SuDS measures will tangibly improve surface waters)
European Commission (2013)	Supporting information to the Commission's Green Infrastructure Strategy, '*to promote the deployment of green infrastructure in the EU in urban and rural areas*'	• Enhanced efficiency of natural resources • Climate change mitigation/adaptation • Disaster prevention • Water management • Land and soil management • Conservation benefits • Agriculture and forestry • Low carbon transport and energy • Investment and employment • Health and well-being • Tourism and recreation	Very high level values (e.g. total NPV) from 120 GI-related projects around Europe.	???	???

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
		• Education • Resilience			

Foster et al (2011)	Includes information on the costs and benefits of "green"
	
	infrastructure solutions for bolstering local adaptation to climate change
		Various environmental and social benefits	**Includes values from existing studies. For example:**
			
			• **New York City's** 2010 Green Infrastructure Plan aims to reduce the city's sewer management costs by $2.4 billion over 20 years estimates that every fully vegetated acre of green infrastructure would provide total annual benefits of
			  • $8,522 in reduced energy demand
			  • $166 in reduced CO2 emissions
			  • $1,044 in improved air quality
			  • $4,725 in increased property value
			• Green roofs save 15-45% of annual energy consumption
			• Toronto estimated that installation of green-roofs city-wide could save an initial $313,100,000 and $37,130,000 annually
			• Net economic benefits of mature urban trees range from $30-90 per year for each tree
			• General increases of up to 37% in residential property values associated with the presence of trees and vegetation on a property
			•
				Low (biophysical analysis either side-stepped or quantification of benefits left to user)	Low (welfare and economic impact estimates mixed, unit values not substantiated, high risk of double counting)

Green Infrastructure North West (2010)	Valuation toolkit to enable users to identify and broadly assess benefits of proposed green investments and existing green assets – whether those benefits directly contribute to a local economy, or provide wider non-market returns for society and environment.	• Climate change adaptation/mitigation • Water and flood management • Place and communities • Health and wellbeing • Land and property values • Investment • Labour productivity • Tourism • Recreation and leisure • Biodiversity • Land management	• Average heating energy savings per tree 3-9% • £8,800 (one-off, 2010 prices) per household, view of green space including woodland • Pollutant absorption capacity ($0.04/year for small trees to more than $2/year for large trees) • Amenity – minimum 5-7% premium for houses near parks • Use of green space - £4.46 per trip • Biodiversity – £0.41 to £1.14 per household per year for preserving or creating individual SSSIs	Medium (benefits are a mix of welfare measures and traded economic impacts, not directly comparable	Medium (care needed to define benefit categories and avoid double counting)
Health Economic Assessment Tools (HEAT) for walking and cycling (2011)	Measures value of statistical life	• Health (reduced mortality risk) benefit of recreation	• In the UK, VSL is estimated as around £1.6 million (Dft, 2002). While this estimate is based on fatalities due to transport accidents, this is currently the only official estimate used across all policy areas.	High (based on review of published scientific research. Tool itself is peer reviewed and	High (where walking and cycling are likely to be impacted, although should replace

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
				tested)	default values with UK specific data)
Ifpra (2013)	Ecosystem services approach considering benefits of urban parks compared to other land uses. Documents current scientific evidence for urban park benefits.	Cultural services • human health & well-being • social cohesion and identity • Tourism • House prices Regulating services • Biodiversity • Air quality & carbon sequestration • Water management • Cooling	Largely qualitative description of studies, monetary values not provided.	Low	Low
Naumann et al (2011)	Supports European Commission Green Infrastructure Strategy, which in turn supports Target 2 of the EU biodiversity strategy to 2020 ("By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems").	• Ecosystem services • Wildlife • Socio-economic • Multiple	Includes project database, with 127 GI projects. Quantitative evidence only found in 17 of these. These are cited in Table 25 and include: • Dearne Valley - creation of 300ha of wetlands led to 11 new FTE, increase in visitor numbers from 12,000 to 50,000 per annum • Glasgow Green – 3 fold increase in value of land • Mesnes Park – increase in visitor numbers from 15,000 to 180,000 • Queen Square – 16% house price premium • Mile End Park - 7% uplift in value for residential properties) Tables 27, 28 and 29 suggest, for National Forest, 6,229 ha woodland created led to • 66,000 tonnes carbon sequestered (209 million euros in PV terms; £50 per tonne) • 1,750 ha habitats created (56 million euros) • 84% of local population satisfied by landscape improvements (57 million euros) • 6 woodfuel installations provided (11 million euros) • 8,686,500 visitor days/year (628 million euros; £2.50-£12.50 per visit)	High (estimated values come mainly from detailed, robust studies)	High (may be useful if estimates from larger studies can be scaled down to local/individual GI measures)

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
			• 44 million euros of regeneration benefits (£0.05 per household per hectare of forest created) • 333 forest jobs created • 321 million euros to local economy • 186,000 children involved in environmental education Other projects in database have mainly qualitative descriptions of benefits, but report concludes that GI delivers multiple benefits and that "even partial assessments of the value of the benefits of green infrastructure indicate that they can significantly exceed the costs".		
Pagano & Weber (2003)	Market failures (externalities, public goods, and natural monopoly) in provision of environmental infrastructure in Chicago. Principal focus is identifying potential revenue streams & financing mechanisms that could be used for Green Infrastructure.	• Flood mitigation • Water quality improvement • Ecosystem functioning • Reduced site development costs (by investing in soft, rather than hard, infrastructure)	• $1,000 - $4,000 per lot (residential development) • $4,000 - $10,000 per lot (commercial or industrial developments)	Low (values are from an earlier study)	Low (old study, distant location)
Royal Haskoning (2012)	Collation of values from previous studies, focused on "adaptation action that could cost-effectively manage current and future flood risk in England"	• Reduced risk of pluvial flooding events • reduced loading on surface water sewer systems • Reduction in diffuse pollution in surface water bodies • Provision of an alternative source of non-potable water for domestic and commercial uses, improving water efficiency and reducing water bills • Recharge of groundwater aquifers where appropriate through infiltration measures. • Enhancement of biodiversity through habitat provision • Reduction in energy consumption, particularly through installation of green roofs • Enhanced amenity and quality of life for	Mix of benefit estimates reported, including • net benefit of SuDS to new developments over a 50 year period £56 - £5,608 million (Flood and Water Management Bill, Defra, 2009) • Developers saving £600 per property from not connecting to sewer through the use of SuDS (impact assessment for the national SuDS standards, Defra, 2011) • WaSCs save £60 per year for each development unit built with SuDS (operation and maintenance savings, ibid) • £39,000 overall saving from one avoided flooding incident due to hydraulic overload of the sewer system. (Environment Agency, 2007) • £2.01/m^3 water bill savings based on amount of mains water saved for water saved through use of rainwater harvesting and water butts (ibid)	Low (estimated based on earlier studies)	Low (presents mix of values from range of sources relating to different benefits assessed using different methods)

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
		residents	• Electricity savings form green roofs £5.20/ m^2/year (The Solution Organisation, 2005). • Flood protection - $1,000 per acre-foot (1,230m^3) of reduced flow from a site during 100 year storm. This equates to $0.81/$m^3$ (CNT)		
Stratus Consulting (2009)	Triple bottom line (financial, social & environmental cost-benefit analysis) to controlling CSO events. Sixteen control options (including traditional infrastructure) considered for each of four watershed areas. Two main options considered: • 50% option [runoff from 50% of impervious surface in City of Philadelphia managed through GI • 30' Tunnel option (system of storage tunnels with an effective diameter of 30 ft, serving all watersheds).	• Recreation • Increased community aesthetics (reflected in higher property values) • Heat stress (premature fatalities avoided) • Water quality and aquatic ecosystem improvements • Wetland creation and enhancement (190 acres) • Poverty reduction from local green jobs (additional 15,000 job years) • Energy savings (370 million kWh of electricity and 600 million Btus of natural gas) and carbon footprint reduction ($12/metric ton social cost of carbon) • Air quality improvement (0.5 million gallons of motor fuel delayed; 1,500 MT of SO2 saved; 1.1 million MT of CO2 saved; 38 MT of NOx saved) • Air quality (pollutant removal from added vegetation leading to 1 - 2.4 premature fatalities avoided per year,1.2 heart attacks avoided per year, 700 cases of other respiratory illness days avoided per year) • Construction- and maintenance-related disruption (additional travel time and traffic disruption)	Results for 50% option (2009 million $US, present values) • Increased recreational opportunities $524.5 • Improved aesthetics/property value (50% of value used to account for potential double counting with other benefit categories) $574.7 • Reduction in heat stress mortality $1,057.6 • Water quality/aquatic habitat enhancement $336.4 • Wetland services $1.6 • Social costs avoided by green collar jobs $124.9 • Air quality improvements from trees $131.0 • Energy savings/usage $33.7 • Reduced damage from SO2 and NOx emissions $46.3 • Reduced damage from CO2 emissions $21.2 • Disruption costs from construction and maintenance $(5.6)	High (detailed study)	Medium (recent, robust study but distant location leading to some key differences, e.g. focus on and importance of reduced heat stress)
Taylor (2012)	MSc thesis considering feasibility of retrofitting rains gardens to domestic properties as part of downpipe disconnection programme at case study location in South Wales. Largely uses values from previous studies.	Wide range of financial, social and env	• £30 (approx) rebate if property disconnected from sewerage network • Cites Mourato et al. (2010) value of £171-£575 per person per year for health benefits (quality adjusted life years) associated with using a garden at least once a week • Estimated cost of each CSO is £51,000 (Gordon-Walker, Harle and Naismith 2007) • Ozdemiroglu et al. (2004) WTP for a reduction in environmental impact of CSOs discharging to Thames. Mean WTP for improvements to reduce CSOs was £58.94, reducing to £24.84 for those who never saw the river • 1.3% increase in house prices arising from rain gardens	Medium (based on existing studies)	Medium (useful values but questions on robustness and reliability)

Source	Description	Benefits identified	Indicative values derived/cited	Data confidence	Applicability to this review
			• Education £4,425 (value of visits to scheme)		
Wise et al (2010)	Broadly adopts ecosystem services approach, taking values reported in earlier studies with focus on stormwater management	• Reduced flooding • Water quality • Capital and avoided cost savings • Energy consumption • Property value • Urban heat island effect • Community health • Global climate change	• Air quality - health benefits (fewer premature deaths; fewer cases of chronic bronchitis) of reduced NO2 emissions at \$1680 to \$6380 per Mg in 2006 dollars (Clark et al 2008; US EPA 1998) • Property value - 20% guideline for increased property value for those properties fronting or abutting a park (Crompton 2005). Studies of the impacts of pond frontage on property value have found increases ranging from ten to 25 percent (EPA 1995; Emmerling-Dinovo 1995). • Recreation - direct use value of \$70,308 per acre of Boston parkland (Harnick and Welle 2009). Direct use values approaching \$100,000 per acre in Philadpehia parkland (Trust for Public Land 2008). • Avoided grey infrastructure costs - \$3.43 per 100 cubic feet, or \$0.0046 a gallon (McPherson et al 2006). • avoided construction costs - \$3,500 to \$4,500 per quarter-to-half acre residential lots (NRDC 2006). • Reduced treatment costs – \$8.50 to remove a pound of suspended solids, and \$6 to \$12 to remove a pound of phosphorus (CNT 2009). For range of pollutants, CNT's Green Values Calculator: \$29.94 per acre foot of runoff reduced, or \$0.0000765 per gallon. • Groundwater recharge – water recovered for cities or industries was \$100 per acre-foot, while water for pasture irrigation was \$5 per acre-foot) (USDA 1967). CNT (2009) - \$86.42 per acre-foot • Noise – 32.10 euros (46.79 USD) and a median value of 23.5 euros (34.26 USD) per decibel per household per year. Or average reductions in property value per one decibel increase in noise level of 0.55% and 0.86%, respectively (Navrud 2003)	High (comprehensive review, wide range of studies, values, units)	Medium (US based, so input data/assumptions will need to be replaced with UK specific data

In addition to the studies shown in Table 4.7, thirteen studies from the USA are described in USEPA (2013). There is no consistency between the various studies presented in the report as to how the economic benefits of stormwater control measures have been assessed and a variety of different approaches have been taken. The studies also incorporate collectively a wide range of reasons for the analyses and various different scales from local to city-wide: "The Portland Bureau of Environmental Services focused its analysis on a single best management practice (BMP), green roofs, to gain support from developers and building owners. The Philadelphia Water Department (PWD) conducted a benefit-cost analysis (BCA) to compare the benefits and costs of city-wide grey and grey/green stormwater management alternatives".

