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Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

Deliverable 2.2.5

Development of generic Best Management Practice (BMP) Principles for the management of stormwater as part of an integrated urban water resource management strategy.

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Briefing Note

SWITCH Document: Development of generic Best Management Practice (BMP) principles for the management of stormwater as part of an integrated urban water resource management strategy.

Deliverable reference: Deliverable 2.2.5

Author(s) and Institution(s):
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Audience: The deliverable is of relevance to drainage engineers, urban planners, consultant environmental engineering groups, landscape architects and ecologists responsible for introducing Best Management Practices (BMPs) into new developments and for retrofitting urban surface water drainage systems. It is also of relevance to urban water resource managers and regulatory agencies with responsibility for urban surface water drainage infrastructure in terms of statutory legislation and design implementation for surface water drainage systems.

Purpose: This deliverable provides an analysis of the generic principles of selecting and implementing BMPs in an urban environment.

Background: The SWITCH project sets out to identify, develop, apply and demonstrate a range of scientific approaches and solutions which will contribute to effective and sustainable urban water management.

Section 1 provides an introduction to the role of BMPs in Integrated Urban Water Resource Management (IUWRM). The technical principles of water pollution, flood, source and site control BMPs are discussed in Section 2. Receiving water volumes and water quality, water reuse and ecology principles in relation to BMPs are considered in Section 3. BMP operation and maintenance (O&M) principles and responsibilities and the inspection of BMPs are addressed in Section 4. Section 5 considers the principles behind selecting and designing BMPs in relation to amenity and aesthetics, community stakeholder consultation, public health and safety risks and environmental education. The costs and benefits of BMPs are discussed in Section 6 and legal and urban planning principles are discussed in Section 7.

Potential impact: The review will potentially have an impact on cities and towns that wish to introduce Best Management Practices (BMPs) or sustainable urban drainage systems.

Recommendations: The dissemination of this review should be linked to the environmental and long-term economic benefits of adapting existing drainage systems to environmentally sustainable design criteria.

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Executive Summary

The key elements of a sustainable stormwater management strategy are clearly set out through the development of generic Best Management Practice (BMP) principles in this report. The advantages and disadvantages associated with different decision-making processes are described, and the conflict between an integrated approach and engagement with local stakeholders is recognised. This document uses information generated within SWITCH Tasks 2.2.1 and 2.2.4, and Work Packages (WPs) 1.1 (Development of a strategic approach and of indicators for sustainability and risk assessment) to 1.3 (Integration of existing infrastructure) and 6.1 (Governance for integrated urban water management). It feeds directly into the development of WP1.4 (Strategic planning, implementation and performance assessment) and it has been written in coordination with WP5.1 (Water sensitive urban design) through the presentation of concepts that are also integrated into the Design Manual of Tasks 5.1.1 and 5.1.5.

Section 1 of this deliverable provides an introduction to the concept of Integrated Urban Water Resource Management (IUWRM), Water Sensitive Urban Design (WSUD) and the role of BMPs in IUWRM. The principles behind the prevention of pollution to receiving waters by BMPs, flooding mitigation, source and site control by BMPs and the integration and retrofitting of BMPs into existing infrastructures are discussed in *Section 2*. In addition, the implementation of BMPs in new developments and the benefits to stormwater flow, storage management and surface water quality are discussed. Receiving water volumes and water quality, water reuse, and ecology principles in relation to BMPs are considered in *Section 3*. BMP operation and maintenance (O&M) principles and responsibilities and the inspection of BMPs are addressed in *Section 4*, as is the monitoring of their performance and the pre-requisites for effective O&M of BMPs.

Section 5 considers the principles behind selecting and designing BMPs in relation to community information and environmental education and public awareness, amenity and aesthetics and community stakeholder consultation and will be complemented by the output from Task 5.1.5. BMP public health and safety risks, design in relation to sustainable development principles, and their biodiversity potential and energy and resource use are discussed. The financial aspects associated with BMPs including the costs and benefits of retrofitting BMPs and their potential insurance costs are discussed in *Section 6*. Legal and urban planning principles are discussed in *Section 7*. In conclusion, the generic BMP principles within an IUWRM strategy and the implementation of IUWRM are summarised in tabular form for easy reference.

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Background: The SWITCH project sets out to identify, develop, apply and demonstrate a range of scientific approaches and solutions which will contribute to effective and sustainable urban water management. Section 1 of this deliverable provides an introduction to the role of BMPs in Integrated Urban Water Resource Management (IUWRM). The technical principles of BMPs for water pollution, flood, source and site control are discussed in Section 2. Receiving water volumes and water quality, water reuse and ecology principles in relation to BMPs are considered in Section 3. BMP operation and maintenance principles and responsibilities and the inspection of BMPs are addressed in Section 4. Section 5 considers the principles behind selecting and designing BMPs in relation to amenity and aesthetics, community stakeholder consultation, public health and safety risks and environmental education. The costs and benefits of BMPs and legal and urban planning principles are discussed in Sections 6 and 7 respectively.
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1 Introduction

"Water resources sustainability is the ability to use water in sufficient quantities and quality from the local to the global scale to meet the needs of humans and ecosystems for the present and the future to sustain life, and to protect humans from the damages brought about by natural and human-caused disasters that affect sustaining life" (Mays, 2007).

In order to sustainably manage water resources on a global scale, it is necessary to begin at a local scale by ensuring that efficient and effective local water management strategies and infrastructures are in place. Urban areas vary enormously in their water resource management history and the water resource utilities and infrastructure designs that have resulted from that. Municipal and industrial demands on the available water resources also vary greatly from place to place so there can be no clear cut strategy for sustainable water management that will be effective in all cases. The stormwater management scenario in any given urban area consists of a series of site-specific traits that are characterised principally by the physical and geographical nature of the environment, the population behavioural traits, and the economic climate.

The stormwater strategies, both conventional and innovative that have been described and assessed within the scope of the SWITCH project may be applied with varying levels of success in different urban areas or management scenarios, with BMP scenarios having the potential to provide varying levels of benefit in different locations. The aim therefore of this SWITCH Deliverable is to develop a set of underlying management principles that can be used as a guide to decision-making with regard to stormwater BMPs. These principles will provide guidance to facilitate the decisions of urban area planners in Europe and other continents and will relate to the BMPs described and discussed in the SWITCH project (WPs 2.1 and 2.2).

A great deal of work has been conducted in the international arena with regard to Water Resource Management (WRM) and sustainability and it is important that the findings of this work are integrated into the outputs from the SWITCH project. Sets of principles or values have previously been developed by international and European organisations for various water management scenarios and it is the intention of this work to integrate BMP principles into the framework of these existing ideologies. This introductory section summarises the existing management principles taken from international declarations such as the "Dublin Statement" and from European Directives of relevance to BMPs and discusses how BMPs have a role to play in the implementation of Integrated Urban Water Resource Management (IUWRM).

1.1 The concept of Integrated Urban Water Resource Management

Integrated Urban Water Resource Management (IUWRM) is a concept designed to facilitate sustainable water use in urban areas. Urban areas have a number of water management issues that are often addressed separately by planners and environmental managers. The key issues of urban water management are drinking water security, wastewater treatment and sanitation, flood control, surface and ground water quality, ecological concerns, and recreation. Novotny and Brown (2007) proposed a concept entitled "Cities of the Future", in which past and future urban developments are to be integrated with the landscape, habitat, transport, and drainage infrastructures. This concept proposes that urban stormwater and treated effluents are to be reused for landscape irrigation and groundwater recharge and that a total hydrological mass balance can therefore be achieved where water supply, stormwater, and wastewater are considered and managed in a closed loop.

The concept of IUWRM has been developed by water managers and stakeholder organisations around the world. Accordingly, a number of sets of principles have been developed by both international and European organisations in order to assist and guide the implementation of IUWRM strategies that contribute towards the goal of sustainable water use in urban areas.

The "Dublin Statement" (International Conference on Water and the Environment, 1992) emphasises the following main points;

- Freshwater resources are finite and vulnerable requiring the simultaneous management of social and economic concerns with environmental protection;
- A participatory approach is required, encouraging the active consultation of all stakeholders in planning and implementation;
- The role of women is important to all aspects of WRM, from provision and protection to decision-making and implementation, and institutional governance should support their participation;
- Water has an economic value in all its uses and services and should be recognised as an economic good in order to discourage wasteful use and environmental damage. Waste discharge controls are also necessary and are not trade-offs for industrial growth or prosperity.

According to the Global Development Research Centre (GDRC, 2009), Integrated Urban Water Resources Management (IUWRM) is "a participatory planning and implementation process, based on sound science, which brings together stakeholders to determine how to meet society's long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits".

The GDRC describes the principal components of an IUWRM system as:

- Supply optimisation, including assessments of surface and groundwater supplies, water balances, wastewater reuse, and environmental impacts of distribution and use options;
- Demand management, including cost-recovery policies, water use efficiency technologies, and decentralised water management authority;
- Equitable access to water resources through participatory and transparent management, including support for effective water users association, involvement of marginalised groups, and consideration of gender issues;
- Improved policy, regulatory and institutional frameworks, such as the implementation of the polluter-pays principle, water quality norms and standards, and market-based regulatory mechanisms; and
- Inter-sectoral approaches to decision-making, combining authority with responsibility for managing the water resource.

Stormwater has an important influence on a number of aspects of the IUWRM system due to its impacts on discharge peaks, pollution pathways, movement of sediments, flooding, and as a disease vector. These issues are enhanced in urban areas due the impervious nature of many urban surfaces and the population density.

"Agenda 21" (UN Department for Sustainable Development, 1992) used the principles from the "Dublin Statement" in developing its approach to an "environmentally sound management of water resources for urban use". Much of the focus of Agenda 21 is on the elimination of unsustainable consumption patterns, but there is also significant mention of the disposal and treatment of wastewaters as integral to the protection of fresh water resources. Agenda 21 proposes a number of

actions with associated specific activities that should be integrated into current urban water management practices as follows;

- Protection of water resources from depletion, pollution and degradation;
- Efficient and equitable allocation of water resources;
- Institutional/legal/management reforms;
- Promotion of public participation;
- Support to local capacity-building; and
- Provision of enhanced access to sanitary services

The use of Sustainable Urban Drainage Systems (SUDS), a term used in the UK, or Best Management Practices (BMPs) as they are known in the US and continental Europe and are referred to in the SWITCH project, can contribute to the implementation of these actions and they therefore represent an important element of sustainable stormwater management, which contributes in turn to the successful implementation of an IUWRM strategy.

1.2 Water Sensitive Urban Design

Urban water supplies are under increasing pressure to meet the demands of growing populations and changing industries. In many parts of the world, this is occurring within a context of climatic change that may involve an increased frequency of extreme events such as flooding or extended droughts. To ensure a secure water supply into the future, cities must become 'water sensitive' by reducing water use per capita, minimising waste water, encouraging water recycling, and mitigating anthropogenic impacts on aquatic ecosystems.

Water Sensitive Urban Design (WSUD) is defined within the SWITCH project as interdisciplinary cooperation of water management, urban design and landscape planning which considers all parts of the urban water cycle, open space and urban design and provides synergy for the ecological, economic, social and cultural sustainability. WSUD varies greatly in terms of the techniques used and the scale of the operations. Technologies may be incorporated into newly developed buildings such as the use of green roofs, grey water recycling systems, or porous paving. Alternatively, they may be incorporated into the local infrastructure with examples including roadside swales or detention basins.

The use of WSUD technologies in new developments will represent limited impact towards creating water sensitive cities unless there is a wider and well coordinated approach to urban water management that accounts for the entire water cycle within a local, regional and national policy context. This needs to integrate water, land, air, energy, and waste issues and may include both structural and non-structural solutions (i.e. educational or preventative measures).

In 2004, the Australian government developed a policy blueprint to improve the way in which water resources are managed in Australia. The outcome of this was the Australian National Water Initiative (NWI) that began a process of reform by publishing position statements on water resource issues. Priority issues were identified and commitments were made including one to develop innovative ways of achieving more efficient and sustainable water use in Australian cities. The NWI recognises the importance of integrated urban planning in the development of water sensitive cities and consequentially WSUD developments have been supported as well as the provision of guidelines for evaluating options for WSUD. Institutional and regulatory models for achieving integrated urban water cycle planning and management are currently under review in Australia.