This report brings together the most comprehensive set of surface water related studies so far published worldwide. Although different, each of the thirteen studies had common characteristics and overall lessons could be drawn for the analysis of the overall benefits of economic analysis of the use of GI (SuDS) for surface water management.

The conclusions from the report were:

- The use of SuDS instead of piped (Grey) infrastructure is invariably less costly even without considering the added benefits over and above managing stormwater quality (the primary purpose of each of the thirteen systems)
- Very few of this type of economic study have been undertaken in the USA "due to uncertainties surrounding costs, operation and maintenance (O&M) requirements, budgetary constraints, and difficulties associated with quantifying the benefits provided by LID/GI".

The overall lessons learned were:

- Reasons for undertaking the analysis
    - to address public concerns and gain public and stakeholder support;
    - to gain funding from a wide range of stakeholders
    - to obtain developer support
    - to share costs between the State and other partners
    - for local, state, federal government policy and financial support
- Using economic studies to optimise the benefits of investments
    - to develop an easily understandable means of assessing the benefits and costs of options for stormwater management (Capitol Region Watershed District)
    - to support findings that showed that a GI approach was the only feasible option for water quality improvements (Chalotte-Mecklenburg)
    - to demonstrate the significant opportunities arising from using GI for CSO spill abatement (New York City)
- Costing less than grey infrastructure options
    - Substantial cost savings for a multi-family, commercial and warehouse development compared with grey approaches (City of Lenexa)
    - Permeable pavement found to be cheaper in whole life cost terms than bituminous or concrete road pavements in downtown areas as it is cheaper for maintenance longer term (West Union, Iowa)

  - GI found to be cheaper than a new separate storm sewer and GI also provided more water quality benefits (Capital Region Watershed District, Iowa)
  - Ecoroof programme NPV showed both immediate and long term benefits; for an ecoroof with a 40 year life the net present benefit to the owner is some $400,000 (Portland, Oregon)
- Provision of multiple benefits
  - Not all projects reviewed considered the quantification of all of the possible benefits
  - Public and private benefits need to be considered separately so that each can be seen to exceed the costs (Portland, Oregon)
  - The use of GI provides some 20x the value compared with the sewer tunnel option to manage CSO spills for the same performance (Philadelphia)
  - By considering the overall benefits over a long timescale the benefits of GI were shown to outweigh the costs, and also the benefits from the alternative options, providing greater long-term value to the community (Los Angeles)
  - Although not monetised, the non-market benefits of using GI instead of a piped drainage system to manage flooding, were found to be considerably greater. (Capitol Region Watershed District).
- GI approaches can be successfully integrated into capital improvement programmes
  - A benefit evaluation matrix helped to define the institutional framework required to deliver the solution (Kirkland, WA)
  - GI integrated into long-term planning processes taking a watershed approach to adaptive stormwater management (Milwaukee Metropolitan Sewerage District)
  - New scrutiny and examination of drivers for implementing projects so as to provide the greatest overall benefits (Charlotee-Mecklenburg)
  - Inclusion of GI projects in long-term capital planning (Los Angeles)

A number of other sources in addition to Table 4.4 and the USEPA (2013) study above were also investigated but not considered further due to lack of monetary valuation evidence or published material of sufficiently high quality as shown in Table 4.8

Table 4.8 other sources of SuDS benefit valuation considered, but not found to be of any significant contribution here

Source	Link
SUDSnet International Conference - Multiple Benefits from Surface Water Management	http://sudsnet.abertay.ac.uk/presentations/National%20Conf%202012/SUDSnet_2012_ConferenceBook_web.pdf
SUDs Cost Benefit Analysis: Harrow Way SUDs, Kent	http://sudsnet.abertay.ac.uk/May%202011/Petrova_SUDS%20Cost%20%26%20Benefit%20Analysis.pdf
Comparative Costings for Surface Water Sewers and SuDS: Daniels Cross, Newport, Shropshire	http://www.susdrain.org/files/resources/evidence/defra_suds_costings_housing_daniels_cross_.pdf
A simple economic model for the comparison of SUDS and conventional	L.N. Fisher-Jeffes and N.P. Armitage, http://web.sbe.hw.ac.uk/staffprofiles/bdgsa/temp/12th%2

Source	Link
drainage systems in South Africa	0ICUD/PDF/PAP005246.pdf
A cost comparison of traditional drainage and SUDS in Scotland	Duffy, A., Jefferies, C., Blackwood, D., Waddell, G., Shanks, G. and Watkins, A. (2008). A cost comparison of traditional drainage and SUDS in Scotland, *Water Science & Technology*, Vol. 57 No 9 pp 1451–1459
Sustainable Urban Drainage Systems for Roads (Scotland)	http://www.scotsnet.org.uk/documents/SudsforRoads.PublishedAug2009.pdf
Forest Research	http://www.forestry.gov.uk/fr/INFD-8AEHPX
Sustainable Urban Drainage Systems (SUDS) – More than a drainage solution?	S. Kennedy, L. Lewis, E. Sharp and S. Wong (2007) Proc. Novatech conference, Lyon. http://documents.irevues.inist.fr/bitstream/handle/2042/25177/0423_219kennedy.pdf?sequence=1
Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto	http://www.toronto.ca/greenroofs/pdf/fullreport103105.pdf
Translating Legislative Requirements and Best Practice Guidance into a Systematic, Multi-Criteria Decision Support Framework for Effective Sustainable Drainage Design Evaluation	Chow J-f (2013) Proceedings of 2013 IAHR World Congress
Towards the best management of SuDS treatment trains	N.R.P. BASTIEN (1), S. ARTHUR (2), S.G. WALLIS (3), M. SCHOLZ http://web.sbe.hw.ac.uk/staffprofiles/bdgsa/Scott%20Arthur%20Papers/Towards%20the%20Best%20Management%20of%20SuDS%20Treatment%20Trains.%20DIPCON%20KOREA.pdf

In addition, there are various studies that have estimated the value of improvements that may be relevant to SuDS schemes, but which have not been used in any of these studies reviewed. For example:

- Defra (2013b) values local environmental quality in neighbourhoods. This found that willingness to pay for an improvement in trees was around £2.33 per person per month, the same as the value for an improvement in odour;
- Environment Agency (2013b), which includes values for various ecosystem services associated with improvements to the water environment, including creation of wetlands, angling, recreation and flood control; and
- eftec (2010), which provides guidance on the valuation of environmental benefits from habitat creation and restoration within the context of flood and coastal erosion risk management (FCERM) projects and strategies.

In summary, this review has revealed that there are a number of methods and approaches being used to include benefit assessments in appraisals and decision-making. However, linking SuDS to measurable outcomes is problematic.

Further, in many instances the source of the data used is opaque and often highly specious. There are also acknowledged double-counting issues (e.g. GINW, 2011) and a great deal of uncertainty and variation in the values presented. Therefore, as yet none of the approaches can be considered to be comprehensive or sufficiently robust for general applicability to SuDS benefit assessment.

5 IMPLEMENTING SUDS

5.1 Funding Review

There are many benefits of SuDS as detailed elsewhere in this report, the linkages between benefits, interventions and the requirement to evaluate the outcomes are complex and fraught with challenges. The underlying concept for securing funding for traditional FCERM is that of partnership working and beneficiary contribution (e.g. Defra/EA, 2011). Funding SuDS delivery often needs to build on the partnership approach requiring a creativity to fundraising applications that considers the reduction in flood risk as just one of the many benefits. To ensure success in securing funding, projects need to be developed that package together a number of outcomes and outputs with a range of delivery partners as well as a good understanding of who the beneficiaries are.

Table 5.1 provides a top line summary of the main funding sources that are available and the kind of benefits that a project will need to deliver if it is to be successful in its attraction of funding.

Data in Table 5.1 has been compiled from 'Partnership funding and collaborative delivery of local flood risk management' prepared by Halcrow Group Ltd in 2012, updated and revised by CH2MHill's Fundraising and Partnership Specialist in August 2013. Judgements about appropriate benefits have been made by CH2MHill's fundraising team using assumed values and the general themes published by the funders.

There are many instances where local need can override a funder's given funding themes and conversely where funds are provided seemingly in opposition to the funders' own given guidelines. The devil is also in the detail, many funders will fund types of projects within given parameters or if certain conditions are fulfilled, such as securing a set proportion of matched funding from the community or only providing set percentages of capital or revenue funding. Table 5.1 is intended as a high-level guide to highlight the requirement for each project to identify and promote a broad range of benefits if it is to increase its likelihood of securing funding.

5.2 Funding Detail

Table 5.2 considers the funding sources in more detail, giving guidance as to how applications should be made, by who and when. All of the sources of funding listed are considered good prospects for flood mitigation and risk management measures but some are more relevant to SuDS than others. This is indicated in the score given in the final column. This scoring is derived from the experience of the CH2MHill's funding team, combined with the funder's published guidance and should only be taken as indicative. There are regional variations with some funds; so more detailed research should be undertaken if the data will be used for a project specific fundraising plan.