The Australian Government has funded an integrated resource-planning project to assist urban water service providers and government agencies in determining the following aspects:

- regional water availability;
- regional water use (while protecting and delivering environmental and social values); and
- provision or support of water services (through water use efficiency, source substitution, supply options) for their region in the future.

The project proposes to develop guidance on incorporating climate change into utility planning, and it will use an issues paper on integrated urban water cycle planning and management that has been produced by the Australian Government National Water Commission (2009). This paper has helped to identify the priority areas for current and future work, including:

- enhancing the coordination of water resource and urban planning at a whole-of-government level;
- assisting water agencies to undertake integrated water supply and demand planning and regional supply strategies;
- reviewing and clarifying entitlements to new sources of water (e.g. recycled water, stormwater, desalination water); and
- examining issues relating to intra-urban trading and trading between urban and rural sectors.

The approach adopted by the NWI is exemplary in its holistic approach to the reform of water resources management as it provides detailed management solutions for environmental, economic, and social concerns including those of Australia's indigenous people and all within a climate of population growth during prolonged drought conditions. There are lessons to be learnt from the Australian approach that can be applied to integrated urban water resource management strategies around the world.

D5.1.5 of the SWITCH project has developed a WSUD design manual that can be used as a reference document or guide to the achievement of successful WSUD schemes. It compliments the principles set out in this document and may be read in association with this document.

1.3 BMPs and IUWRM

The concept of BMPs is well documented (CIRIA, 2009; International Stormwater BMP Database, 2009) with a Code of Practice already developed in the UK (National SUDS Working Group, 2004). BMP technologies and techniques are described in detail in SWITCH Deliverables 2.1.1a; 2.1.1b and 2.1.4 and have been shown to offer many benefits to stormwater storage and flow regulation, water pollution control, wildlife habitats, and amenity value. As a result, BMP systems have become increasingly accepted as an essential element of low impact developments and their implementation is central to the movement towards achieving IUWRM around the world.

The EU FP6 DayWater project identified six areas of managerial expertise that relate to all aspects of IUWRM and stormwater management. These six areas can serve as a framework for the development of principles relating to the use of BMPs within IUWRM and so this deliverable follows this approach by addressing, in separate sections, the following aspects:

- Technical;
- Environmental;
- Operation and maintenance;
- Social and urban community benefits;
- Economics;

- Legal and urban planning.

Generic principles for the successful implementation and use of BMPs are presented in light of these issues, demonstrating how BMPs represent a feasible management approach to the implementation of an IUWRM strategy.

For reference, the SWITCH deliverable for Task 1.1.1 reports an inventory of conventional and innovative approaches for urban water management. It also describes the evolution of the IUWRM ideology through international and European debate and strategy development. The SWITCH deliverable for Task 2.2.3 describes a number of issues, risks and barriers that exist in relation to the successful achievement of sustainable surface water drainage management in urban catchments (Ellis *et al*., 2006). It is important that the principles developed within the scope of the current deliverable address these risks and barriers, and work towards providing solutions.

The barriers to successful UK surface water drainage management listed in SWITCH deliverable 2.2.3a and the sections of this report that will propose solutions are listed in *Table 1*. BMPs have a role in the implementation of IUWRM strategies as they can prevent or counteract some of these barriers whilst simultaneously providing solutions to the multiple management concerns of urban water resources. The principles set out in this report intend to counteract or prevent these barriers to successful IUWRM implementation. *Table 1* shows in which section each counteracting principle can be found.

Table 1 Decision-making barriers and counteracting principles

Decision-making barrier or limitation	**Report section containing a counteracting principle**
Lack of clear, strategic responsibility for surface water flooding	Legal and urban planning
Lack of clear identification of institutional leadership and responsibilities for local surface water flooding (especially for wet weather exceedence due to pluvial flooding)	Legal and urban planning
Coordination and integration of planning processes in relation to flood risk	Legal and urban planning
Lack of local/regional surface water management plans (SWMPs)	Legal and urban planning
Local Authority resource capabilities and organisational capacity	Legal and urban planning
Adoption of BMP/SUDS drainage systems	Legal and urban planning
Right-to-connect to public sewer system for new urban developments	Legal and urban planning
Definition of "sewer" and inclusion of BMP/SUDS within standard definitions.	Legal and urban planning
Extension of impermeable surfaces and urban "creep"	Legal and urban planning and Technical
Responsibility for modelling and mapping extreme wet weather pluvial (exceedence) flooding	Legal and urban planning and Technical
Restriction on sewer design levels and standards	Technical
Information and data sharing between stakeholders	Technical and Social and Urban Community Benefits
Lack of community perception and awareness of flood risks	Social and Urban Community Benefits
Lack of capital and maintenance funding to establish and implement coordination and partnership proposals as well as introduction of alternative planning and drainage systems	Economics

2 Technical

The BMP approach to IUWRM is based on a management train of four hierarchal technical principles. The BMP hierarchy consists of prevention, source control, site control, and regional control, with the various BMP systems offering solutions at each level as follows:

1. Prevention: minimising impermeable surfacing; road sweeping.
2. Source control: rainwater harvesting; pervious paving; green roofs; soakaways.
3. Site control: runoff routing to soakaway; infiltration basin.
4. Regional control: detention pond; wetland.

Storm events in urban areas pose particular technical management issues at the different levels of scale and the following principles demonstrate how BMPs are integral to effective and sustainable urban stormwater management. These principles relate to the three indicators of sustainability used to mark the technical success of BMPs as described in the DayWater project. These are flood control, pollution control, and adaptability to urban growth.

The technical factors described in this section refer to the functional aspects of BMPs such as stormwater storage, flow management, and benefits to the water quality of receiving bodies. Also considered are the technical aspects of selecting the correct BMP for a given scenario and the technical challenges and barriers to their implementation within a framework of existing infrastructures.

2.1Technical principles relating to pollution and flood control

Preventing surface water pollution from contaminated stormwater as part of an IUWRM strategy involves the careful management of stormwater flows as well as the treatment of polluted stormwater. A strategy that reduces or prevents the pollution of stormwater should be prioritised over a strategy that focuses on the treatment of polluted waters, either combined wastewater or stormwater, after a storm event. Stormwater contamination can be prevented through the use of BMPs in some cases, so this section describes the relevance of BMPs in a preventative IUWRM strategy.

2.1.1 The prevention of a deterioration to receiving water quality by using BMPs

Stormwater should be prevented from reaching receiving waters unless it has first been treated by an appropriate BMP or at a wastewater treatment plant.

A threat to receiving water quality in Accra was identified by SWITCH Deliverable 2.1.1b as being due to a lack of suitable interceptors between stormwater flows and receiving waters. These may be interceptor sewers, storage BMPs, or a wastewater treatment plant. The implementation of these technologies is commonly prevented by a lack of investment or by political or social issues associated with the informal development of riparian areas that prevent the construction of interceptors. It is important that polluted stormwater is prevented from reaching receiving waters by installing interceptor sewers where they do not already exist, or by optimising the efficiency of those that do exist through improvements and maintenance.

Both structural and non-structural BMPs have the potential to prevent receiving water pollution and both should therefore be considered in an effective IUWRM strategy.

Structural BMPs are those that are engineered or constructed using man-made materials and/or natural systems, whilst non-structural BMPs tend to preserve existing open space or protect natural systems for improved drainage and filtration, or they use urban planning and maintenance measures to manage urban water flows. Road sweeping, as a maintenance related non-structural BMP, has significant potential in reducing the level of pollutants that reach sewage systems and receiving waters by physically removing them from urban road surfaces. This is particularly true of contaminated particulates, as described by Muhammed and Morris Hooke (2006) who showed that street sweeping is able to remove significant quantities of heavy metals from areas categorised as residential, commercial, and high traffic areas. As a measure to prevent pollutants from reaching sewers, a fit-for-purpose street sweeping regime should be developed for all urban areas. The design of a successful regime will incorporate the physical characteristics of the local area, any seasonal variations that may affect drainage (i.e. leaf litter in autumn), and road use data. Other BMPs that prevent the pollution of receiving waters are those that allow the settlement or filtration of stormwater flows, e.g. infiltration basins and trenches (*Figure 1*), and swales (*Figure 2*).

Figure 1 Example of an infiltration trench

Figure 2 Example of a swale

It is important to include both structural and non-structural BMPs in any good IUWRM strategy as they prevent the movement of pollutants from stormwater into receiving waters in different ways. A combined approach is therefore more robust and able to remove a greater quantity of pollutants overall than any one BMP alone.

2.1.2 The role of BMPs in the prevention of flooding

Impermeable surfacing should be minimised in urban areas

Impermeable surfaces such as concrete accelerate the rate at which stormwater reaches sewers or receiving urban waters. As urban areas with a combined sewer system commonly have combined sewer overflows (CSOs) with associated pollution events, it is advisable to reduce the amount of water flowing to sewer following a storm event where possible. It is possible to reduce the quantity of stormwater flowing to these receptors by encouraging infiltration, which can be achieved through a

number of BMPs including porous paving and road surfaces with an infiltration bed, by providing localised temporary storage instead of immediate run-off *(Figure 3).*

Figure 3 Pocket wetlands and porous road surface, Manly, NSW, Australia

This type of measure should be implemented in all new developments wherever possible, and consideration should also be given when retrofitting developed areas (see *Section 7.1*).

Green roofs are effective at retaining rainfall within the growing media and plants. They are often favoured in developed urban areas where retrofit solutions are the only realistic ways of integrating BMPs and where aesthetics are also important. Modelling and mapping of extreme pluvial exceedance flooding can assist the correct implementation of this type of BMP. It enables planners to identify areas that are commonly affected by surface run-off and to implement localised infiltration and storage mechanisms that could reduce the impact of exceedence periods on the wider stormwater management system.

BMPs should be used to expand existing stormwater drainage and storage systems where climate change predictions forecast increased precipitation and associated flooding.

The storage potential of BMPs can contribute to improved flood prevention. This is particularly relevant in areas affected by the predicted increases to storm frequency and intensity related to climate change and the associated potential increased risks of flooding. A significant level of development and maintenance investment may be required if the existing hydraulic system is underperforming. Elevated flood risk caused by climate change is expected to be more pronounced in areas that are already subject to flood risk due to anthropogenic activities such as increased impervious urban surface cover, decreased areas of vegetation, or deforestation. IUWRM strategies should consider how BMPs can contribute to current flood prevention and also how they may counteract future flood scenarios which have been forecast in relation to existing climate change data.

Tools for modelling and mapping extreme wet weather should be developed and employed for the prediction of pluvial exceedence flooding and for the planning of BMPs as mitigation measures and data should be shared with stakeholders.

Some EU countries use sophisticated mapping and modelling tools to predict heavy rainfall and any associated flood risks. The UK Flood Forecasting Centre, for example, works with the Environment Agency and the Meteorological Office to provide a continuous national forecasting service that monitors meteorological conditions and models how hydrological interactions create a flood risk. This provides an early warning system to inform the public that they may be at risk, and it allows flood risk maps to be created that highlight areas where mitigation measures such as BMPs may be

best employed. This type of collaboration is occurring elsewhere in Europe through the European Flood Alert System project that was designed to develop a continental-scale flood forecasting system for European river basins (Gouweleeuw *et al.*, 2004). Research effort should be continued in this area both within individual countries and Europe-wide in order to create accurate forecasting tools that may reduce the impacts caused by extreme weather and to facilitate planning decisions regarding the use of BMPs in flood management.

For information and data gathered by modelling and mapping to have a positive impact on IUWRM strategies, it must be shared as much as possible between stakeholders. This includes scientists, policy makers, urban planners, and the general public who may be affected by flood risk.

2.2 Technical principles relating to source control

SWITCH Deliverable 2.2.1b has identified a number of situations that can result in persistent and chronic pollution of water bodies as a result of ineffective source control.

Source control aims to mimic, as far as possible, the natural drainage characteristics of a site. In practice, by alternately storing and releasing stormwater, source control systems increase the time period of release which would occur naturally. Source control elements include infiltration structures that return all of the water to the ground (pervious pavements, soakaways, infiltration trenches), structures that store water (water butts, rainwater tanks) and structures that attenuate flow rates (swales, filter strips) and allow settlement of sediment particles. Source control systems, either stand-alone or linked systems as part of a treatment train should be introduced to new developments or retrofitted to reduce runoff volumes discharged to receiving waters.

US design standards require that the outflow from source control BMPs should not exceed pre-development peaks. The Environment Agency for England and Wales require peak outflow volumes of 4 litres per second per hectare although this figure is contentious. Sewer design level guidelines and standards should be reviewed such that minimum capacity restrictions are increased to improve the transmission of storm flows and to reduce the frequency of CSO pollution incidences. Minimum capacities should be tailored to the local climatic conditions and population density.

2.3 Technical principles relating to site control

2.3.1 The integration and retrofitting of BMPs into existing infrastructures

SWITCH Deliverable 2.1.2 describes the potential for BMPs to integrate with existing infrastructure, whilst SWITCH Deliverable 1.3.1 discusses a framework by which research and other developments in urban water systems can best be integrated into existing infrastructures and management systems. Retrofitting is the modification of an existing drainage system via the addition of a sustainable drainage feature to improve the efficiency of the hydraulic regime or to improve water quality (SNIFFER, 2006).

Urban areas are often restricted by the amount of space available for the construction of BMPs. As a result, small BMPs such as water butts and those that can be integrated into existing structures such as green roofs are often the preferable solutions for retrofitting (*Section 6.2*). The BMPs that are considered to be most suitable for retrofitting are listed below Woods-Ballard *et al.* (2007).

- Green roofs
- Soakaways
- Water butts
- Rainwater harvesting
- Filter strips
- Infiltration trenches
- Swales
- Bioretention systems
- Pervious pavements
- Geocellular systems
- Sand filters
- Detention basins

Barriers to retrofitting BMPs identified by Hunt & Roger (2005) and listed in SWITCH Deliverable 1.3.1 are summarised below.

- Lack of knowledge or awareness
- High initial costs
- Maintenance costs
- Long payback periods
- Risk aversion
- Lack of viable targets
- Complex systems
- Lack of communication
- Lack of experience
- Public perception
- Public behaviour
- Social acceptability
- Lack of legislation
- Lack of information
- Politics
- Profit margin of water companies
- Water quality
- More pressing issues
- Lack of viable monitoring

BMP technologies and visions should be carefully integrated into existing urban water policies and retrofitted into existing urban and rural area infrastructures, with necessary concessions made for local characteristics and public awareness

The concept of retrofitting existing systems to improve their capacity for source control and water reuse is central to the success of BMP objectives. A range of retrofit solutions has been suggested in a SNIFFER report (SNIFFER, 2006). This report also proposes a generic methodology for retrofitting BMPs that is based on a phased approach that involves stakeholders and an appraisal of options before the design and implementation stages are reached. This approach is useful for practitioners wishing to introduce BMPs into developed areas

Retrofitting BMPs in urban areas has been conducted with success in many parts of the world, being implemented both as individual structures and in tandem as 'treatment trains' with other BMPs. For example, a combination of green roofs, swales, detention ponds, and small wetlands were retrofitted in an inner city suburb of Malmo, Sweden in order to reduce the impact of CSO related flooding following heavy storm events. The ponds are designed to attenuate 10-year event rainfall, and the green roofs are effective at reducing total run-off. This type of retrofitting involves significant costs associated with both construction and maintenance activities. Some retrofit options however, can have a significant positive impact on reducing CSO discharges and flood risk but involve a far lower degree of engineering and construction. In Portland, Oregon for example, a downspout disconnection programme has been running since 1995. More than 56,000 households have participated in the programme whereby their roof-draining downspouts have been disconnected from the mains sewers and allowed to drain freely into soil. In addition to the water quality and ecological benefits to the local Willamette River from reduced CSO discharges, residents have found that their local environment improved due to gardens being better irrigated by the use of downspout water (Portland Environmental Services, 2009).

In Dagenham, England a stream that receives substantial runoff from a nearby urban catchment was retrofitted with a settlement chamber and three beds of surface flow constructed wetland separated by

weirs to control and evenly distribute the flow (Scholes *et al*, 1999). Planting with *Typha latifolia* and *Phragmites australis* was found to effectively reduce the levels of suspended solids and aqueous metal concentrations in the stream discharge. A requirement for greater public awareness was identified at the site however, due to the toxins known to accumulate in the settlement chamber which was accessible to the public and also because horses were allowed to graze on the *T. latifolia* with potentially detrimental consequences on the effectiveness of the BMP. Careful planning of retrofit BMPs is therefore crucial to the success of BMPs in achieving their objectives.

2.3.2 The implementation of BMPs in new developments

BMPs should be included in the drainage and flood management plans for all new developments as a contribution towards achieving the objectives of River Basin Management Plans (RBMPs) as set out in the EU WFD. There are fewer barriers to their implementation in new developments than where they are intended for retrofitting. They must still be appropriately selected for the local conditions and development type however, and careful consideration must always be given to their maintenance requirements and role within wider IUWRM issues.

At the time of writing, the UK government has proposed the development of new "Ecotowns" that will be designed to be exemplar settlements of 5,000-20,000 homes that meet the highest standards of sustainability and green credentials. This would include sustainable water management techniques and the implementation of BMPs from the outset of planning. The final Planning Policy Statement has recently been published (CLG, 2010) explaining the planning criteria for these developments. It is feasible for developments of this nature to serve as inspiration to other urban areas undergoing development.

BMPs should be implemented in new road developments as storage, settlement and filtration techniques and should be used to divert road runoff from public sewerage systems.

Road runoff contains a number of vehicle-related pollutants and debris such as rubber and metal deposits, antifreeze, salts from winter gritting, engine oil, and a wide variety of litter. The cleaner production principle described in *Section 2.4.2* emphasises the importance of keeping different waste streams separate where possible and BMPs offer solutions to pollution caused by road runoff. Regular road sweeping can reduce the pollutant content of road runoff whilst swales, pervious paving, and retention ponds can reduce runoff quantities going to public sewer. Diversion of road runoff away from the public sewerage systems reduces the loading on municipal wastewater treatment plants (WWTPs) and allows them to cope better with storm events thus avoiding the discharge of overflows to receiving waters.

The Stockholm Highway Runoff Pond SORBUS project near Lilla Essingen, Stockholm, Sweden uses a sedimentation pond and filtration setup, biofilter, and two reactive filters (bark and limestone) for the treatment of runoff from an elevated motorway and its surrounding urban area. The cold climate of the area causes stormwater runoff from this area to be contaminated with antifreeze chemicals and salts that are applied to this road in larger quantities due to its elevation and the associated higher risk of road ice formation. Monitoring is on-going but the treated water is of sufficient quality to be discharged directly into nearby Lake Mälaren (Baun *et al.*, 2005). This project demonstrates how it is possible to divert road runoff from the sewerage network and how BMPs can treat vehicle emission contaminated runoff to a high enough level for it to be discharged safely into receiving waters.

2.3.3 Site-specific characteristics

Site-specific characteristics must be carefully considered when selecting the most appropriate BMP for implementation in any given area. The DayWater Multi-Criteria Comparator (DayWater, 2009b) identifies water table level, soil hydraulic conductivity/soil type/infiltration rate, and contributing

drainage area as site characteristics for use as indicators in the selection process. Any standards or guidance that may be developed to assist the governance of BMP construction and operation should take this into account.

The physical circumstances of urban areas should be carefully considered when selecting the most appropriate BMPs.

Soil type must be considered in the selection of the most appropriate BMP for a given area. The presence of clay-rich soil in the Dunfermline area of Scotland for example, limits the potential for retrofitted BMPs that rely on infiltration due to the impervious nature of the soil. Some circumstances will allow the drainage of stormwater stored in a BMP into the ground as the water is of sufficient quality and there is no risk of groundwater contamination, whilst other areas may need to encourage evaporation. Furthermore, in countries that suffer from or control disease spread by insect vectors like malaria or dengue fever for example, it may not be advisable or permissible (e.g. Singapore) to create BMPs that involve standing water. The larger BMPs such as constructed wetlands require a large land-take area, which is not possible in all urban areas so it is clear that the physical circumstance in a given area must be given full consideration when developing an IUWRM strategy that involves BMPs.

2.4 Technical principles relating to regional control

2.4.1 Benefits to stormwater flow and storage management

Many BMPs serve as runoff attenuation and detention mechanisms enabling them to contribute to both stormwater flow control and flood management. This is particularly important in urban areas where the percentage of the catchment covered by impermeable surfaces is usually high (around 50%), coupled with high population densities and high property values. As a result, BMPs are becoming more frequently included in urban drainage management plans and are increasingly constructed as integral parts of new urban developments.

BMPs offer a means of storing urban runoff and stormwater flow and of regulating the post-storm event discharge into receiving waters with benefits to flood and pollution control.

BMPs such as detention basins, retention ponds and wetlands can store surface runoff, which thereby provides a flood attenuation service to the surrounding urban area. The release of flow from these reservoirs can be controlled such that peak discharges can be better managed through an urban catchment. For example, the proposed (planning decision to be made by 11 March 2010) Clay Farm residential development near Cambridge (UK) (www.clayfarm.co.uk) has a drainage strategy that includes the discharge of the runoff from four catchment areas through attenuation ponds into the nearby Hobson's Brook. The ponds are designed to hold runoff and to discharge it into the local brook at a controlled rate in accordance with Environment Agency regulations. Shallow vegetated swales are also included in the plan for conveyance and storage where space is adequate. Dry detention basins, wet ponds, and existing ditches are also included in the development's drainage strategy, the intention being to satisfy sustainable principles set out in local planning documents by reducing surface water run-off flows, surface water pollution, and by providing flood hazard protection. The drainage strategy prioritises source control by maximising infiltration as near to source as is reasonably practicable via the use of soakaways, permeable paving, small localised swales and ditches. Balancing facilities are also planned for surface water attenuation and detention that will be capable of accommodating a 100-year event including an allowance for climate change.

2.4.2 Improvement of surface water quality

A number of studies have investigated the technical pollutant removal efficiency of BMPs. For example, an experimental study conducted by Tang *et al.* (2008) found that outdoor constructed wetlands are able to remove up to 72-81% of benzene from hydrocarbon contaminated wastewater streams (where the influent benzene concentration was approximately 1g/L), whilst Moore *et al.* (2002) identified an ability for constructed wetlands to significantly reduce concentrations of the pesticide chlorpyrifos. The ability of BMPs to successfully remove pollutants depends on several factors including the influent pollutant concentrations, the BMP treatment train design and the land area available for their construction. The benefits that BMPs can offer to surface water quality is recognised and they should be implemented as part of wider strategies in national and regional plans to facilitate compliance with the EU Water Framework Directive.

A cleaner production approach should be applied to IUWRM by the development of stormwater BMPs in urban areas.

As part of the pollution control principle described by the DayWater project (Revitt *et al.*, 2008; DayWater, 2009a), the cleaner production approach behind the UNEP 3 Step Strategic Approach (Nhapi and Gijzen, 2005) should be applied to urban water management scenarios via the implementation of BMPs.

In brief, the three steps of the UNEP Strategic Approach are prevention, treatment for reuse, and planned discharge with stimulation of self-purification capacity. BMPs can contribute to each of these three aspects of the approach, and they can demonstrate the application of the four principles of the cleaner production approach as shown in *Table 2*.

Table 2 BMPs and the cleaner production approach principles

Principle		BMP contribution to achievement of cleaner production principle
1	*Use the lowest amount of input material, energy or other resources per unit of product*	BMPs offer a resource and energy efficient method of storing and treating urban runoff and stormwater flows.
2	*Do not use technology of a higher quality or performance than is necessary.*	The use of BMPs can reduce stormwater flow volumes to WWTPs which will save energy and resources at the WWTP. BMPs may also be sufficient for preventing certain PPs from reaching surface waters.
3	*Do not mix different waste flows.*	The use of BMPs can divert, store and treat stormwater flows that would otherwise be combined with sewage flows through conventional drainage routes.
4	*Evaluate other functions and uses of by-products before considering treatment and final disposal*	The storage of urban runoff and stormwater flows in BMPs may potentially provide an urban area with wildlife and amenity value as a by-product of a storm event that would not otherwise be possible if all stormwater passes through conventional drainage routes.