Table 5.1 Third Party Funding at a Glance

Funder	Applicant body	Application Timing	Application Requirements	Funding Allocation	In a word, suitable for…	Suitability for Suds (1 is high, 3 is low)
Flood Defence Grant in Aid	Flood risk management authorities	End of June	LFRA needs to construct a Medium Term Plan in liaison with their EA FCR Manager which then leads to a series of application stages.	See EA website for detailed guidance	All flood types	2
Local Levy	Regional Flood and Coastal Committee	Annual	Local Levy is held by the RFCC, the details of its application are voted for annually by elected members on the RFCC	Programe of expenditure is set by the RFCC accroding to local and regional priorities	All flood types	2
Community Infrastructure Levy	LA's are responsible for setting and collecting CIL charges. Once collected LA's are free to allocate the funding in line with processes established by the LA in question.	None	Varies according to LA	Need to sell flood risk as a local priority; need to be included as early as possible on the LLFA's Infrastructure Delivery Plan	All flood types	2
Developer based contributions (s106)	Local planning authority is responsible for negotiating, collecting and managing funding obtained from developers.	Any but note early engagement requirement to build project into LA s106 purposes.	Varies according to LA	S106's are linked to an agreed purpose specified in the agreement terms for each development.	New developments	1
Council Tax Levy	LA's are responsible for setting and collecting Council Tax and then redistributing where applicable	Varies according to LA but usually budgets are drawn up in Sep /Oct for the following financial year	LA Flood Risk Managers should work with Members, Finance Officers and colleagues in other departments to promote flood risk management as a priority.	For specific expenditure requirements; requires agreement through a referendum of the whole Authority area	All flood types	1
Council Tax Precept	LA's are responsible for setting and collecting Council Tax and then redistributing where applicable	Varies according to LA but usually budgets are drawn up in Sep /Oct for the following financial year	LA Flood Risk Managers should work with Members, Finance Officers and colleagues in other departments to promote flood risk management as a priority.	Specific components of council tax may be levied and redistributed to other agencies. This can be used to fund LFRM capital delivery and / or ongoing maintenance of flood defences or surface water management systems. Well suited for smaller annual summs	All flood types	1
Public Works Loan Board	Local Authorities, IDB's and Parish Councils	None	By registered applicant only; by telephone	Applicant has to demonstrate its ability to meet the costs of borrowing through future revenues.	Infrastructure	3
Business Rate Supplement	Upper tier LA's can levy a local supplement on the business rate	Annual	Consultation and in some cases a ballot of local businesses.	Must demonstrate a clear case for a positive cost benefit to local businesses	Business growth	2
Regional Growth Fund	Private sector companies and private / public partnerships	Round 5 details will be announced in Autumn 2013	Working closely with RGF advisors to develop a robust business plan and economic appraisal of the project	The RGF has been designed to create jobs so this must be a clear outcome; minimum bid of £1m	Business growth	3
Tax Increment Funding	LA with private sector partners	None	Infrastructure in areas of deprivation that will stimulate business growth	Raises money up front on developments which will be recouped through increased business rate revenue when the project is complete	Business growth	3
Business Rate Retention	Local Authority - From April 2013 central government allowed LA's to retain a set proportion of Business Rates to allocate as they saw fit.	Annual	LA Flood Risk Managers should work with their colleagues to ensure the flood risk portion isnt allocated elsewhere as funds are not ringfenced.	Must demonstrate a positive impact on business growth	Business growth	2
Revenue Funding for new LLFA	Allocated by Defra and managed internally by LA's	Annual	LA Flood Risk Managers should work with Members, Finance Officers and colleagues in other departments to promote flood risk management as a priority.	Must demonstrate a case for the reduction of flood risk	All flood types	1

Funder	Applicant body	Application Timing	Application Requirements	Funding Allocation	In a word, suitable for…	Suitability for Suds (1 is high, 3 is low)
New Homes Bonus	Dept for Communities and Local Government allocates the New Homes Bonus	Annual when council budget is set	According to local priorities	Funding is meant to reduce the strain on public services and local amenities caused by new housing developments so is designed to mitigate the strain an increased population causes.	New developments	2
Business Improvement Districts	Collected by LA's	Annual	LA Flood Risk Managers should work with Members, Finance Officers and colleagues in other departments to promote flood risk management as a priority.	Must demonstrate a positive impact on business growth	Business growth	2
Asset Backed Financing	Asset-backed vehicle present in the area	None	The ABV levers long term investment from the private sector using LA assets.	Best suited to areas that offer a portfolio of assets and a pipeline of regeneration assets	Regeneration	3
PPI / PFI	Alliances between public and private bodies set up to deliver a specific public project	None	Creation of a suitable investment vehicle	Tend to suit large scale infrastructure projects	Infrastructure	3
DEFRA one-off grants & pilot projects	Flood risk management authorities	Not set	Vary according to the call for proposals	Vary according to the call for proposals	Various	2
WFD funding	Third sector groups and Local Authorities	None	U/K	Projects need to deliver outcomes in line with the WFD - reduced pollution of groundwater, promote sustainable use of water.	Environment	2
Catchment Restoration Fund	Third sector groups	Annually - May?	Connects actions at a catchment scale so looking for applications with a suitable scope	Reducing the impact of diffuse pollution from urban and rural land use	Environment	2
Primary Healthcare Trust	Any	None	This isnt a formal funding stream. Funding can be secured through close partnership working and shared outputs and outcomes	Needs to contribute to local health requirements - child obesity, smoking etc	Health	2
ERDF	Managed by the Local LEP	Varies - usually annually	The new regional allocations for 2014 to 2020 have been announced by Vince Cable. LEP's have until end Jan 2014 to submit their European Structural and Investment Strategies for agreement with the National Growth Board. Funding for SuDs work can be secured by lobbying the lcoal LEP and ensuring it's inclusion in their business case.	Must support economic growth through upskilling the work force, job creation, innovation and greater employment diversity	Business growth	1
LIFE+	Any - but must be a partnership with a lead applicant that meets EU requirements for financial stability etc	2013 onwards timeframe not yet announced		Split mainly between biodiversity and climatechange. Potential for other flood mitigation work under biodiversity - suggest SuDs potential lies with climate change and urban programmes	Environment	3
ESF	Managed by the Local LEP. *20% of ESF funding will be committed to social inclusion projects, thus LEP's are obliged to deliver a proportion of their outcomes through working in partnership with the third sector. Must be match funded and Big Lottery have committed to acting as a 3pf*	Varies - usually annually	The new regional allocations for 2014 to 2020 have been announced by Vince Cable. LEP's have until end Jan 2014 to submit their European Structural and Investment Strategies for agreement with the National Growth Board. Funding for SuDs work can be secured by lobbying the lcoal LEP and ensuring it's inclusion in their business case.	Youth unemployment, social integration, community resiliance, meeting locally defined needs	Social ills	3
Volunteering	Any non-profit making group	None	Community impact. Will require media profile to meet corporate's aspirations	Needs to tie into corporate's aspirations for the area, promoting their name etc.	Community	2

Funder	Applicant body	Application Timing	Application Requirements	Funding Allocation	In a word, suitable for…	Suitability for Suds (1 is high, 3 is low)
Sponsorship	Any non-profit making group	Varies - some companies have funding rounds others deal with requests as they come	Varies. Some corporates have an application process, others are purely reactive	Needs to tie into corporate's aspirations for the area, promoting their name etc.	Community	1
Private Beneficiary Funding	Usually EA or LA - no rules per se	None	Face to face. Requires good knowledge of the area and an ability to demonstrate a robust business case that shows the financial benefit to the proposed interventions	Hard to link individual SuDs interventions to specific beneficiaries so requesting contributions to a package of works that will demonstrate a benefit together will meet with a greater chance of success	Commercial benefit	3
Water Company Investment	Usually EA or LA - no rules per se	None	Face to face. Requires good knowledge of the area and an ability to demonstrate a robust business case that shows the financial benefit to the proposed interventions	As with the beneficiary pays concept it is usually tricky to tie SuDS work to a specific beneficiary. The case here would need to support the company's ability to meet regulations regarding the preservation of water as a resource and potential pollution threats	Commercial benefit	3
Heritage Grant	Registered charity, LA, Any constituted non-profit making group	Quarterly	Two phase application process which can take over 2 years	Applications must fullfill HLF's criteria of engagement, participation and conservation	Built & natural heritage	3
Heritage Enterprise	Registered charity, LA, Any constituted non-profit making group	Every three months	Two phase application process which can take over 2 years	Applications must fullfill HLF's criteria of engagement, participation and conservation	Heritage regeneration	3
Landscape Partnership	Registered charity, LA, Any constituted non-profit making group	Annually	Two phase application process which can take over 2 years	Applications must fullfill HLF's criteria of engagement, participation and conservation	Built & natural heritage	3
Reaching Communities	Registered charity, LA, Any constituted non-profit making group	Annually	One main application with a time line of around 5 months	Community need must be clearly evidenced; only £50k capital expenditure; projects are sought that work with 'communities in need'	Community	3
Grant Making Trusts	Registered charity	Varies according to the trust.	Varies, usually an initial EoI of 2 sides of A4 followed by a business plan	There are many grant making trusts each with their own funding themes. As a rule of thumb the project will need to be led by the community and demonstrate sustainability	Various	1
Landfill Tax Credit Scheme	Registered environmental body	Varies according to the landfill grant distributor	Usually a single stage application, more for the larger organisations	Relevant funds are for biodiversity and public amenity	Community	1
Volunteering	Any	None	Community led	If the opportunity can offer training or certified experience it increases its attractiveness	Community	2
Public Appeal	Registered charity	None	This can be a cost heavy way to raise funds. A good base of community support is required and appeals to warm supporters are much more effective	Appeals with a set target and a time limit are more likely to succeed	Community	3

Table 5.2 Funding Detail

Key

- Strong potential
- Modest potential or secondary funder requirement
- Low potential

Note

This matrix is intended as an initial guide to help direct fundraising efforts and relies on assumed values. If project or area specific knowledge suggests a funding source may have greater or lesser potential than is suggested by the matrix then such evidence should take precedence.

5.3 Funding arrangements

As the payers for surface water management schemes may not be the same as the beneficiaries it is important to understand who pays and who benefits. In Section 3.1.4, Box 3.3 illustrated a retrofit green streets study in Coventry that also incorporated SuDS. Table 5.3 shows the distribution of benefits for a green street retrofit in Coventry. Most of the benefits are attributed to street trees (influenced by the availability of evidence).

Table 5.3 Attributed benefits for green streets in Coventry (Aecom & STW, 2013)

Benefit	Environment Agency / Regulators	Severn Trent Water	Property owner/ Developers	Council/ Community	Physical Scale	Time scale
Alleviating sewer flooding £83-million (Stoney Rd: £31,500)	Reduced flood-associated costs with interconnected river flooding	Reduced sewer flood-associated costs	Flood avoidance and reduced insurance risk	Flood avoidance	Improvements seen at every scale – focusing on at risk areas first would be most beneficial	Immediate
Improved river water quality £4.1-million (Stoney Rd: £1,200)	Meet statutory obligations	Avoid water framework directive penalties	Improved environment and associated benefits	Improved environment and associated benefits	Improvements to many streets would be required before noticeable river quality improvements seen	Long term
Reduction in surface water management Bill reduction: £131.4-million (Stoney Rd: £40,200) Combined sewer management £296,000		Reduced management costs	Lower drainage bills	More efficient urban infrastructure	Improvements at every scale; substantial benefits only seen at large scale.	Immediate
Property values £1.2-billion (Stoney Rd: £805,000)			Increased property values	Increased economic value and council taxes	Large improvements can be achieved for most streets	Immediate
Energy cost savings £48.8-million (Stoney Rd: £18,500)			Lower energy bills	More efficient urban infrastructure	Individual household bills will improve at site scale	Long term
Carbon dioxide sequestration £102,500 (Stoney Rd: £30)	General environmental improvement			Mitigates climate change	Requires many street retrofits to make an impact	Long term
Air quality £12-million (Stoney Rd: £4,500)	General environmental improvement			Improves local health	Requires many street retrofits to make an impact	Long term
Local job creation £7.4-million (Stoney Rd: £2,800)			More economic activity increases land value	Increases economic productivity	Will require large scale implementation before substantial impact is made	Long term
Biodiversity (not monetised)	Meet statutory obligations			Improves environmental value	Impacts can be seen at every scale	Long term
Pedestrian movement and recreation (not monetised)		Better access to Severn Trent Water building	Better access to services and railway station	Improves health and recreation	Benefits do not require large scale implementation	Long term
Urban heat island (not monetised)	General environmental improvement	Reduces stress on infrastructure		Improves health and comfort	Minor improvement at site scale; real benefits accrued when used implemented across city centre	Immediate
Groundwater recharge or rainwater reuse £6.7-billion (Stoney Rd: £2-million)	Benefit to local watercourses and groundwater	Create a resilient water supply	Lower water bills through new non-potable source	Retaining local water sources	Need to be done at considerable scale to avoid developing alternative sources	Immediate

Apart from the four main groups of beneficiaries there are many more who potentially benefit, ranging from society as a whole (conceivably the entirety of humanity if the measures contribute to sustainability) to individual property owners; as well as non-human beneficiaries such as wildlife (e.g. birds in the trees). However, simplistic assumptions about such benefits are dangerous and highly context dependent. For example, considering street tree benefits; there is a ‘1 million’ street tree retrofit programme in New York City[34] (Ashley et al, 2011) that has already installed thousands of new trees. Despite the apparent benefits there are also disbenefits to property owners and occupiers who are responsible for keeping the sidewalks clear of leaves in front of their properties. Some residents are unhappy about having to do this for the new trees.