3 Environmental

The three main indicators for the environmental performance of BMPs, as described by the DayWater project, are impacts on receiving water volumes, receiving water quality, and ecology (DayWater, 2009a). These indicators all refer to the natural environment but it should be noted that the human environment is also of significance within this chapter.

The key points for consideration with regard to IUWRM and environmental concerns are listed below with the indicators that relate to them shown in brackets:

- Drainage and flood prevention (receiving water volumes);
- Pollution control in relation to the protection of drinking water sources and ecosystem health (receiving water quality);
- Water saving/reuse (receiving water volumes);
- Protection and enhancement of habitats, species and natural processes (ecology);
- Protection and enhancement of bathing areas and other recreational waters (receiving water quality);
- Stakeholder engagement (all indicators).

The Victorian Stormwater Committee of Melbourne, Australia have developed a set of principles for WSUD within their document "Urban Stormwater – Best Practice Environmental Management Guidelines" (Victorian Stormwater Committee, 1999). Three of the five principles relate to environmental concerns, demonstrating an emphasis placed on the value of natural systems and the need for IUWRM to carefully integrate the protection and enhancement of these systems with the management of other issues such as economics. The environmental principles mentioned are:

- Protect natural systems;
- Integrate stormwater treatment into the landscape;
- Protect water quality.

3.1 Principles regarding receiving water volumes

The main points regarding the impact of BMPs on receiving water volumes are made in *Section 2.1* as this is also considered to be a technical aspect of BMP performance. This aspect is also included here because receiving water volumes are important to the protection of natural systems and aquatic ecosystem health.

BMPs should be implemented to protect and maintain water volumes in receiving water bodies such that natural physical and biological processes are unaffected.

River hydrodynamics are vital to aquatic ecosystem health and are the main driver for river evolution due to the effects of variable flow rates on sediment regimes. The EU Habitats Directive (92/43/EEC) is designed to maintain biodiversity through the conservation and protection of wildlife habitats. In aquatic environments this includes the conservation of the hydrological and sedimentary processes on which aquatic biota depend. Complementary to the Habitats Directive, an objective of the WFD is to improve the chemical and biological status of surface water bodies and in order for this to be achieved, the hydrological balance of a given water body must be managed and maintained. This is particularly relevant for water bodies that are used as a drinking water source because abstraction has

the potential to significantly alter flow rates, especially in areas or periods of low rainfall. In England and Wales, drought permits can be issued by the Environment Agency to water utility companies during prolonged periods without rain to ensure that abstraction levels do not alter the flow regimes.

Certain BMPs can be used as water storage mechanisms that can be managed to maintain the flow of a river. The Brent Reservoir in northwest London was originally designed to provide water storage and supply for the Grand Union Canal in the 19th century, but is currently functioning as an effective wetland BMP by storing, treating and releasing stormwater which supplements the flow of the River Brent that finally discharges to the River Thames (*Figure 4 and5*).

Figure 4 The Brent Reservoir, NW London, UK

Figure 5 Floating rafts in the Brent Reservoir (www.wikipedia.com)

3.2 Principles regarding water reuse

BMPs that store water should be encouraged and facilitated in water scarce areas.

Rainwater harvesting in water storage tanks and water butts is a simple and effective way of reducing water demand or water scarcity in semi-arid or seasonally dry areas. Storage containers have been constructed from a variety of materials including clay, concrete, metal and plastic and they can be situated above or below ground. The International Rainwater Catchment Systems Association has documented numerous projects that have assisted the purchase and installation of water storage

containers in countries such as Uganda, Sri Lanka, Thailand and Brazil (IRCSA, 2009). Rakai is located in the southern hills of Uganda and has a tropical bimodal climate. Small (700 litre) jars have been made by a women's group to collect water from roofs and supplement their potable and non-potable water needs. The jars cost less than US$70 each to produce. The town of Badulla is located in a hilly area of Sri Lanka and also experiences a tropical, bimodal climate. Rainwater is used as a main water source and groundwater sources are few and tend to be at the foot of the hills. To reduce the burden of carrying water, the local authority provided 5,000 l ferrocement tanks at a cost of about US$150 per tank, which are used to collect water from roofs for most household water supply. The tanks are now being adopted nationwide for use in areas where access to other protected water sources is difficult. Khon Kaen is located in north east Thailand and experiences a tropical monsoon climate. The "Thai jar", with a capacity of 1-2 m^3, was selected for one of the world's largest roofwater harvesting projects. The jars were produced commercially on a large scale and for less than US$30 per jar, thus enabling the purchase of the jars throughout the population. Petrolina is in the semi-arid belt of north east Brazil. Rainfall is low and varies from year to year. Tanks with 1-2 m^3 capacity are used to store water for potable and non-potable use by each household. They are usually provided by NGOs as the cost, starting from US$200 per tank, is unaffordable by the local population.

3.3 Principles regarding receiving water quality

The EU DayWater project has conducted research to quantify the average quality of urban surface water run-off from a variety of urban land uses including residential developments, industrial areas, and roads (www.daywater.org). The main BMP principle regarding receiving water quality is that BMPs can reduce the loading of many pollutants such as suspended solids, heavy metals, oils, nitrates and phosphates, and other parameters such as biological oxygen demand (BOD) and total organic content (TOC). In Table 3, the upper end of the range of removal efficiency for total suspended solids (TSS) , hydrocarbons, total metals and bacteria is 80% or above in eight, five, five and three types of BMP respectively, but only 50% in two types of BMPs for total nitrogen (TN). Both human and animal sources of bacteria may contaminate drainage water and where human inputs are minimal, animal inputs should be investigated.

Table 3 Performance efficiency, maintenance requirements, habitat and aesthetic value of BMPs (DayWater, 2009a)

Treatment Facility	Hydraulic Design Robustness	% Removal Efficiency						Maintenance Requirements	Habitat and Aesthetic Value
		TSS	Total Nitrogen	Bacteria	Hydro-carbons	Metals			
						Total	Dissolved		
Gully/Carrier Pipe System	High	10 - 30	-	-	5 - 10	10 -20	0	• Low to moderate • Costly to replace	• None
Filter (French Drain)	Low - Moderate	60 - 90	20 - 30	20 - 40	70 - 90	70 - 90	10 - 20	• Low to moderate • Costly to replace • Clogging potential	• Inconspicuous • Unobtrusive • No habitat value
Infiltration Basin/Trench	Low - High	60 - 90	20 - 50	70 - 80	70 - 90	70 - 90	20 - 35	• Moderate to high • Costly to reinstate • Susceptible to clogging	• Inconspicuous, unobtrusive • Limited habitat value
Swales	High	10 - 40	10 - 35	30 - 60	60 - 75	70 - 90	15 - 25	• More costly than conventional drainage	• Moderate visual appeal • Selective planting can enhance habitat value
Sedimentation Lagoon	Low - Moderate	50 - 85	10 - 20	45 - 80	60 - 90	60 - 90	20 - 30	• Moderate to high • Costly to desludge	• Some aesthetic value
Oil/Grit Interceptor	Low - Moderate	30 - 70	10 - 15	35 - 65	40 - 80	30 - 60	0 - 5	• Moderate to high • Costly to maintain	• None
Dry Detention Basin	Moderate to High	60 - 80	20 - 40	20 - 40		40 - 55	0 - 15	• Moderate	• Limited
Extended Detention Basin	High	30 - 60	5 - 20	10 - 35	30 - 50	20 - 50	0 - 5	• Moderate	• Moderate visual appeal • Can enhance habitat value
Detention Basin • 6-10 hour detention • 16-24 hour detention	 High High	 40 - 80 50 - 90	 20 - 40 20 - 40	 40 - 50 60 - 75	 30 - 60 50 - 75	 30 - 60 45 - 85	 5 - 10 10 - 25	 • Moderate to high • Moderate to high	 • High aesthetic appeal • Moderate to high habitat value especially if vegetated
Retention Basin	High	80 -90	20 –40	40 - 60	30 - 40	35 - 50	10 - 20	• Moderate	• Moderate
Wetland	Moderate - High	70 - 95	30 - 50	75 - 95	50 - 85	40 - 75	15 - 40	• Moderate to high • Costly to replace plants	• High visual and habitat appeal

BMPs can offer settlement and filtration treatment to urban runoff and stormwater flows with a benefit to the water quality in the receiving water environment.

Stormwater represents a significant pollutant pathway from roads and gutters into surface waters, particularly following a heavy or sudden rainfall event when contaminated sediments can be washed from the drainage system. Combined Sewer Overflow systems (CSOs) in cities such as London can also cause pollution incidents following a storm event when the system can become inundated forcing raw sewage to be discharged directly into surface waters. BMPs offer an opportunity for runoff and stormwater flows to be stored, settled and even filtered in some cases, and for part of the flow to be diverted away from urban sewerage systems with the potential for reducing the frequency of CSO-related pollution events.

3.4 Principles regarding ecology

BMPs should be implemented in order to provide wildlife habitats in urban areas for the benefit of local ecology and aesthetics.

BMPs such as green roofs, swales, and constructed wetlands have the potential to offer wildlife habitats (depending on their size and design) that may otherwise be limited in many urban areas. The ecological and aesthetic benefits provided should be recognised as contributions towards the ecological objectives of urban development plans. In order to protect existing habitats during the planning and implementation of BMPs, these habitats should be surveyed by an experienced ecologist. The habitat value of BMPs can be enhanced by locating them close to existing habitats such as wetland areas, to enable natural colonisation by plants and animals (SEPA, 2009). When planting BMPs, the use of initial fertilisers should be avoided. No herbicides, fertilisers or other chemicals should be applied in ongoing maintenance (Cambridge City Council, 2009). The principle design features of BMPs for wildlife protection are; restricting access to one third of a linear water feature on one side only; minimising crossovers e.g. bridges and restricting access by the public to maintenance tracks in order to protect plants and animals (Cambridge City Council, 2009.

At the London 2012 Olympic Park, a Waterspace Masterplan has been developed to introduce BMPs and ensure water quality, natural habitats and biodiversity are integrated. A target of 1.8 ha of constructed wetland or reed bed and four ponds, each of a minimum area of 50 m^2 will be created within the Olympic Park. The reed bunting is one of the Olympic Park Biodiversity Action Plan (BAP) species which will benefit from this habitat creation (ODA, 2008)

3.5 Principles regarding landscape and aesthetics

Aesthetic factors in urban landscapes have been found to influence the level of satisfaction experienced by communities (Langsin *et al.*, 1970) and they are considered to be important in influencing perceptions of environmental quality. This is particularly relevant to residential areas as these perceptions have the potential to influence house prices. The habitat and aesthetic (H&A) values of a range of BMPs are summarised in Table 3. Wetlands and detention basins have high H&A values, swales and infiltration basins and trenches have low H&A values and French drains and oil and grit interceptors have no H&A value.

The integration of stormwater treatment into the landscape is included in the key principles developed by the Victorian Stormwater Committee of Melbourne and it is also considered here to be an

important BMP principle within the context of an IUWRM strategy. There is further discussion of this subject in *Section 5.1* and *Section 5.2.*

BMPS should be integrated into the existing urban landscape to provide an aesthetic benefit where possible

BMPs have been implemented in many projects in Melbourne, Australia as part of the drive towards an increased implementation of WSUD (*Section 5.2*). The Essendon car park in Melbourne is one such project, whereby gravel trenches are used to drain and filter stormwater runoff from the car park surface. A rock feature was included in this system for aesthetic purposes as well as to contribute to infiltration processes. The design manual presented in D5.1.5 of the SWITCH project gives advice on how to combine stormwater management with urban design to create cities that seek to maximise improvements to aesthetics, function, usability, and public perception. This manual may be used as a guide for planners or decision makers that wish to integrate BMPs into an existing urban landscape whilst simultaneously improving local aesthetics.

4 Operation and Maintenance of BMPs

Structural BMPs are considered to form a key part of sustainable developments by reducing impacts that might otherwise occur to water resources as a result of surface water runoff (CIRIA, 2009). Like all drainage systems, maintenance is required to ensure continued optimum efficiency and to prevent system failures. Maintenance requirements may be on a regular, occasional, or monitoring basis and commonly involve visual inspections of inlets, outlets and screens, the removal of litter and debris, landscaping, and the replacement or rationalisation of excess plant growth (DayWater, 2009a).

4.1 BMP Operation and Maintenance

Establish stakeholder responsibility for funding and implementing a BMP O&M programme at the planning stage

The responsibility for operation and maintenance (O&M) is arguably the greatest perceived barrier to the implementation of BMPs as alternative urban drainage systems. It is therefore essential that O&M is fully considered from the outset of a BMP project in order that the stakeholder responsibilities are clear from the outset.

4.1.1 O&M responsibilities

Standard agreements need to be developed to clarify responsibilities and costs between stakeholders

The design principles of BMP structures are reasonably well established and have a range of supporting guidance material and manuals available throughout Europe, Australia, USA and other countries. However, concerns about long term BMP operation and maintenance are widespread and relatively little guidance is available although the basic elements of a required management strategy are clear (Ellis, 2005). Standard agreements need to be developed to ensure that all stakeholders (developers, local authorities, government agencies, water companies) involved are aware of their responsibilities, long-term funding for stakeholder O&M is agreed at the outset, costs are distributed equitably, and activities are co-ordinated (CIRIA, 2009). An O&M management plan can be drawn up to formalise such agreements (*Section 4.2*).

A Water Environment Research Foundation (WERF) study (www.werf.org) found that the maintenance of BMPs in the UK and US was dominated by vegetation management rather than by sediment, solid waste or trash removal, or by structural repair. In many cases, high sediment loads associated with construction activities were capable of causing almost irreparable damage to downstream BMPs, especially those relying on an infiltration component. The study indicated that aesthetic rather than technical factors influenced most BMP maintenance budgets. Communities were more likely to fund maintenance to improve the visual state of a system rather than its performance. However, the study noted that 'authorities consistently agreed that lack of routine maintenance leads to greater long-term expenses. For example, structural damage caused by growth of large trees in embankments could be easily prevented with periodic mowing - and the cost of mowing is far less than the cost of structural repair.'

4.2 Establishing an O&M management plan

An O&M management plan should be prepared prior to the construction of BMPs, including consideration of major remedial activities and long term funding.

An O&M management plan should have specifications detailing how, when and by whom servicing is to be undertaken with schedules of work itemizing both regular and occasional maintenance together with monitoring and the potential remedial requirements which are listed in *Table 4* (Ellis, 2005; Woods-Ballard *et al*., 2007).

Table 4 Examples of possible remedial O&M activities for different BMPs

Basins & Wetlands	Filter Strips & Swales	Infiltration BMPs	Porous Surfacing	Green Roofs
- Erosion damage - Inlet/outlet damage - Riprap replacement or re-alignment - Headwall, bypass damage etc (as required)	- Erosion damage e.g. channelling - Inlet/outlet damage - Swale slope stability - Check dam repair - Replacement of "level-spreader" gravel strip trench - Rehabilitation and turf/grass replacement	- Debris/sediment blockage - Cleaning and/or replacement of infill and geotextile - Repair and/or replacement of perforated under-drain pipes - Installation of sediment forebay or pre-settling facility	- Renewal of clogged sub-surface stone reservoir - Repair/replacement of any geotextile liner(s) - Repair/renewal of any under-drain piped system - Sediment clearance from any pre-filtering system	- Renew surface vegetation and/or thatch

4.2.1 Maintenance frequencies and tasks

The frequency of undertaking maintenance tasks for BMPs depends on the location and type of facility and the requirements of the owner (Lampe *et al*., 2007).

Maintenance activity frequency should be determined in the O&M management plan giving consideration to the requirements of the BMP facility.

The following overall levels of maintenance apply:

- **Low/Minimum** is the basic level of maintenance required to maintain the design function. If maintenance of vegetation is not undertaken on a regular basis, then outlets are susceptible to blockages which will subsequently impact on performance.
- **Medium** is the level of maintenance required to maintain desired function and appearance.
- **High** is an enhanced maintenance regime which is driven by appearance and amenity. In addition to grass cutting and litter picking, inspections will be frequent and any minor defects will be immediately remediated. As a result, activities which are required to maintain functionality will be undertaken as part of amenity maintenance.

A summary of maintenance levels for a range of BMPs has been shown in Table 3. Most of the BMPs require a moderate (medium) level of maintenance, although this may increase to high if the system is in a public park and its appearance is important.

When the maintenance level has been decided, tasks can be categorised as being either routine and/or corrective:

- Routine tasks are carried out by contractors without specific intervention by a supervisor.
- Irregular tasks are normally required to correct defects, are much less frequent, and are necessary to address a specific issue which might affect operation or safety.

The key maintenance tasks for all BMP types have been identified by Woods Ballard et al (2007). For swales, bioretention systems, infiltration basins, detention ponds, ponds and stormwater wetlands, regular inspection, litter and trash or debris removal, cleaning of inlets and outlets and vegetation management are required. Grass cutting and the removal of cuttings in swales and the removal of dead plants or harvesting of plants in stormwater wetlands are specific examples of vegetation management and soil spiking or scarifying will also be required in bioretention systems. Litter and debris removal reduce the risks of inlet and outlet blockages, minimise pollution risks and maintain the visual and aesthetic value of the BMPs.

Table 5 and 6 identify the maintenance activities and associated frequencies for BMP ponds and conventional storage chambers at the DEX development near Dunfermline, Scotland (Duffy *et al.*, 2008). Visual inspections of the ponds are more frequent after year three (monthly) than for the more detailed engineering inspection of storage chambers (twice per year). Silt removal however, is dependent on local conditions but has an assumed annual frequency for the storage chambers whilst being intermittent for the ponds when construction is complete.

Table 5 Maintenance activities and frequencies for DEX ponds

Activity	Frequency
Inspection	Monthly (from year 3)
Litter Picking	Monthly
Grass Cutting	3 per year
Weeding	1 per year
Prune / Trim	1 every 3 years
Algae Removal	Seasonal in first 3-5 years
Silt Removal	Regularly during construction. Intermittently once construction complete. Frequency depends on catchment conditions (soil type etc)
Aquatic Plant Aftercare	Seasonal in first 2 years
Fence/ Sign Maintenance	Seasonal – winter danger signs. Reactionary – usually related to vandalism
In/ Outlet Maintenance	Reactionary – clearing blockages
Filter Drain Maintenance	Reactionary – if structure becomes overwhelmed from overland runoff

Table 6 Assumed maintenance activities and frequencies for storage chambers at DEX

Item Description	Frequency
Routine	
Grass cutting (rate allows for 8 cuts per year)	8 per year
Litter removal (rate allows for 8 visits per year)	8 per year
Engineers inspection of structures	2 per year
De-silt inlet / outlet structures	1 per year
Controlled disposal / haulage of silt	1 per year
Irregular	
Blockages	Every 10 years
Jetting	Every 10 years
Repair Broken Components	Every 10 years

4.2.2 Inspection of BMPs

A record should be provided for each visual inspection and remedial task that is performed

A record should be kept of each inspection of BMPs on a standardised sheet. Two examples of outline inspection sheets which have been adapted for use with pervious pavements and stormwater treatment wetlands are shown in

7a and 7b. The O&M inspection sheets contain a detailed list of items to be inspected together with a recommended frequency. The inspection sheet for pervious pavements is brief in comparison to that for stormwater wetlands on account of its relatively simple construction and fewer components.

Table 7a Outline inspection sheet: pervious pavement, operation, maintenance & management

Name/Location:…………………………………. Site status:…………………………………………

Site Manager/Landscape Foreman:……………………………..Reporting Office/Tel:…………………

ITEM	FREQUENCY	SATISFACTORY or UNSATISFACTORY	TICK (when work done)	DATE	INITIAL
Pavement surface					
Clogging*	Three monthly				
Silt accumulation*	Three monthly				
Litter	Three monthly				
Water ponding *	Three monthly				
Weeds	Annually				
Depressions and rutting	Annually				
Cracked or broken blocks	Annually				
Inspection chamber	Annually				

NOTES/COMMENTS…………………………………………………………………………………
………

Signature:…………………………………. **Position/Status:**…………………………….
Date:………………..

*** = Also after Major Storms**

Table 7b Outline inspection sheet: wetland operation, maintenance & management

Name/Location:…………………………………. Site status:…………………………………………

Site Manager/Landscape Foreman:……………………………..Reporting Office/Tel:…………………

ITEM	FREQUENCY	SATISFACTORY or UNSATISFACTORY	TICK (when work done)	DATE	INITIAL
Wetland Vegetation					
maintain 50% surface area coverage of wetland plants after 2nd growing season	Annually				
new plantings	As necessary				
Dominant wetland plants; distribution according to landscape plan?	As necessary				
Evidence of invasive species	Annually				
Water depth; (maintain adequate water depths for desired wetland plant species)	As necessary				
Plant removal; dead plants and/or "choked" by sediment build-up	As necessary				
Evidence of eutrophication	As necessary				
Pre-Treatment Pool/Sediment Forebay					
sediment removal (Depth < 50% design depth	As necessary				
Inlet(s)					
riprap	Annually				
litter screens	Quarterly*				
blockages	As necessary*				
pontoons	Annually				
booms	As necessary				
stilling area	As necessary				
Outlet(s)					
riprap failure	Annually				
litter screens	Quarterly*				
drain pipes	Annually				
blockages	As necessary*				
endwalls/headwalls	Annually				
slope erosion	Annually				
drop manhole	Annually*				
valves	Annually				

Table 7b (continued)					
Riser Pipe					
orifice obstruction	Annually*				
cracking/spalling/corrosion	Annually				
sediment accumulation in riser	Annually*				
control/drain valves	Annually				
Wetland Pool					
floatables/gross debris	Annually*				
visible pollution e.g. oil	As necessary*				
shoreline erosion	As necessary				
Peripheral Slopes/Buffer Zone					
grass mowing	As necessary				
erosion/rabbit and animal burrows	Annually				
prune shrubs/trim edges etc	Annually				
spraying (*Separate note below if undertaken*)	As necessary				
Other					
signage problems (vandalism, repair etc.)	As necessary				
boardwalks/seating	As necessary				
fencing	As necessary				
grafitti	As necessary				
condition of access route(s)	Annually				
complaints (*Separate note below*)	As necessary				
other public hazards (*Separate note below*)	As necessary				

NOTES/COMMENTS…………………………………………………………………………………………
……

Signature:…………………………………. **Position/Status:**…………………………….
Date:………………..

*** = Also after Major Storms**

Ellis *et al.* (2003) have provided detailed O&M requirements for stormwater treatment constructed wetlands and pointed out that maintenance frequencies will normally be determined by site-specific needs but maintenance operations should include:

- checking inlet and outlet structures
- checking weir settings and water levels
- cleaning-off surfaces where solids and floatable substances have accumulated to an extent that they may block flows
- removal of gross litter/solids
- checking sediment accumulation levels; jetting/cleaning sediment traps, removal of sediment; (wetlands, sediment traps, infiltration trenches etc.)
- bank erosion

- general maintenance of the appearance and status of the vegetation and any surrounding landscaped zones. Control of weed growth.

4.2.3 Removal of sediment

During the construction phase it is important that steps are taken to ensure that minimal amounts of sediment are allowed to enter a constructed wetland system. Therefore, ideally the constructed wetland should be built as late as possible in a highway construction programme and the surrounding banks should be vegetated as early as possible to prevent the in-wash of both sediments and nutrients. In order to carry out the O&M requirements, "all-weather" vehicular access is required to constructed wetlands. In the post-construction phase, sediments will require removal from settlement trenches, ponds and final settlement tank, if present. Ellis *et al*. (2003) suggest that a routine maintenance programme should include a minimum frequency of annual inspections to assess whether sediment removal is necessary and inspection following major storm events to determine whether litter and gross solids have been introduced and need removing. This periodicity can be subsequently reviewed based on experience. The effects of failing to establish an O&M plan and its adoption are shown in *Figure 6* where sediment has not been removed from a settlement trench and it has been colonised by plants.

Figure 6 Inlet settlement trench to constructed wetland, Great Notley Garden Village, SE England, UK

4.2.4 Maintenance of the substrate and plants

Maintenance requirements for constructed wetlands typically involve ensuring continued hydraulic conductivity of the substrate (by washing or replacement). Decaying algae and unwanted macrophyte growth may need to be removed from pre-treatment ponds and final settlement ponds. Adjustment of water levels may be required during planting or periods of drought to maintain healthy macrophyte growth.