5.4 Payments for ecosystem services

Payments for Ecosystem Services (PES) schemes focus on creating markets for ecosystem services, by bringing together the providers of these services and those that benefit from them (Defra, 2011b).

PES can be defined as payments to compensate for actions undertaken to increase the levels of desired ecosystem services. PES is a market-based approach linking those involved in ‘supplying’ ecosystem services more closely to the ‘beneficiaries’ of ecosystem services; potentially in cost effective ways and making use of new streams of finance.

The following principles are important for PES:

- There is a close link between the payment and the delivery of ecosystem services: the “directness” of payment.
- There is a voluntary nature to the transaction, i.e. not because they are forced to trade by regulation or in order to meet a mandatory cap
- PES should recognise only the “additional” benefits from ecosystem service delivery that arise, above and beyond land users meeting their statutory requirements.

A simple example of how a PES scheme might work is shown in Figure 5.1.

[34] For every $1 invested, New York street trees return $5.60 in benefits. [http://www.milliontreesnyc.org/html/about/urban_forest_facts.shtml] accessed 19-08-13

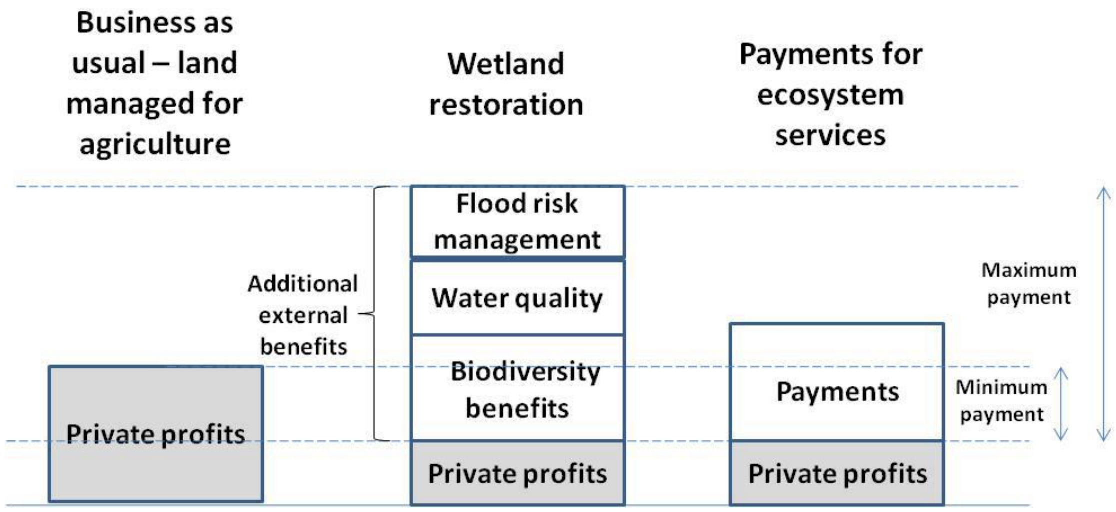

Figure 5.1: Simple example of PES (Defra 2011b)

In this example of wetland restoration, the payment negotiated is given in column 3. The payment needs to be at least at the minimum level that will compensate the land manager for the reduction in private profits or opportunity cost for the wetland restoration actions. For the payment to deliver net benefits, the payment must not be greater than the value delivered by the additional ecosystem services (in this case, flood risk management, water quality and biodiversity). If the payment agreed lies between this minimum and maximum amount, then both the land manager (the seller or provider) and the various beneficiaries (buyers) can benefit from a PES agreement. Transaction costs associated with setting up the PES would reduce this zone of potential mutual benefit, so it is important that these are minimized.

The payments relate to not just one ecosystem service but a bundle of services: flood risk management, water quality and biodiversity. This highlights that land management actions under PES will often deliver multiple benefits. In this case, if only one of the ecosystem services was targeted, the payment rate might not provide sufficient incentive to the provider. However, by accounting for multiple services, the scheme becomes cost effective and also avoids the need for multiple programmes, thus reducing overall transaction costs. This expands the opportunities but also the complexity from PES schemes.

There is a growing research literature on the use of PES, and also an increasing number of case study examples, including within the UK. However, none of these apply specifically to SuDS (see https://www.gov.uk/ecosystems-services).

SuDs can be seen within this context, with the wetland example above an illustration that could conceivably apply also in a more urban setting. The principles can be applied to all ‘green’ SuDS.

6 CONCLUSION

It is very clear that SuDS and equivalent systems worldwide can and do provide added benefits in addition to their primary water quantity and quality management functions. These added benefits are pervasive and add to the societal value especially in urban areas in regard to economic, environmental and social benefits. Realising these benefits and accounting for them is, however, not straightforward.

The complexity of the interconnected networks of services, utilities and uses of land in urban areas and the ways in which these are planned challenges the obvious transition from the familiar and tried-and-tested predominantly below ground system of pipes for surface water management, into one which is predominantly surface based and thus more evidently consumptive of land. This transition has been successfully made in many developed countries like Australia and USA and is underway in many other places such as Scandinavia, Netherlands, Germany and even France.

In England, the diversity of ownership issues of land and assets, mean that the opportunities to realise the direct and wider benefits of SuDS are often impossible to take (Ellis, 2013). White's (2008) absorbent city, which is seen to be receding even further in the UK (Scott et al, 2013)[35] could by promoting and linking green corridors and nodes help to better utilise water where it falls.

Future cities are being envisaged from various viewpoints, for example, the water sensitive city in Australia where water stress and ecosystem degradation are major concerns (CWSC, 2013). Whereas in a UK flagship project 'RETROFIT'[36] the significance of water is considered secondary and the place of urban drainage systems of clearly no relevance whatsoever (e.g. Dixon & Eames, 2013, do not mention surface water and barely mention water). Hence trying to ensure that SuDS are properly on the agenda in future UK thinking is still a major challenge, even for those researchers who should be more enlightened.

There is also an important barrier to realising the benefits due to the disconnects between the green infrastructure disciplines (eg. landscape architects), the ecosystem services disciplines (ecologists) and the physical infrastructure disciplines (planners and engineers). Even the planners are typically disconnected from the drainage engineers (e.g. Zhou et al, 2013) and there are sub-sets within engineering, with the highway engineers being even more remote (Potter et al, 2011).

Figure 6.1 Combining the WFD and ecosystem approach (Vlachopoulou et al, 2013)

[35] White has now moved to New Zealand partly in frustration with the slow pace of change in the UK (Pers. comm. 2013)
[36] www.retrofit2050.org.uk is an EPSRC funded project and was accessed 20-08-13

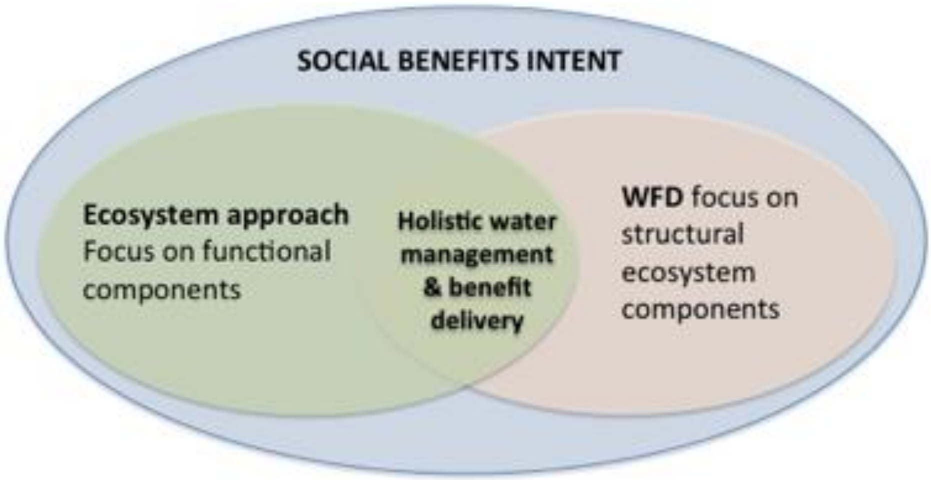

Figure 6.1 Combining the WFD and ecosystem approach (Vlachopoulou et al, 2013)

Yet, the role of taking a GI and an ecosystem services approach together with using SuDS in delivering benefits and value to society is indisputable. For example many of the requirements of the WFD (the over-arching framework for water management in Europe) can be SuDS related, as defined in a Natural Environment Research Council (NERC) project (e.g. Vlachopoulou et al, 2013), Figure 6.1. Perhaps there is too much consideration of rural aspects of the WFD and RBMPs so that the 'urban' futures specialists and professionals largely ignore it.

Despite the above issues, there is growing take-up of SuDS across the UK. In London for example, Ellis (2013) provides information regarding local authority flood mitigation use of SuDS (Table 6.1) being included in planning applications for 3 inner London Boroughs. Note that a number of the measures in Table 6.1 are not green SuDS.

Table 6.1 Pluvial flood control measures in London included in planning applications (Ellis, 2013)

Flood control objective	Measure	Numbers including in planning applications
Surface water storage	Harvesting Flood storage and attenuation basins	3 12
Impervious surface water runoff	Porous paving Soakaways and infiltration trenches	2 21
Other source control	Green roofs, wetlands, treatment train approaches	54

At a public and community level there is poor engagement in the UK regarding green-SuDS-ecosystem services and wider amenity benefits. This is despite the efforts of CIRIA and others like Hydro International. Media penetration is lacking and what there is, it is usually ill-informed and misleading. Worldwide there are good examples of engagement in linking blue and green via internet media[37], but this needs to be effectively designed to engage people and communities. Much of what exists in the UK is aimed at professional groups, not communities and is still not very effective as illustrated by the lack of interest shown by the RETROFIT project.

Lessons need to be learnt from pioneering engagement activities in e.g. Netherlands (Lems & Valkman, 2003) and Australia (Ferguson et al, 2013; 2013a), and especially in the USA, where standards for local runoff management (known as TMDLs) are set by groups that include representatives of the public (DTI, 2006).