4.2.5 Monitoring of BMP performance

Monitoring of BMPs is extremely important to ensure a successful operational performance and early detection of changes in constructed wetland performance, for example, requires adequate data collection and analysis. All urban stormwater wetlands should be systematically monitored for at least inflow and outflow water quality (concentrations and loadings), flow characteristics and evidence of short circuiting, water levels and indicators of biological condition, preferably monthly and minimally on a quarterly seasonal basis. Nuisance species, weed growth and biological condition of the plants should also be noted such as reduced lengths of longest leaves, chlorosis or loss of green leaf coloration and curling of the plant leaf tips etc. Water quality parameters should include

temperature, pH, conductivity, DO, BOD, TSS with metals, hydrocarbons and nutrients as required, together with information on sediment depth. Ideally, one storm event during each season should also be sampled to provide information on short-term storm event performance.

4.2.6 Benefits of O&M of BMPs

Based on the experience of the BMPs installed at the M42 Hopwood Motorway Station Service Area, UK, Robert Bray Associates (2009) consider that the care of BMP schemes should include:

- Procedures that are simple and are easily understood by site managers;
- Procedures that can be undertaken by landscape contractors or site personnel and are resilient to use and abuse.
- Reduced maintenance costs as they can be managed as part of normal landscape care and avoid the need for expensive specialist contractors.
- The elimination of expensive cleaning of gullies and interceptors, avoiding the catastrophic failure of pipe drainage and allowing time for remedial action.

4.2.7 Pre-requisites for effective O&M of BMPs

In order to achieve an effective O&M programme for BMPs and sustain their performance and appearance, the following points should be addressed:

- Establish stakeholder responsibility for funding and implementing a BMP O&M programme at the planning stage
- Allocate responsibility for funding for major remedial activities in the long term.
- Prepare an O&M management plan prior to the construction of BMPs.
- Determine the levels of maintenance; low, medium and high.
- Determine the maintenance tasks required and their frequency.
- Provide a record of each visual inspection and remedial task required on a standardised sheet

5 Social and Urban Community Benefits

The potential benefits of introducing or retrofitting BMPs to an existing community need to be carefully explained to the residents. The probable increase in property values resulting from the introduction of ponds and wetlands and the enhancement of biodiversity and the visual landscape by these BMPs are major potential benefits. A consultation process involving representatives of all the stakeholders and especially the residents is important to provide an understanding of the principles of BMPs, including their reduction of flood risk, water conservation and improvement of water quality. The range of professions that will be represented by the stakeholders indicates the need for the exchange of information and data between them and for clear, simple presentations on the role, design and appearance of BMPs. A series of stakeholder meetings is normally required in order to achieve a consensus between the authorities, developers and the community.

5.1 BMP design and selection in relation to public information and awareness

5.1.1 Providing public/community information and raising awareness of the role of BMPs in enhancing the environment and reducing the risk of floods

Education, information and training programmes for the local community should be employed throughout the lifetime of a BMP facility.

Nurturing community awareness of the role of BMPs and enhancing their acceptability is crucial to their success. Information from signboards, leaflets, community newsletters, local newspaper articles and internet websites should be provided. Community participation workshops can be held to inform and consult with the community on proposed BMP developments. Community representatives (e.g. Residents Association officers) should be members of stakeholder groups organised by local government. Information and data sharing between representatives of all stakeholders is critical to developing understanding and agreement.

Habitat and aesthetic factors also play an important role in influencing public opinion even when safety and health risks may be present and recognised.

BMP facilities of lower aesthetic value lead to lower public awareness and interest and raised anxiety that their operation will be harmful to the local environment. However, this misperception may be caused by a lack of both an understanding of the role of the BMP facilities and awareness of their potential to reduce flood risks. In contrast, ponds, basins and wetland BMPs that include managed habitats with wildlife and surrounding open spaces tend to have a positive public perception.

Maintenance of these BMPs (e.g. pond cleaning, vegetation improvement, litter and solid waste removal etc.) is a key issue if this positive perception and enhanced awareness is to be sustained. The importance of maintenance is discussed in *Section 4*.

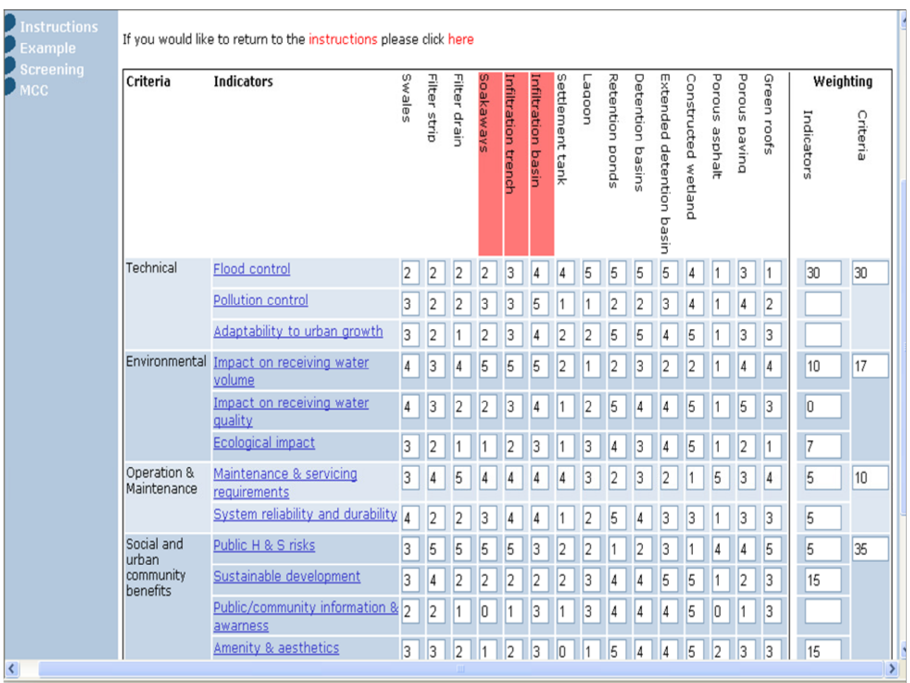
5.1.2 Consultation with stakeholders when planning for BMPs

Stakeholder consultation can influence BMP planning decisions so must be valued and conducted with care.

A Multi Criteria Comparator (MCC) score system assigned a value on a range of 1 (low) – 5 (high) to different types of BMP for six criteria sub-divided into indicators (*Figure 7*); (Ellis *et al.*, 2008; DayWater 2009b). The MCC supports end-users in selecting the preferred type of BMP for a particular location in relation to a range of site-specific socio-economic and environmental criteria.

The importance of community consultation is shown by the results of using a simplified version of the Multi Criteria Comparator (MCC) in a large housing development project in Trumpington village near Cambridge UK, which involves retrofitting part of the existing surface drainage system (Shutes et al., 2006). The prototype MCC included three BMPs and a conventional drainage option and the residents assigned the highest score to a constructed wetland followed by, in order of preference, swale, infiltration trench and conventional drainage. The MCC exercise provided the community participants with an understanding of the role, design and appearance of BMPs and reduced their opposition to the development plans.

The plans for both the Trumpington and Great Notley Garden Village (*Section 5.6.2*) developments were initially opposed by the respective communities due to the perceived loss of environmental quality and the increases in population and traffic density. A series of meetings were held with both communities with presentations from local authority planners and developers. The introduction of environmentally enhancing BMPs such as ponds and wetlands was emphasised as an improvement in the existing agricultural land with its monoculture fields and restricted public access. The provision of visual presentations, displays and websites assisted the consultation process. The meetings were co-ordinated by an experienced facilitator and a charismatic director of the property company that planned to develop both sites. The development plans for the Trumpington village site have been accepted by the community and are awaiting formal approval. Great Notley Garden Village was completed in 2000 and has been the subject of a series of Discovery TV programmes illustrating sustainable planning and development principles. However, the provision of a budget and the adoption by the local authority of responsibility for the operation and maintenance (O&M) of BMPs in the initial plans is essential as, at Great Notley Garden Village, O&M of the constructed wetland was not agreed until 10 years after its development, resulting in deterioration in its appearance and performance *(Section 5.6.2). Figure 6* shows the colonisation of one of two concrete settlement trenches where sediment has not been removed.



Instructions
Example
Screening
MCC

If you would like to return to the instructions please click here

Criteria	Indicators	Swales	Filter strip	Filter drain	Soakaways	Infiltration trench	Infiltration basin	Settlement tank	Lagoon	Retention ponds	Detention basins	Extended detention basin	Constructed wetland	Porous asphalt	Porous paving	Green roofs	Weighting: Indicators	Weighting: Criteria
Technical	Flood control	2	2	2	2	3	4	4	5	5	5	5	4	1	3	1	30	30
	Pollution control	3	2	2	3	3	5	1	1	2	2	3	4	1	4	2		
	Adaptability to urban growth	3	2	1	2	3	4	2	2	5	5	4	5	1	3	3		
Environmental	Impact on receiving water volume	4	3	4	5	5	5	2	1	2	3	2	2	1	4	4	10	17
	Impact on receiving water quality	4	3	2	2	3	4	1	2	5	4	4	5	1	5	3	0	
	Ecological impact	3	2	1	1	2	3	1	3	4	3	4	5	1	2	1	7	
Operation & Maintenance	Maintenance & servicing requirements	3	4	5	4	4	4	4	3	2	3	2	1	5	3	4	5	10
	System reliability and durability	4	2	2	3	4	4	1	2	5	4	3	3	1	3	3	5	
Social and urban community benefits	Public H & S risks	3	5	5	5	5	3	2	2	1	2	3	1	4	4	5	5	35
	Sustainable development	3	4	2	2	2	2	2	3	4	4	5	5	1	2	3	15	
	Public/community information & awarness	2	2	1	0	1	3	1	3	4	4	4	5	0	1	3		
	Amenity & aesthetics	3	3	2	1	2	3	0	1	5	4	4	5	2	3	3	15	

Figure 7 Multi-criteria comparator on DayWater website

(www.daywater.org)

The potential for the positive public perception of BMP types can be summarised as follows:

- BMP facilities having a permanent pool together with enhanced habitat provision (wetlands, extended detention basins, retention basins) clearly present the highest potential in terms of public perception and acceptability as they can be aesthetically pleasing offering a variety of amenity and recreational opportunities in addition to their primary flood and/or pollution control functions .

- Detention basins and lagoons offer more limited opportunities but do benefit from green open space for games, informal leisure and pet-walking activities with the latter having the advantage of an open water body.

- Filter strips and swales have less potential and the former may have no aesthetic value although there may well be a public awareness of their flood attenuation and conveyance capacity whilst porous surfacing may be perceived negatively as requiring costly maintenance.

- The public perception and awareness potential of below-ground BMP facilities is inevitably much more restricted and requires major educational effort to enhance and maintain local community awareness of recharge and harvesting potential.

- Green roofs may enhance the natural image of a development and thus have potential for increasing the perception of its environmental and aesthetic impact by the community.

- Rainwater harvesting BMPs are normally provided for non-potable uses. Contact with humans can result in perceived health issues although in rural Australia, up to 90% of properties have rainwater tanks of a required minimum capacity of 2 m^3, and the water is often used for drinking. However, Toowoomba in Queensland, Australia, held a referendum that rejected the planned use of harvested rainwater as drinking water despite the chronic water shortage.

5.1.3 Changing the public perception of water reuse

The public perception and acceptability of water reuse should be improved

Even though water collected and recycled by rainwater harvesting BMPs may only be provided for non-potable uses, contact with humans can result in perceived health issues although a 'near zero risk' approach has been adopted by the authorities in Australia.