6.1 Gaps in Knowledge

We know how to:

- design, build and operate SuDS (CIRIA, 2007) and also how to build GI (e.g. Newton et al, 2007),
- utilise previously developed land to create new green spaces (Brown et al, 2011),
- assess the benefits of using trees in urban landscapes (Armour et al, 2012)
- how to aim for maximum ecosystem benefits (Dale et al, 2011) within construction and development processes.

Other CIRIA guidance deals with designing out crime in public places (Clarke & Gilbertson, 2011) although this does not highlight the value of green spaces in contributing in general to crime reduction as claimed by CNT (2010). There is even guidance as to how to bring this together in retrofitting surface water management (Digman et al, 2012).

However, evidence and an agreed methodology to show conclusively how SuDS perform, are cost-beneficial in an urban context and to assign monetary or other values to their wider benefits contributing to green spaces and ecosystem services is still lacking.

Perhaps this is why there is poor understanding amongst communities and others as to their benefits. Even elsewhere in the world the assumptions made to quantify the added-benefits of SuDS and equivalents are heroic in regard to many of the criteria being used. The added value of using surface water management systems in Philadelphia, estimated as almost $3bn (US) is attractive, appealing and persuasive. Yet the robustness of this assessment is questionable.

More evidence is needed in terms of all aspects of SuDS performance and value and while green infrastructure and ecosystems services literature and

[37] just one example from USA: http://www.waterblues.org/trailer/chapters.html accessed 20-08-13

understandings can help, there is still a need for surface water infrastructure specific knowledge.

There are a number of knowledge gaps in understanding what the wider benefit values of SuDS are. These range from the factors that can be quantified and potentially monetised, to factors that are highly subjective. The latter uncertainties are not confined to SuDS or water systems (e.g. O'Breina & Morrisa, 2013).

The use of SuDS and water in general for GI and ES, tends to be framed differently depending upon the driver for change and also the professionals and decision makers involved (e.g. Mell, 2012). Those primarily interested in GI often overlook the importance of water (e.g. Mayor of London, 2009), whereas those interested in drainage often overlook the added-value of using GI. Often the reasons for this relate to the terms within which the interested parties are working and their duties and boundaries of working. Therefore it is essential that partnership working addresses these constraints. Various pilot projects in England are already showing that this can be effective (e.g. Cascade, 2013). Nevertheless more needs to be done to understand and promote such effective partnerships, not only between professionals, but also with communities.

Much of the benefit value for SuDS and drainage systems is actually considered in terms of LID; i.e. by lessening impacts, rather than necessarily providing positive enhancements. Most appraisals use a comparative assessment via checklists, spider diagrams or other similar formats that provide a quick subjective visual image for decision makers (e.g. Ashley et al, 2012; Potz & Bleuze, 2012). Few, if any actually attempt to quantify the benefits, certainly in the UK.

The same difficulties found in sustainability assessments are also inherent in assigning and quantifying benefits arising from the use of SuDS (Ashley et al, 2008; Hurley et al, 2010). It is possible to quantify the reductions in pollutant emissions, changes in carbon and energy use and wastes in both the embodied aspects of SuDS and also in supply chains for SuDS use, construction and decommissioning, using established techniques such as LCA and then compare these between SuDS and piped drainage systems. LCA has been used notably by EA (2009) in the UK when considering SuDS, although the outcomes were questionable due to the definition of the boundaries used (Ashley et al, 2011).

de Sousa et al (2012) used LCA to show that green infrastructural approaches performed better than piped in a New York study for CSO spill reduction when comparing carbon footprints. This approach is not a direct benefit assessment, rather an LID assessment as it considers impacts rather than benefits. The other issue with LCA is that it relies on established databases (usually standard software packages) and none of these have been set up so far for SuDS/BMPs, although Flynn & Traver (2013) consider the GI LCA of a biofiltration system in Villanova, USA in a speculative analysis. However, UNEP-SETAC the arbiters of LCA have recently developed guidelines on global land use impact assessment on biodiversity and ecosystem services in LCA methods (Koellner et al, 2013). Because of the lack of agreed LCA data, CNT (2010) and Koellner at al, 2013 needed to develop empirical relationships for quantifying emissions, energy, carbon etc. With an agreed relationship between carbon and the value of reducing its' use and emissions, such as used by e.g. UKWIR (2008) and Defra (2012) it is then possible to assign a monetary benefit value to quantified reductions in emissions and resource use from the use of SuDS.

With the advent of recommendations and guidance for ES, it is now also possible to use a standardised set of criteria to evaluate the contribution to and from ES provided by SuDS. Although not classifiable as SuDS, the use of ES for the management of flood risk and rejuvenation of the run-down MayesBrook park in a deprived area of NE London (Everard et al, 2011a) (outlined in the case studies in Digman et al, 2012) illustrated the potential for both quantifying the ES from such a scheme and also assigning monetary value to these benefits. Unfortunately, the veracity and robustness of the assessment, whilst seductive, cannot be defended scientifically at the present time. Doubtless there were uncertainty assessments made in the study to determine the robustness of the findings, but these are not in the public domain and are unverifiable.

Similar concerns can be expressed regarding the GINW (2012) analysis of the benefit value of the retrofitting of SuDS in Halewood Primary School, Knowsley (case study in Digman et al, 2012). The dominating significance of an increase in cultural services and in land and property values respectively in these studies is highly subjective and the property value benefits in particular have been questioned (eg. Petrova, 2011).

Most of the applications assigning value to the use of SuDS have taken place outside the UK. Notably in USA (CNT, 2010); Denmark (Zhou et al, 2013) and Australia (CWSC, 2013) where the use of the evaluations is for BMPs or WSUD and therefore not directly translatable into UK practices.

Take-up of GI and source control SuDS is highly dependent on local understandings and acceptability and the realisation of the wider benefits as to what this could bring may not be attainable at least in the short to medium term in the UK (e.g. for a US example, see Montalto et al, 2013). There is a major perception barrier for householders and property dwellers regarding their willingness to accept SuDS and what they might see 'is in it for them'. It may be simpler for ES as 'environmental' and 'ecology' messages have been promoted in the media, by society in general and especially in schools. Aligning this with the Localism agenda, may provide through local groups and bridging organisations the means to generate momentum for GI and ES as is happening in New York City (Connolly et al, 2013). Hitching SuDS appropriately into this is going to be crucial if the maximum net benefits from green, ecosystems and water are to be achieved. Any valuation methodology or tool needs to be devised considering how this can best be used to persuade these important community groups as to how important this is (e.g. Eckart et al, 2012).

There are often difficulties due to the contradictory needs of differing regulations, drivers and targets amongst the various participants in delivering a multi-valued SuDS scheme as in the USA (e.g. Keeley et al, 2013). In the latter, regeneration and economic growth targets and especially funding, ownership and maintenance complexities militated against improving public perceptions and willingness to pay.

Moving from a mono-functional to a multi-functional use of urban space and accommodating the transformational aspects of land use, as ‘no space is finished’ (Digman et al, 2012), will be vital for the delivery of the many benefits of SuDS. Although transformations of land use appear to be controlled and controllable especially in urban areas, observed phenomena such as urban creep and autonomous transformation demonstrate that ideas for control may be optimistic (e.g Bomans et al, 2010). If open space SuDS are to be reliable, then this change needs to be better controlled otherwise their functionality as regards water management and in terms of the wider benefits provided will be compromised over time.

A standardised valuation may help to offset the perceptions about and very real fears regarding risks of incurring liabilities and even litigation in the future. In the USA, litigation has driven the development of BMPs, LIDs and SCMs as environmental groups were able to enforce the provisions of the Clean Water Act (1972) gradually via this means (DTI, 2006). Nevertheless litigation regarding the funding of stormwater measures (raising taxes illegally in some States), accidental drownings in BMPs and resistance to using SCMs exists there. In the UK Bamford et al (2006) proposed a protocol for the water industry to minimise risks such as these, however, this has not be generally taken-up.

In summary, there is a lot of pertinent information, data and methodologies for evaluating the wider benefits that may accrue from the use of SuDS. However, none of these is entirely convincing and many are not well grounded in science.

The use of a benefit-transfer approach is common especially in UK applications, but the lack of contemporary or comparative benchmarks, exemplars and robust base data, mean that the accuracy of this approach is questionable in regard to SuDS.

This review has taken an overview of the various sources of information and methodological tools, drawing on recent analyses and summaries by others (e.g Eftec, 2013). There is now a need to further investigate in detail the assumptions and reliability of the data used in the various methodologies to identify which of these is reliable and usable in the context of SuDS benefits and which are unreliable and questionable. From this a new baseline tool can be developed that will use only robust data and criteria; but will provide guidance for the use of other crucial information where this is not available or not safe.

New, primary valuation studies may also be needed to fill any gaps in understanding of the benefits around SuDS. These could include travel cost or hedonic price approaches, which could be particularly useful in assessing the value of amenity, quality of life and other ‘cultural’ impacts.

In terms of uptake of SuDS and frameworks for benefit valuation, fear of uncertainty affects the various players in different ways; but is a major impediment to changes in practice (Bijlsma et al, 2011) of the sort that is needed if SuDS and the associated benefits are to be utilised better. The latter studied all of the actors in the participatory processes in relation to the WFD:

> *“The observed low tolerance for process uncertainty of participants made them opt for a rigorous “once and for all” settling of the conflict.”*

The experts sought to reduce the scope of the discussions by bringing in boundaries; typically a constraining of innovation. Others, in the context of ditch flood risk management, have broken down barriers through learning alliances and managed to innovate, mainly in the wake of a crisis in the decision making process (e.g van Herk et al, 2011). The difficulties of doing this regarding SuDS use in the UK should not be underestimated.

7 DECISION MAKING FOR MAXIMUM BENEFIT VALUE

Decision makers are in a new world. In the past decisions could be made to fulfil the direct requirements of the issue, service and utility under consideration. Now, with knowledge that uncertainty about future drivers is not going to reduce, there needs to be greater regard given to decision making that is flexible, no regret and multi-beneficial. Decision makers and their advisers need to be active learners and to remember that they serve society as a whole, not simply the immediate client or needs.

Making decisions regarding making the most of SuDS primary water related functions; multiple benefits within economic, social and environmental domains are not going to be straightforward in future. There will be many players, partners and disciplines involved and never enough information to overcome the reticence of some of those involved. Yet, somehow this must be done if the maximum value to society is to be achieved. There are signs that partnerships can work in England in the various Defra supported pilot project related to the WFD, catchment approaches and in SWMPs (e.g. Vlachopoulou et al, 2013).

A decision support framework has been provided for sewerage undertakers to decide on the costs and benefits of using retrofit SuDS and other measures to manage CSOs and sewer flooding (Wade et al, 2009). This emphasises the importance of compliance with regulatory standards from early on in the process. There are also a number of other imperatives that are growing in significance as the timescale for their implementation brings deadlines closer. Article 9 of the WFD sets out a vision for ensuring that water services are properly costed stating that full costs are passed on to those utilising the services water provides:

"Cost recovery is about the amount of money that is being paid for water services. The principle, however, extends not only to the financial costs of the provision of water services, but also to the costs of associated negative environmental effects (environmental costs) as well as forgone opportunities of alternative water uses (resource costs)" (EEA, 2013).

The latter goes on to state:

"When prices do not reflect the full costs and benefits of production and consumption, the facts about resource scarcity and environmental values aren't made known — and nor are the actual costs of producing or consuming goods and services. Since they have nothing else to hand, however, people must base their decisions on such erroneous information".