Sieker *et al*. (2008) have described the advantage of a decision matrix to assist decision makers, some of whom may have little knowledge of stormwater management and the stages of developing a matrix. The selection of indicators should be discussed and agreed on among the decision-makers. In the decision matrix approach it is necessary to include a variety of alternative solutions. It is very often the case that some solutions (e.g. decentralised options) are excluded from the decision-making process because of subjective judgements but if solutions are not suitable the indicators will confirm it. Including "bad" solutions makes the decision-making process transparent and traceable. The process of setting up a decision-making matrix is not straight-forward and filling the matrix involves two tasks:

- Quantification: the effect of each different alternative solution has to be quantified for each indicator. This can be done by measurements, simulation (e.g. rainfall-runoff modelling) or other calculations (e.g. cost calculations). In some cases (e.g. for an indicator amenity) expert judgment may also be necessary.

- Aggregation: measurements or modelling results usually give a lot of very detailed data that cannot be directly used to fill a matrix. Therefore it is necessary to aggregate the results over time, space and sometimes also over sub-indicators (like the EU-WFD aggregates different water quality parameters to an ecological status).

Finally, when the matrix is complete it provides a good base for decision-making (Figure 8). If decision matrices are very complex, Multi Criteria Assessment (MCA) can be applied as a mathematical tool to identify optimal solutions. However, practical applications of the decision matrix approach have shown that decision-makers often want to make their decision on their own without the assistance of computerised decision-making tools. If weightings are not applied to the indicators then the tool automatically implies an equal weighting. Like the selection of indicators, the group of decision-makers should apply the weightings. A decision matrix is a tool to support a group in the decision making process.

5.2 Amenity and Aesthetics of BMPs

Amenity and aesthetic qualities of BMPs should not be undervalued

The integration of aesthetic, amenity and recreation are of particular public concern in terms of visual pollution and landscape character encountered on many urban watercourses and channels. There is local community concern for the landscaping and amenity value of urban drainage systems which can provide enhanced lifestyle quality, if they are appropriately designed and developed and maintained following public consultation.

If BMPs are intended to provide an amenity function, a full range of supporting infrastructure and educational materials should be provided. This can include interpretation boards, benches, dipping points, nature trails, wildlife information, visitor centres, wardens, bird hides, boardwalks, fencing and/or barrier planting to protect sensitive habitat areas and prevent access to deep water.

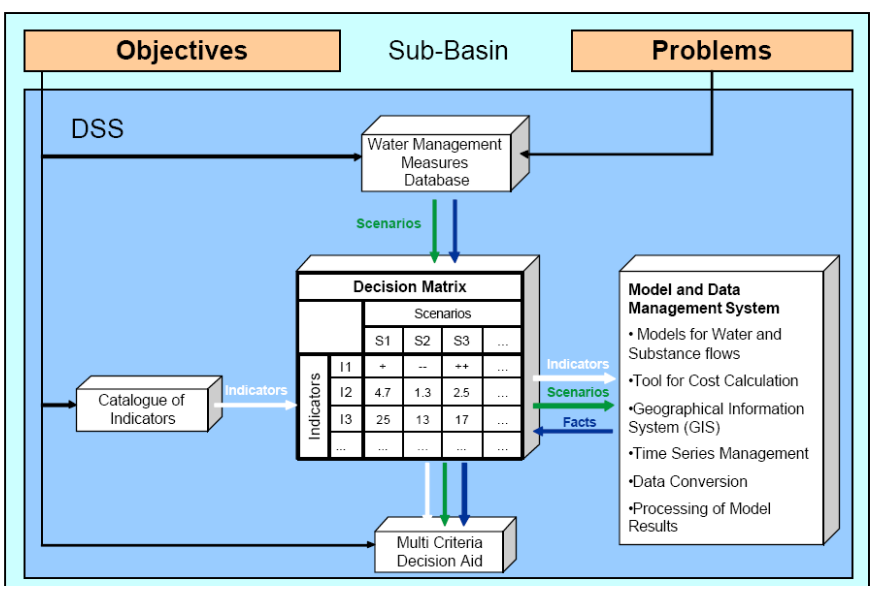


Figure 8 Flow chart for developing a decision system (Peters *et al.*, 2004)

An assessment of the value to the public of Amenity and Aesthetics in the design of BMP systems is based on the occurrence of sewage litter and odour which are the most frequent sources of public complaints. General litter and unusual colour of the water are of less concern to the public as they may be temporary post-flood phenomena.

The MCC scores have been allocated on the assumption that the individual BMPs have been installed and maintained to their design performance potential. A constructed wetland can offer a wide range of potential habitats and ecological opportunities as well as sustainable fishing, ornithological, educational and other community benefits and is therefore allocated the highest score 5. However, most constructed wetlands are subject to oil sheens and some litter, with the emergent reed species during winter die-back periods having less aesthetic value and decaying vegetation may be odorous.

The design manual presented in D5.1.5 of the SWITCH project further illustrates the benefits of BMPs to amenity and aesthetics.

5.3 Environmental Interpretation and Education

All BMPs can potentially offer opportunities for raising public awareness and environmental interpretation and education. This can be achieved in many different ways from sign boards for information to structured education campaigns. This section describes BMP principles of relevance to maximising educational opportunities that can arise from BMP schemes.

5.3.1 Environmental education in schools

BMPs can be located at educational facilities for the mutual benefit of urban stormwater management and environmental education

A BMP system located in a primary school in Redditch, UK, contains swales that collect overland flows from an adjacent site and the runoff from the school car park and playground, providing source control. The main driveway is drained to an extended detention basin. These systems connect to a constructed wetland, which also takes runoff directly from the roof and provides amenity as well as an educational resource (*Figure 9*). Risk is managed by appropriately designed education of the school children.

Figure 9 Constructed wetland, primary school, Redditch, UK

www.ciria.org/suds/cs_matchborough_school.htm

5.3.2 Signboards

Signboards can offer a simple and effective method of informing the local community of BMP benefits

A Water Sensitive Urban Design (WSUD) programme has been introduced to Australian cities. For example, bio-retention beds to trap sediment, nutrients and other pollutants from road runoff have been created and robustly constructed adjacent signboards explain their design and function (Shutes, 2008). In contrast, the small signboard at Hampstead Heath, a public park in north London, is neither weather nor vandal proof and provides limited information on the role of the small constructed wetland treating water at the inlet to a boating pond (*Figure 10*).

Figure 10 Signboard and constructed wetland, Hampstead Heath, London, UK

5.4 Public Health and Safety risks of BMPs

The health and safety risks of any BMP scheme should be carefully assessed and made known to the public.

In terms of detailed design, health and safety risks will need to be considered on a site specific basis as all drainage systems contain some elements of risk. In general, stormwater BMPs can offer improved safety over conventional drainage systems given the reduced presence of gully pots, drain covers, kerbside faeces etc which present pedestrian and cycling hazards, whilst total separation means fewer routes for vermin to enter piped systems. In addition, the reduction in volume and peak flow rates will also reduce the hazards of downstream flash floods to the public and sewer operators as well as the aquaplaning potential on paved surfaces. If designed appropriately, BMPs should present few risks in terms of health and safety although there are undoubtedly concerns associated with the provision and operation of drainage facilities in public open spaces which have the potential for legal liability resulting from, for example, access to open water or vermin breeding vectors.

5.4.1 Health and Safety points of reference

The potential level of health and safety (H&S) risk of individual BMPs is based on the following five points of reference:

- ***Open water***: the presence of an open water body in or adjacent to urban developments can potentially provide a safety hazard especially for small children with deeper water bodies and high potential flow velocities presenting the greatest risk.
- ***Insect vectors***: shallow standing waters particularly if possessing a vegetation cover, have the potential for colonisation by insect vectors, especially the vectors of dengue fever and malaria,

during hot, humid weather conditions. In addition, such water bodies have the potential for nutrient loading, leading to eutrophication and the possible development of algal blooms.

- ***Bacterial and Vermin Exposure***: separately sewered stormwater has the potential for misconnections to the system that could lead to the discharge of litter, gross solids and bacterially contaminated effluent. Even where there are no wrong connections, surface stormwater can be bacterially contaminated from bird and pet excreta and thus contain both pathogenic bacteria and viruses.
- ***Flooding and Aquaplaning***: impermeable surfaces can rapidly generate and convey high volumes of runoff during wet weather events which can pose a hazard to driving conditions and to below-ground sewer operations. During winter periods, such surface water can freeze and cause ice hazards for both motorists and pedestrians.
- ***Surface heave and Obstructions***: surface water draining over paved areas can lead to frost heave during winter with prolonged dry periods causing surface cracking and subsidence. The resulting surface obstructions can then present hazards to pedestrians, cyclists and motorcyclists. The presence of screens, inlet and outlet structures are also potential safety hazards.

5.4.2 Reducing Health and Safety risks of BMPs

Health and safety risks of BMPs should be mitigated at the planning stage, particularly for those involving standing water.

A summary of the methods to reduce the H&S risks outlined in Section 5.4.1 is shown in *Table 8* followed by recommendations for different BMP types.

Table 8 Summary of methods to minimise Health and Safety risks

Health Risks	**Minimising Risks**
Insect vectors	Reduce stagnant water sources including solid waste. Introduce insectivorous fish to open water in ponds.
Micro-organisms	Reduce adjacent sources; dog waste, geese, incorrectly connected sewage pipes.
Algae blooms	Reduce nutrient sources; grass cuttings, fertilisers.
Vermin	Reduce food waste sources; unoccupied housing. Establish or maintain local authority vermin control unit.
Safety Risks	**Minimising Risks**
Open water	Introduce shallow margins, barrier planting, signboards and lifebelts
Flooding	Introduce source control BMPs including water butts and tanks. Increase permeable surface e.g. pervious roads and pavements
Surface heave	Replace concrete with brick paving and increase foundation depth
Obstructions	Add landscaping to or highlight (paint/sign) BMP screens, inlet and outlet structures

Vegetated retention basins, ponds and wetlands: The permanent water in retention basins, ponds and wetlands clearly poses a safety risk in terms of public access. Shallow margins and "scramble" rocks can minimise the safety hazard with barrier planting excluding access from deeper sections of the permanent pool but some BMPs may need fencing. The retention basins of Pont Yblon and Saint-Denis, France, highlight public or community difficulties that can be encountered through the use of

BMPs in urban areas, particularly those that hold open water. These two retention basins and the surrounding areas have the potential to provide a source of amenity benefit for local inhabitants (fishing, running and walking). However, access is currently forbidden for health and safety reasons (sanitary, public safety, legal responsibilities). The end user (DEA Seine Saint Denis) would like to change this situation by allowing free access to the area.

The constructed wetland inlet settlement pond shown in *Figure 11* receives a cocktail of urban runoff and some industrial pollutants but there is neither a signboard hazard warning of dangers nor a lifebelt even though local children use the area for recreation. In *Figure 12*, untreated wastewater flows through the open concrete channel in the foreground to several constructed wetland cells and presents a potential hazard to human health. The risk of mosquito breeding has been reduced at the Putrajaya wetlands in Malaysia (*Section 5.6.1*) by the introduction of insectivorous fish to the inlet and outlet ponds.

Figure 11 Settlement pond and constructed wetland, NE London, UK

Figure 12 Constructed wetland, Shenzhen, S China

Mis-connections to the stormwater drainage system can also lead to health risks from bacteria, viruses from human and animal sources and direct contact sports (e.g. canoeing) may need restrictions during and following wet weather periods. These BMP types pose additional risks from insect vectors and

algal blooms but these can be overcome with careful design. *Figure 4* shows the Brent Reservoir, a semi-natural wetland in winter, whose two feeding streams discharge stormwater runoff. Canoeing and sailing activities present a relatively low hazard to human health from waterborne diseases in the winter but the risk increases from algal blooms during the summer. Floating rafts provide nesting and roosting sites for birds and provide a bird watching site as part of the amenity and recreational opportunities (*Figure5*).

Detention basins pose potential safety risks during filling periods under wet weather conditions and may also be associated with litter, organics and other toxic materials which could present a source of health risk from vermin and bacteria. Barrier planting and shallow side slopes (with fencing where necessary) can readily overcome these safety and health risks.

Figure 13 shows a dry detention pond in a suburb of Malmo, Sweden which is also used as a public amphitheatre (Villareal *et al*., 2004). Community participation and education was an important factor in the reduction of the H&S risks of surface drainage. The potential health risk from contact with bacteria and toxic metals on surfaces receiving runoff during periods of rainfall was explained to the public.