Who should pay? And what benefits do they provide or accrue? Any supporting framework for benefit valuation needs to consider who it is for and therefore what it needs to look like. Can one framework be suitable to all users and funders needs? FCERM funding criteria, including benefit assessment and the critical level of benefits to costs are considered by Ranger et al (2011). The beneficiaries of flood defence investment in England were in 2011:

> *"Funding for flood protection and response has historically come from the taxpayer. They estimate the beneficiaries of this investment to include: the public sector (estimated at 31% of benefit); insurers (and indirectly, the domestic and business policyholders, 43%); businesses (11%); householders (10%) and agriculture (5%). Private actors will typically purchase flood insurance (where available); this conveys benefits to the individuals but also to society more generally through risk sharing (also in the UK, there is an element of cross-subsidisation, so more benefit is gained by more exposed insureds)."*

There is reference to the Pitt review recommendations that more SuDS need to be used and large infrastructure avoided to minimise sunk costs and lock-in into the future. The flexibility and adaptability of SuDS needs to be better recognised in the decision making processes (Gersonius et al, 2013).

Table 7.1 is an extract from Ranger et al (2011) summarising the adaptation options for flooding in the UK.

Table 7.1 examples of adaptation options for flooding in the UK (adapted from Ranger et al, 2011)

Adaptation option	Summary charac-teristics	Geo-graphical constraints	Relative economic costs	Relative economic benefits	Common co-benefits	Common trade-offs	Lifetime (lead-time turnover)	Flexibility and sunk costs	Distribution of costs and benefits	Risks
Enhanced 'hard' drainage and sewerage systems	Anticipatory; complement	Typically urban	High if early capital replacement: low if in line with turnover	Potentially high	None		Long (100 years)	High sunk costs, can incorporate flexibility	Taxpayer funded with local benefits	Risk of failure if not maintained
Large-scale 'soft' infrastructure – natural barriers, natural storage, enhanced soil conditions	Anticipatory; typically complement	Requires large land areas for natural ecosystems	Medium (£10-100k small scale wetland and channel restoration; £1-10m major channel restoration, storage or flood plain reconnection)	Medium (uncertain, potentially high local benefits)	Ecosystems and associated	Other land uses; downstream risks	Medium	Lower sunk costs	Local benefits: range of possible funders	Potentially higher risk of failure and more uncertain benefits than hard infrastructure
Urban soft infrastructure (green roofs, permeable pavements etc.	Anticipatory; typically complement	Typically urban	Medium (green roofs – additional £10-20 per sq. ft.; surface options £100 – 200k per small scale project)	Uncertain	Ecosystems, cooling and insulation of urban areas and buildings		Medium	Lower sunk costs	Local benefits: range of possible funders	Potentially higher risk of failure and more uncertain benefits than hard infrastructure

Table 7.1 illustrates the so-far limited place of urban 'soft' Infrastructure, including SuDS in the range of adaptation options in relation to flood management. This is only one of the potential benefit domains and an equivalent table could be drawn up for eg. water quality; amenity; placemaking etc.

Why is there a need for estimating the added benefits from using SuDS? USEPA (2013) points out the added costs of undertaking such an assessment and that these may be unreasonable for the scale of project of benefits that may be important. Therefore a business case needs to be made for the need to do this. This needs to be appealing to the prime movers, users and implementers of surface water drainage systems. Whilst the demonstration of clear and widely accepted additional benefits from using SuDS makes a business case for their use (as in USEPA, 2013), there is a prior stage that is the need for the business case to demonstrate that the analysis of benefits is a valuable thing to do. If the users of SuDS, including householders, property owners, users and dwellers for example, demanded that their drainage system was built to a clear benefit to cost advantage and that they wished to know what this was (as in the investors in MayesBrook Park ecosystem services, Natural England, 2013), then such analyses would become routine. For this to happen there needs to be more effort given to promoting the use of SuDS in the UK at a public level. Elsewhere, for example, in USA, Australia and Germany public demand is such that these systems are now 'the norm' and expected. This is despite there not being clear and positive benefit-cost estimates in these countries that include the wider benefits of SuDS usage.

There are a number of finance models for surface water management in the UK considered by Crawford-Brown & Gosse (2011) classified as being provided from: tax financing; third-party financing; stakeholder financing; full-cost pricing; and developer/land-owner financing. The risks associated with these are also considered, however, the benefits considered were very narrowly defined and hence this excludes many other forms of financing variants.

When considering the need to include the entire range of costs and benefits in application of Article 9 of the WFD in relation to water management, the EEA (2013) study found relatively low levels of internalisation of the costs through e.g. taxation: "makes it unlikely that they can recover any (fair) share of environmental and resource costs". Despite promoting the polluter pays principle (PPP) there is almost no evidence that PPP is considered by decision makers in relation to water systems in Europe. The report clearly illustrates that the costs for e.g. increased pollution of watercourses caused by urban development need to be passed on to those responsible (the developer and onward to the property owner/occupier). Special criticism is levelled at the UK countries in the report as water charges are based on property size and not usage and therefore do not incentivise wasteful use reduction and by implication, the generation of surface runoff from properties.

Cooperation and voluntary agreements are recommended to share and create mutual benefits from changing the way that water is used and environmental systems accessed and impacted. Trading mechanisms and voluntary pricing instruments are recommended for this.

Dealing with risks related to "the complications of appraising interconnected investments with multiple objectives" (Booth, 2012). Requires consideration of the inter-dependencies and requires failure mode and effects analysis. This is why application of Real (in) Options analysis is so useful in this context (de Neufville & Scholtes,2012; Gersonius et al, 2012).

In considering this Booth (2012) says:

> *"Financial and multi-criteria investment appraisals can become more complex if interconnections between infrastructures are considered:*
>
> *(a) The different infrastructures may be governed by different appraisal guidelines*
> *(b) Public and private sector infrastructures may need appraisal and these may have very different discount rates.*
> *(c) There may be a 'package' of investments, with an investment in each affected infrastructure as well as the connection between them. One can try to appraise each component of the investment individually but apart from differing appraisal guidelines for differing infrastructures, one also has to untangle the overlap of costs and benefits or synergies."*

All of the above apply to the complex interactions and interdependencies between SuDS and the added benefits they may provide.

Booth (2012) recommends the use of multi-criteria analysis (Defra, 2005 & DCLG, 2009) for these potentially competing and interacting dependencies and an Enterprise Risk Management (ERM) (COSO, 2009) framework together with the benchmark ISO 31000 risk standard.

Multi-Criteria Cost-Benefit Analysis (MCCBA) is a combination of CBA and MCA, providing a recommended starting point for the evaluation of projects or policies involving changes in agricultural and natural ecosystem services (Sijtsma et al, 2013). It is claimed to provide a tripartite perspective including: basic health; economic welfare and higher well-being. The latter relates to nature whereas the first two of these are anthropocentric, drawing on Disability Adjusted Life Years (DALYs) and NPV for economic welfare. Although aimed primarily at agricultural practices, such an approach may have some merits in application when considering the overall benefits deriving from SuDS although it would likely only be applicable at a large catchment or city scale.

Any supporting guidance, tool or framework needs to be set within the main context in which urban development is set: land use planning. Ideally some form of GIS based platform that is referenced to databases for land use and forms is required, one which includes green spaces (e.g. Gaston et al, 2013) and also has appropriately defined and referenced SuDS features. With an increasing interest in the economic development support derived from green and ES, like it or not, a business case needs to be founded in the value and benefits provided by SuDS over and above their purely water functionality. This business case needs to be formulated using established techniques for assessing natural and other capitals, eg. for rural land use planning (Bateman et al, 2013). This is being done elsewhere, for example in the USA where recent articles in the grey literature are promoting green roofs via sound economics (e.g. Doshi & Peck, 2013). It also needs to be as participatory and inclusive as possible if it is to get the buy-in of communities and all concerned (e.g. Fish et al, 2011) and to be complemented by a simple and usable means of assessing and reporting on the uncertainty of any benefits assessment for SuDS.

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APPENDIX A INVENTORY OF BENEFITS FROM ASHLEY ET AL (2012)

Note: those monetised in stormwater studies shown in red.

Protection of air/water/ planet		
Benefit	Boundary conditions	Evaluation criteria
Improves water quality This can be defined as related to receiving water quality and hence to reductions in impacts (CNT) or as potentially helpful for Rainwater harvesting where this is utilised.	"Using green infrastructure for stormwater management can improve the health of local waterways by reducing erosion and sedimentation and reducing the pollutant concentrations in rivers, lakes and streams. The impacts of green infrastructure on water quality, while well documented, are too place-specific to provide general guidelines for measurement and valuation. The water quality improvements associated with green infrastructure, furthermore, are not of sufficient magnitude to be meaningful at the site scale. This benefit, therefore, is best evaluated in the context of watershed-scale green infrastructure implementation." This criterion needs to be set at least at the catchment scale within which the water quality is assessed. Benefits can accrue across generations and timescales.	The CNT definition for this falls under reductions in stormwater runoff (Figure 5) and each of the five GI SuDS included in the tool is claimed to assist with this. Studies in USA have estimated implicit marginal prices for a one meter change in water clarity (turbidity reduction) ranging from $1,100 to $12,938 per waterfront property. Elsewhere in USA estimated home price impacts of water quality changes not merely for waterfront properties but for the entire watershed found marginal implicit prices for changes of one milligram per liter in TSS concentrations of $1,086 and in dissolved inorganic nitrogen concentration of $17,642 for each home in the watershed. In addition to direct water quality marginal values, CNT also provide estimates of the value of not having to treat runoff at wastewater plants – for example a 5,000 ft^2 green roof contributes to an annual electricity savings from reduced water treatment needs of 110.77 kWh. This can be costed in terms of a marginal benefit value.
Increases water recycling This is a benefit when considered for ES as it reduces burdens on the natural environment and need to abstract. It also benefits water suppliers as it reduces demand.	According to UKNEA[38], if a process is long term and indirect it falls under ES supporting services. However, if it is a short term and direct process it will fall under ES regulating services and subcategory water quality. However, the precise category is not necessarily significant for the application here. Much of this will relate to locally beneficial harvesting in	Estimation of the value of increased water recycling needs to be linked to the benefits of both maintaining environmental flows in natural water bodies (data should be available for agricultural irrigation impacts avoided) and also in avoided mains water supply – i.e. the cost per unit of supplied water, usually potable. There are other monetisable benefits under the social and cultural categories and double counting needs to be avoided. This is not considered by either CNT

[38] http://uknea.unep-wcmc.org/ accessed 10-08-12

	European applications.	or GINW.
Reduces need for grey infrastructure This relates to constructed infrastructure rather than green/renewable in the CNT definition.	Grey infrastructure tends to be at a local or neighbourhood scale, although linear systems such as pipelines may be regional. Most grey infrastructure has a 30 year lifetime before major renovation. Green infrastructure will have a shorter lifetime on average.	CNT state that the value of reducing grey infrastructure derives from the benefits transfer method of avoided costs resulting from the use of green infrastructure. One US city estimates that it costs the city $2.71/ ft^2$ in infrastructure costs to manage the stormwater generated from impervious areas using: *total expenditure for grey approach ($) * % retained = avoided cost savings ($)* For a 5,000 ft^2 conventional roof, capital expenditure is $13,550. However, for a green roof, which in this particular study has been shown to retain 56%, There is an avoided cost savings of $7,588. The SEA streets in Seattle provide cost savings for the city of 15–25%, or $100,000– $235,000 per block, as compared with conventional stormwater control design.
Improves habitat	There are other monetisable benefits under the social and cultural categories and double counting needs to be avoided. This criterion needs to be set at least at the catchment scale and even beyond. Benefits can accrue across generations and timescales.	CNT states that the value of habitat improvements are valued either through Contingent Valuation methods (e.g. conservation of an endangered species) or via the market process of goods that are either directly produced from the habitat in question, or elsewhere provided the habitat in question provides breeding/nursery grounds. CNT does not provide a framework for the assessment of habitat improvement benefit. GINW show that in the UK, improvement of habitat that has an international, national or local habitat/biodiversity designation (e.g. SSSI) often result in higher valuations. For, example a Willingness to Pay (WtP) of £0.41-£1.14 per household per year was given for preserving a SSSI, compared to £0.33-£0.90 per household per year to increase an area of commercial woodland by 12,000 ha. The GINW tool uses an application of benefit values transfer from other

		studies within the literature in order to value habitat improvement. It is recognised that there is no widespread support for the use of WtP to value habitat/biodiversity. There is also little evidence in the literature of urban biodiversity values.
Improves groundwater recharge[C]	The benefit depends on the spatial and time scale and management level. Local values may be small, but accumulated GI measures over larger spatial scales affects other benefits, such as amelioration of contaminated land, soil erosion/stability, preservation of cultural heritage and reduction of the need for grey infrastructure (avoided costs). Double counting thus needs to be avoided.	Aquifer levels are a function of the relationship between discharge (abstraction, evaporation and interaction with surface waters) and recharge. As GI affects groundwater recharge in highly site-specific ways, neither the CNT nor GINW approaches define specific guidelines for the quantification and valuation of groundwater recharge benefits of GI. However, the importance is recognised.
Ameliorates contaminated land[S]	This is likely to be localised in scale although impacts and benefits to human health may be more widespread[39]. Cleaning up contaminated land is also a benefit across generations which can also support ecosystems.	Contaminated land can arise from a number of sources in both urban and rural areas. The presence of contaminated land may have an effect on the use of the land, as well as creating a source of pollution. None of the approaches (CNT, TEEB or GINW) define specific guidelines for the quantification of this topic.
Air quality regulation [ES] (REGULATORY)	This is potentially a trans-national benefit. For example via greenhouse gas emission controls mitigating climate change, human health value of restricting pollution etc.	From TEEB '*Trees and green space lower the temperature in cities whilst forests influence rainfall and water availability both locally and regionally. Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere.*' The urban park forest in Cascine Park, Italy,was shown to have retained its pollutant removal capability of about 72.4 kg per hectare per year (reducing by only 3.4 kg/ha to 69.0 kg/ha after 19 years, despite some losses due to cutting and extreme climate events). Harmful pollutants removed included O_3, CO, SO_2. NO_2, and particulate pollutants as well as CO_2. TEEB advocates the use of the hedonic

[39] In the UK the baseline approach is given in the CLEA handbook: http://www.environment-agency.gov.uk/static/documents/Research/clea_software_v1.05.pdf (accessed 10-08-12)

		valuation methodology – the amount of money that would be paid for higher air quality.
Increases photosynthesis (production of atmospheric oxygen), soil formation, nutrient cycling &/or primary production ES (REGULATORY and SUPPORTING)	Potentially as above	TEEB 'Soil fertility is essential for plant growth and agriculture and well-functioning ecosystems supply soil with nutrients required to support plant growth.' There are no explicit definitions of guidelines for this topic within TEEB, CNT or GINW
Erosion regulation and soil stability ES (REGULATORY)	This is relevant locally and possibly regionally.	TEEB 'Soil erosion is a key factor in the process of land degradation, desertification and hydroelectric capacity. Vegetation cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and agriculture and well-functioning ecosystems supply soil with nutrients required to support plant growth.' This is linked to the contribution to local/global economy, as well as habitat and water quality. Value could be linked to avoiding loss of productivity of land? GI generally improves soil stability in organic soils, avoiding soil moisture reduction and degradation of organic material. Avoided leaky piped solutions also reduce risk for mechanical instabilities. There are no explicit definitions for this topic.
Supports Pollination ES (REGULATORY)	This is of global and inter-generational value in supporting biosystems.	TEEB 'Insects and wind pollinate plants which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats'. There are links to improved habitat which must not be double counted. Value could be linked to avoiding loss of productivity of land?

Flexibility and Adaptability to climate change		
Benefit	**Boundary conditions**	**Evaluation criteria**
Reduces flooding C, **/Storm protection** ES	CNT states that the context of flooding is highly site specific. Spatial boundaries need to be defined, as well as	CNT state that as the context of flooding is highly site specific, no general instructions for the valuation of reduced flooding are given. Several

(REGULATORY)	considerations with regards to time scale (e.g. acceptable return period).	methodologies are discussed within the report. Hedonics can be used to assess how flood risk is priced into the real estate market. Insurance premiums paid for flood damage can be used as a proxy for the value of decreased flood risk. Other studies have used CV techniques. The most robust technique uses hedonics to investigate housing price discounts associated with a floodplain location. A 2-5% Discount was found for houses within the 100 yr flood plain when compared to those outside.
Reduces salt use on roads in winter[c]	There is a risk for double counting and thus clear definition of the benefits boundary is necessary. Valuation of the benefits by calculating only avoided salting costs does not take into account the increased values by improved habitat, water quality and preservation of cultural heritage. There are potential catchment scale benefits from this.	Of the 5 GI measures included within CNT, Permeable pavements, depending on their structure, are claimed to reduce the requirement for salt on roads in winter, by up to as much as 75%. The National Research Council (NRC) indicates that road-salt use in the United States ranges from 8 million to 12 million tons per year with an average cost of about $30 per ton, although this cost has increased in recent years. In winter 2008, many municipalities paid over $150 per ton for road salt; projections for 2009 reported salt prices in the range of $50–$70 per ton
Increases available water supply[c, ES] (PROVISIONING)	This should be considered at local, regional and catchment scales.	CNT uses the reduction in stormwater runoff in order to assess the valuation in terms of water treatment reduction, grey infrastructure reduction increased water quality and reduced flooding. Therefore there is no direct assessment of water supply provision. It was estimated that in the US, outdoor irrigation accounts for almost one-third of all residential water use, totalling more than 7 billion gallons per day. Given this estimate, using rainwater for irrigation purposes can substantially reduce the amount of potable water used residentially, effectively increasing supply. The total amount of water available for harvest is calculated in CNT by: annual rainfall (inches) * area of surface (SF) * 144 sq inches/SF * 0.00433 gal/cubic inch * 0.85 collection efficiency
Reduced stormwater runoff[C, ES]	Valuation of benefits includes avoided stormwater treatment costs (improves water quality) and avoided costs of additional	Within the CNT approach, the first step in valuing water benefits is to determine the amount of rainfall (gallons) retained on the site. This is

(REGULATORY)	grey infrastructure. These are specific benefits under protection air/water/planet and there thus is a risk for double counting. This should be considered at local, regional and catchment scales.	then used as the resource unit for all water benefits. All 5 GI types listed within the CNT guidance provide some level of stormwater runoff. The levels of runoff retained depend on site specific variables. Valuation of benefits from reduced stormwater runoff include: avoided stormwater treatment costs and avoided costs of additional grey infrastructure.

Contribution to local/global economy		
Benefits	**Boundary conditions**	**Evaluation criteria**
Increase in labour productivity[G]	The spatial, time and benefit boundaries are important to define, related to spin-off effects by the chosen option. If an option e.g. improves habitat or sustains cultural heritage, labour productivity in dependent tourist industries will increase, which again improves labour productivity in other connected industries. This is likely to be very locally effective but potentially affecting entire economies. The increase in jobs arising from the selection of different alternatives, e.g. grey vs green infrastructure will be very locally dependent. In general green jobs will last over longer periods of time than grey, for which construction periods will employ many people, with a rapid decline in operation, restricted to maintenance and ultimate replacement/end of life dismantling.	Evidence for increase in labour productivity is given in GINW. Well planned and accessible GI can be expected to have an impact on labour productivity. The impacts include: Physical health improvements – resulting principally from increased exercise and improved air quality; Mental health improvements – from the calming effects of the presence of trees and green spaces, and also from physical exercise. Both of which are linked to health benefits; improvements at work - psychologists have noted that when workers have access to plants and green spaces they can be more patient, better at problem-solving and more productive; A reduction in short-term absenteeism. To estimate the labour productivity benefit of GI, two impacts must be considered: 1. Impact on labour productivity and 2. Increased profit as a result of reduced costs of recruitment. Both of these enhance the GVA per firm. However, there is a lack of empirical evidence for these. At present decrease in short term absenteeism that can be attributed to increased health of those who take physical exercise as a result of a walking/cycling intervention can be assessed. WHO in US showed a reduction in short-term absenteeism of 6-32% for those that did 30 mins exercise/5 days. In UK this could result in approximately 0.4 days gross salary costs. This value must then be combined with average gross salary costs and the number of affected working people to give a gross salary cost.

Provides food crops, fibre & fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, &/or ornamental resources (shells, flowers etc.) ES (PROVISIONING)	Potentially a trans-national benefit for food and other provisioning services. Often not a direct local benefit where these services are exported out of the region they grow/are generated in.	From TEEB 'Ecosystems provide the conditions for growing food. Food comes principally from managed agro-ecosystems, but marine and freshwater systems, forests and urban horticulture also provide food for human consumption.' 'Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species.' In addition, Non-timber forests such as latex, rubber and plant oils are important in trade and subsistence. 'Biodiverse ecosystems provide many plants used as traditional medicines as well as providing raw materials for the pharmaceutical industry. All ecosystems are a potential source of medicinal resources.'
Pest & /or disease regulation ES (REGULATORY)	Natural ecological balances may ensure equilibrium conditions being self-regulating. Consideration needs to be at an ecosystem scale. In urban areas this may apply to blue-green corridors.	From TEEB: 'Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites.' Placing a direct monetary value on this is not straightforward, but should not be overlooked.

Life cycle costs		
Benefits	**Boundary conditions**	**Evaluation criteria**
Low Life Cycle Costs	The costs and benefits need to be considered across the entire lifetime of the scheme. There are a number of approaches as to how to define the boundaries for this as outlined in Section 5 of this report.	Life cycle costs are defined as the sum of the present value of the investment costs, capital costs, installation costs, operation and maintenance costs and replacement and disposal costs over the lifetime of the project. Life cycle benefits represent the present of the accrued benefits over the lifetime. The life-cycle net benefits provide the Net Present Value (NPV) = PV benefits – PV costs. Thus the NPV can show that a scheme with higher initial investment costs can yield greater benefits over the lifetime of a project.

Affordability		
Benefits	**Boundary conditions**	**Evaluation criteria**
Investment[G]	This can be long term or short term and local or strategic. Investment could also fall in to provisioning or regulating services depending on the contextual definition. Green infrastructure could bring more potential industries which are provisioning services whereas if it is a long term management issue then it will fall under regulating services.	GINW state that for valuation purposes, GI affects private sector investment, helping to drive economic growth. At the wider scale, GI may provide a context for inward investment, enhancing an areas image. 33% of new investors in the West Midlands cited attractiveness of the region as an important factor in whether they invest. At the site scale, public realm and GI around a particular investment site can help attract and retain companies. Valuing these impacts in isolation from other factors is difficult. Perception surveys can be carried out, as well as assessing the willingness to pay for a high quality environment. Within the GINW tool, it is not currently possible to value the impact of GI on attracting investment.
Has secure funding	Important mainly for longer-term adaptive types of intervention. For many municipalities there is no assuredness of future planned long term funding for incremental change, hence an adaptive approach may not be wise. Security of funding could be considered as regulating services longer term.	Not specifically included in the GINW or CNT approaches. Funding assurance needs to be clear for the duration of the project investment period required.

Risks		
Benefits	**Boundary conditions**	**Evaluation criteria**
Low risk of failure	Could be considered a regulatory service as needs to be considered longer term. Robustness may also be important into the future. Here the term is defined as working across all future scenarios and contexts.	Not included explicitly in the GINW or CNT approaches. Comparative assessment of failure risk is usually the reason why innovations are not taken up. Sticking with tried and tested options can give security in relation to performance. However, many such solutions are 'locked-in' and may have been applicable in the past; but are now no longer sensible as for example, they require too much energy. So here, although there could be a low risk of

		failure, this criterion could indicate a lack of innovation.

Public/professional engagement		
Benefits	**Boundary conditions**	**Evaluation criteria**
Integrates land and water management[s]	This can be at a local level (site), regionally or at a catchment scale. It explicitly recognises the potential value in doing this.	Not explicitly considered in the GINW or CNT approaches as a criterion. However, co-management of land and water is increasingly seen to be beneficial for multi-value creation. See for example, the GRaBS project[40].
Provides educational opportunities[C]	Options improving habitat or sustaining/improving cultural heritage provide educational opportunities. If one takes widest possible boundaries into account, the secondary educational opportunities resulting from maintaining or improving cultural or environmental services should be included in any valuation.	CNT recognise that the provision of educational opportunities is important, however, no explicit method for the quantification and valuation of public education is included in the guide. It is recognised that public education is a vital precursor to achieving widespread adoption of GI, and the realisation of many of the benefits. This is likely to be qualitatively assessed.
Involves citizens in decision making	In principle all stakeholders need to be included here. The scale, scope and means for this are outlined in Section 4 of this report and in the HarmoniCOP guidance[61].	Not included in the GINW or CNT approaches. Project promoters need to decide to what degree involvement, participation or engagement is appropriate.

Amenity provision		
Benefits	**Boundary conditions**	**Evaluation criteria**
Increases visibility of water[s]	This is to raise the profile and potential for the community to value the presence of water in their landscape, neighbourhood or places. Hence the scale will depend on the scope of the project.	No current valuation information for this, although it does relate to the value of properties in the vicinity of water. However, it is important to avoid potential double counting with other criteria when evaluating financial benefits (see 'improves aesthetics').
Provides	This is likely to be local. For	GI can increase recreational

[40] http://www.grabs-eu.org/ accessed 10-08-12

recreational opportunities[c, ES] (CULTURAL SERVICES)	example, despite having a concrete base and no green infrastructure, the 'mirror pool' in the City of Bradford provides recreation opportunities for children during hot weather.	opportunities. CNT state that the value of added recreational opportunities may be measured by avoided costs in connection to health benefits (USA), or via an increase in recreational trips, the "user days", gained from GI. In one Philidelphia study, 1 additional vegetated acre results in approximately 1340 user days/ yr; or 27,650 user days over the 40 year project period. 1 user day equates to $0.71 present value for the 40 year project period which equates to a benefit of £951.40 for each additional vegetated acre, and approximately $19,631 for each vegetated acre over the 40 year project period.
Improves aesthetics[c, ES] (CULTURAL SERVICES)	This is local. It is dependent on the view and cultural background of stakeholders on what is experienced as improved or decreased aesthetic value. It is important to ensure that all potential benefits as a society as a whole are included, rather than to a specific 'client'. Although green infrastructure is generally seen as an increase of aesthetic value, the alternative of losing traditional infrastructure with historic value may lead to a net negative impact even where for example, GI is being used.	Increased greenery has been shown to increase the aesthetic value of neighbourhoods. For example Willingness to Pay studies have shown an increase in property values of 2-10% in areas with new street tree plantings. In Portland, Oregon – street trees have been shown to add $8,870 to sale prices in residential properties and reduce the time on the market by 1.7 days. CNT state that it is difficult to isolate the effects of improved aesthetics and avoid double counting on benefits (e.g. air quality, water quality, energy usage and flood control) that also affect property values. CNT use a value of 3.5% increase. Annual property value gains per tree over a 40 yr average in the Midwest US region range from $4.50 - $23.44 in residential yards depending on the size of tree. Compared to £5.32 - £27.69 for public space, depending on the size of tree.
Improves accessibility[S]	This is a local criterion.	In general accessibility is related to access for those disabled, disadvantaged or otherwise excluded from engagement with the environment, ecosystems or amenity. This could be valued using a willingness to pay approach.

Acceptability

Benefits	Boundary conditions	Evaluation criteria
Has the potential to be replicated[S]	This will apply primarily at a local scale and relates to demonstration / pilot projects illustrating good practice that has the potential to be applied elsewhere. When applied to ES, it can fall in to multiple categories: Provisioning, Cultural and Regulating services. If it is a local formal blue or green space or informal green / blue space. It can also be related to urban greening.	This will not have a direct monetary value.
Is used/supported by local community	Local criterion by definition but should be considered to apply over a long period of time. However, could be amended to apply to a wider community depending upon how the boundaries of assessment are set.	CNT state that one way that green infrastructure can make communities better places to live is through its effect on 'community cohesion'—improving the networks of formal and informal relationships among neighborhood residents that foster a nurturing and mutually supportive human environment. There is also a link between increased vegetation and the use of outdoor spaces for social activity, theorizing that urban greening can foster interactions that build social capital

Media influence		
Benefits	**Boundary conditions**	**Evaluation criteria**
Is positively reported	Mainly local in scale but may also be regional or broader in case of locations that are of national or even wider importance. Reputations can be lost almost instantly now but take a long time to build-up. Example: Bryggen as a World Heritage Site has a high media importance both locally and wider.	Media in all forms, increasingly social media, is now vital for professional interaction, legitimacy and endorsement of interventions and the long-term sustainability of schemes, projects and quality of local areas. So far there are no monetised applications in media interaction endeavours, nor in the value of positive vs negative reporting.

Attention to cultural heritage		
Benefits	**Boundary conditions**	**Evaluation criteria**
Enhances tourism[S, ES]	Important at all spatial and temporal scales, although depending upon scheme may be	In 2008 global earnings from tourism summed up to US$944 billion. Cultural and eco-tourism can also educate people

	most important locally.	about the importance of biological diversity. The value of GI to increased tourism is calculated in TEEB and GINW by assessing the money spent on travel and local expenditure in order to visit a particular site. GINW also includes a tool to estimate the number of jobs supported by tourism and GVA associated with employment. Similar valuation methods are proposed by Getty Conservation Institute (GCI), 2002[41].
Preserves/ sustains/creates heritage	The spatial and especially time boundaries are important when assessing values to heritage.	In the valuation of heritage one can distinguish between *use* and *non-use* values. *Use-value* refers to the direct valuation of the asset's services by those who consume those services (e.g. entry fees paid by visitors to historic sites). *Non-use* value refers to the value placed upon a range of non-rival and non-excludable public-good characteristics typically possessed by cultural heritage. Taken together, the use and non-use values make up what is referred to as the economic value of a heritage asset or of the goods and services to which it gives rise, i.e., the monetary value of these items as assessed by an economic analysis. Three methodologies for assessing values are: contingent valuation methodology (CVM, inkl. WtP), travel cost assessments, and hedonic pricing. (GCI, Assessing the Values of Cultural Heritage, 2002)
Spiritual and religious value ES (CULTURAL)	This is a long-term criterion and here is related to attachment to a specific locale. In some cases this may be national (e.g. Maori culture in New Zealand) in others it may be very local (sacred place).	TEEB 'natural features such as specific forests, caves or mountains are considered sacred or have a religious meaning. Nature is a common element of all major religions and traditional knowledge, and associated customs are important for creating a sense of belonging.' There is no method to assess or quantify Spiritual and religious value within CNT or GINW approaches.
Inspiration of art, folklore, architecture ES	This is likely to be a local criterion.	TEEB 'Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and

[41] de la Torre M. Ed. (2002). Assessing the values of cultural heritage. Getty Conservation Institute, Los Angeles. http://www.getty.edu/conservation/publications_resources/pdf_publications/assessing.pdf [accessed 4-09-12]

(CULTURAL)		natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science. There is no method to assess or quantify Inspiration of art, folklore or architecture within the CNT or GINW approaches
Enhances human capacity: Sustains knowledge, traditions, implicit/tacit knowledge[S, WP4]	Can apply to entire nations and is a longer term criterion than: benefits of "provides educational opportunities", although double counting here is possible.	Many municipalities and organisations struggle to maintain implicit/tacit knowledge, although proper asset records and incident documentation in appropriate formats can reduce the loss of knowledge when staff leave or are no longer available. The economic value of this and enhancements in organisational capacity can be quantified financially by collecting appropriate date over time.
Social relations (e.g. fishing, grazing, cropping communities)	This is also about community cohesion and strength and is likely to be local, but long-term. Cropping communities can be considered as provisioning services as this is related to urban agriculture. Fishing and grazing can be considered as cultural services.	GINW states that Investment in green infrastructure can enhance access to natural green space and provide opportunities for various forms of formal and informal recreational activity – such as fishing. Studies have shown that the value attached to such investment by the public will vary across different forms of recreation and will be area-specific

Energy use		
Benefits	**Boundary conditions**	**Evaluation criteria**
Reduces urban heat island effect[c,] **/ Climate regulation (local temp, GHG sequestration etc.)** ES (REGULATORY)	This is a multi-scale criterion, both spatially and temporally.	The urban heat island (UHI) effect compromises human health and comfort by causing respiratory difficulties, exhaustion, heat stroke and heat-related mortality. UHI also contributes to elevated emission levels of air pollutants and greenhouse gases through the increased energy demand (via greater air conditioning needs) that higher air temperatures cause. Additionally UHI puts a greater demand on outdoor irrigation needs thus increasing water demand and its associated energy uses. Green infrastructure practices within urban areas can help to mitigate UHI and improve air quality through increased vegetation, reduced ground conductivity

		and decreased ground level ozone formation. CNT states that '*While the benefits of mitigating the UHI are important to community health and vitality, current valuation of these benefits is not extensive enough to work through quantifying methods and equations*'
Reduces water treatment needs[c] **/Reduces need for water purification & waste treatment** [ES] (REGULATORY)	Multi-scale possibilities. Falls under supporting services if considering chemical and microbial water quality as it can render the water effectively unavailable for supporting services.	From CNT: For cities with combined sewer systems (CSS), stormwater runoff entering the system combines with wastewater and flows to a facility for treatment. One approach to value the reduction in stormwater runoff for these cities is an avoided cost approach. Runoff reduction is at least as valuable as the amount that would be spent by the local stormwater utility to treat that runoff. In this case, the valuation equation is simply: runoff reduced (gal) * avoided cost per gallon ($/gal) = avoided stormwater treatment costs ($) This figure can be aggregated to a larger scale to demonstrate the cumulative benefit that can be achieved in a neighbourhood/region.