Figure 13 Combined amphitheatre and stormwater detention pond, Malmo, Sweden

Swales can potentially generate high flow velocities and flow depths under extreme storm event conditions, which could pose a safety hazard. Designs should ensure shallow side slopes and longitudinal gradients to reduce such safety risks to a minimum. Standing water in the swale channel could also provide a breeding site for mosquitoes.

Infiltration basins and extended detention basins can pose short term hazards due to the presence of temporary water pools following a storm event if the basins are unfenced or not protected by a bund especially if immediately adjacent to a highway. If the basins fail to drain down sufficiently, the remaining shallow standing water could attract insect vectors.

Permeable surfaces pose potential traffic hazards (e.g. skidding and aquaplaning) from temporary surface water and may be subject to surface frost and icing during winter.

Soakaways, filter drains and infiltration trenches can be subject to subsidence due to erosion of infill materials and/or surrounding soils or may suffer ejection of fill materials as a result of vehicle tracking onto the roadside edges. Inspection covers and wet well access for infiltration trenches also pose a minor safety risk.

Rainwater harvesting systems. Rainwater is relatively free from impurities except those picked up from the atmosphere, but the quality of rainwater may deteriorate during harvesting, storage and household use. Rainwater harvesting normally refers to systems comprised of collection and storage tanks, but swales and detention ponds have also been classified as rainwater harvesting systems (UNEP and SEI, 2009). Higher microbial concentrations are generally found in the first flush of rainwater but the level of contamination reduces as the rain continues. Storage tanks can present breeding sites for mosquitoes (WHO, 2008) but risks from disease vectors and poor hygiene in abstracting water, storing water, or at the point of use can be minimized by good design and practice.

5.4.3 BMP Risk Assessment

Risk assessments should be conducted at the design stage of BMP planning

During the BMP design stage, an assessment of risk should be made that considers the relative risk of each system and also the perception of the risks by the stakeholders. There is a need for consultation with all stakeholders involved with new and retrofitted developments. The views of the community should also be consulted in order to plan the provision of appropriate public information and protective fencing etc for the proposed BMPs.

Apostolaki (2006) conducted public questionnaire surveys at 7 selected BMP sites. The results showed that attitudes towards BMPs appeared to differ according to site characteristics and scheme performance; opinions about local BMP ponds seemed to be determined by the outcome of their establishment; there was a lack of public awareness of BMPs. Safety was not a public concern at sites with well-established ponds and rich marginal vegetation. However, there was concern about safety at sites with newly established ponds, with limited or non-existent marginal vegetation, or where slopes were considered to be too steep. In spite of safety being a concern, about 85% of participants preferred to live next or near to a pond; rather than further away.

5.5 BMPs and Sustainable Development

BMPs have the potential to contribute to the implementation of sustainable development

The EU Sustainable Development Strategy adopted in June 2001 is intended to reconcile environmental protection with social cohesion/equity and economic development with the protection and enhancement of natural resources and the environment underpinning the strategic policy guidelines. The principles of sustainable development contained in the EU guidelines are shared by all member states and are summarised in *Figure 14*.

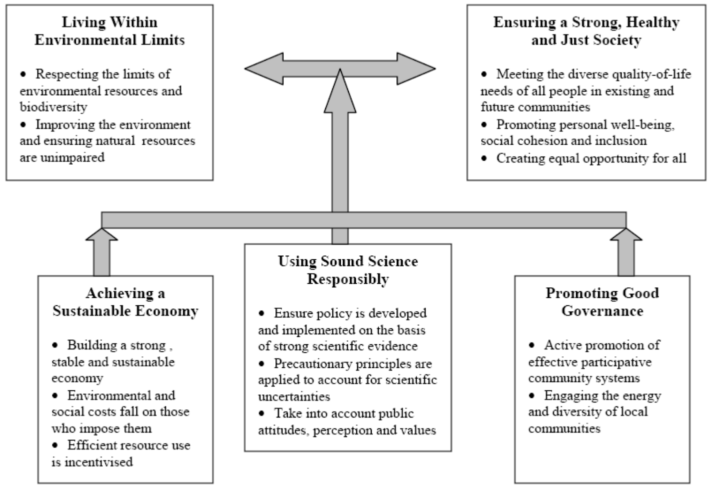


Figure 14 Principles of Sustainable Development (After: HMSO, 2005)

5.5.1 BMP design and Sustainable Development

Table *9* provides a summary of the sustainable development potential for BMPs in relation to biodiversity, community participation and energy/resource use.

Table 9 BMP Sustainable development potential

Benchmark BMP Type		
Biodiversity potential	Community participation potential	Energy and resource use potential
To provide diverse habitats and landscape	Help promote effective participative community systems	Minimise energy consumption during construction, operation and maintenance ie low electro-mechanical costs
Reduce habitat fragmentation and isolation	Encouraging community creativity , energy and diversity	Minimise source material use
Mixed terrestrial, marginal and aquatic habitats	Help meet diverse environmental needs and promoting well-being and quality-of-life	Resource recycling potential e.g. recharge groundwater, irrigation etc
Managed ecological habitats as well as hydrological regimes	Help support special cohesion equality and community neighbourhood	Minimise manufacturing and transport costs and associated emissions
Can help meet environmental legislation and sustainable development objectives e.g. BAPs	Help support local community environmental education and training	
Reduce impacts on adjacent habitats		

5.5.2 Biodiversity potential

This is concerned with the protection, restoration and enhancement of habitats and species. BMPs that help to reduce fragmentation or isolation of habitats and barriers to animal movement will have high biodiversity potential. Positively managed ecological habitats and hydrological regimes also help to maximise the biodiversity impact particularly where they are consonant with existing biodiversity

legislation and regulation. Ponds and basins score highly for this benchmark parameter with wetlands offering the very highest biodiversity potential. BMP infiltration facilities have a lower potential although trenches and basins do have biodiversity potential by virtue of reducing discharge and pollutant impacts on receiving watercourse habitats.

5.5.3 Community participation

This can be either formal or informal in nature and BMPs that are likely to require or support involvement from a range of organisations and to foster long term community partnerships will have high sustainable community potential. Such partnerships can help reduce environmental inequalities and provide a better quality-of-life spread in terms of "greener" and healthier neighbourhoods. In addition, BMPs that offer opportunities for community participation and the forging of partnerships, will promote involvement in local decisions and plans that shape the community environment. Community engagement in BMP implementation, operation and maintenance strategies will support biodiversity conservation, local community identity and environmental education as well as offering opportunities (e.g that may result from BMP retrofitting) to improve the biodiversity effectiveness. Ponds and basins possess high potential for community participation and partnerships but other BMPs such as landscaped swales and vegetated bio-retention systems within public open spaces and car parks also have potential.

5.5.4 Energy and resource use

These are prime sustainable development benchmarks, which seek to minimise the future impact of environmental development as well as to reduce or prevent the impact of development upon additional environmental compartments. BMPs that minimise energy-use and material consumption in their implementation, operation and maintenance will have high sustainable development potential and ensure that they do not exceed the "carrying-capacity" of the local environment. BMPs requiring heavy material use during construction as well as material transport, possess low utility score values particularly if there is a continued energy demand during their O&M lifetimes. However, infiltration facilities have potential for resource re-cycling through groundwater recharge whilst surface water BMPs can also offer some potential for additional use as irrigation water within the local community if gravity-fed systems can be utilized. Porous pavers also have the added sustainable potential, which can accrue from the use of recycled material in their manufacture.

5.6 BMPs and Sustainable Development projects

This section describes examples of sustainable development projects that include biodiversity and community participation potential (*Sections 5.6.1, 5.6.2 and 5.6.4*) and energy and resource use potential (*Section 5.6.3*). The design manual developed in Deliverable 5.1.1 of the SWITCH project presents a number of case studies that further illustrate the many social and urban benefits of the SWITCH project schemes around the world.

5.6.1 Putrajaya City, Malaysia

Putrajaya city, the new Federal Government Administrative Centre in Malaysia is committed to sustainable development and has allocated 70% of the land use as 'green space'. A multiple constructed wetland system enhances both the landscape and biodiversity of the area, with 70 plant species introduced for their aesthetic value or their ability to treat pollution (*Figure 15*). The wetlands have attracted many species of wildlife and a visitor centre and interpretive botanical park illustrate and explain their characteristics and ecological significance to the public (Sim *et al*., 2008).

Figure 15 Constructed wetland cell, Putrajaya, Malaysia

5.6.2 Great Notley Garden Village, England

The increasing demand for housing in Britain has led to the continued development of greenfield sites in locations either near or within commuting distance of cities. Great Notley Garden Village (188 ha) is located in south east England on former agricultural land and contains 2000 homes. Its design is considered to be a good example of sustainable development and includes a country park with an ornamental pond, constructed wetland and surrounding woodland and grassland providing wildlife habitats and a central focus for community relaxation and recreation. The design of the park aims to enhance biodiversity by introducing a mosaic of habitats to replace the former monocultures of field crops. The implementation of the design followed a long process of consultation with and participation by the community in the adjacent village in the planning process. The constructed wetland (7900 m^2) and adjacent recreational pond (16,000 m^2) at the site have been designed to provide treatment and act as a balancing pond to store surface water runoff from the catchment and discharge it into the outfall system of ditches at a controlled rate (Shutes, 2001). However, in the absence of adoption of the system and an agreement on responsibility for its maintenance by the local government and the developer, sediment in each of the two wetland inlet settlement trenches has not been removed and wetland plants have invaded thus impairing the sustainability of the system *(Section 4.2.3, Figure 6).*

5.6.3 World Games Stadium, Kaohsiung, Taiwan

The incorporation of BMPs in the design of the Beijing Olympic stadium, the Melbourne Olympic Park stadium and the Sydney Olympic Park have been noted in a previous SWITCH report (Scholes and Shutes, 2007). The 2009 World Games stadium in Kaohsiung City, Taiwan, is the most recent example in which sustainable development design principles have been applied to a sports stadium (*Figure 16*). The total area, including the stadium and surrounding facilities, is about 19 hectares of which 7 hectares were used to construct green belt, bike track, sports-park, and eco-ponds (artificial wetlands). The stadium is designed to collect rainwater from the roof and store it in tanks, and to recycle and reuse the grey water, which will be used for irrigating grass land, washing solar cells on the roof, and providing a water source for eco-ponds. The eco-ponds in the surrounding parks were designed with gentle slopes, multi-cultures of trees, shrub, and aquatic plant species along the lake shore to imitate a natural river with upstream, middle stream and downstream sections. The stadium and its surrounding environment clearly meet the criteria for BMP sustainable development potential shown in *Table 8* namely biodiversity potential, community participation potential and energy and resource use potential.

Figure16 World Games stadium, sports park and eco-pond, Kaohsiung, Taiwan

5.6.4 Manor Fields District Park, South Yorkshire, England

This case study illustrates the link between the development of BMPs and full participation by all stakeholders. It also demonstrates attention to social dimensions; capacity building; adoption of the best (or most appropriate) existing technologies and practices; landscape and aesthetics, and reliable and sustained financing.

Sheffield is a major city in S Yorkshire, England that is undertaking a number of major inner-city regeneration programmes. In the Manor Fields District Park area, following a review of the options available the housing developer chose to combine traditional urban drainage methods with a BMP scheme (Kennedy *et al*., 2007). As an end-of-pipe retrofit solution, the scheme does not exhibit any source control measures with stormwater routed through the housing project in a conventional pipe network. The BMP design used a series of basins and swales forming a management train to meet the site objectives. Designed with full consideration of all three components of the ‘urban drainage triangle’, the chosen techniques are simple, cost-effective, and easily constructed but robust enough to withstand any vandalism, a common occurrence in what is considered to be a socially deprived area. The design offers maximum visual, community and wildlife benefits whilst being easily maintainable. The basins and swales are also seen to integrate well into the landscape and are easily modified or reinstated offering the desired flexibility for the development of the Manor Fields Park. A local landscape company will subsequently be contracted for the long-term maintenance of the scheme. The developer offered some funding and £250,000 has been allocated to a minimum of 25 years management under the current maintenance budget.

6 Economics

The importance of agreeing a budget and responsibility for long-term O&M costs of BMPs has been emphasised in *Section 4*. There are few published studies of the costs of BMP systems in comparison to traditional drainage systems but the results indicate that, with the exception of the relatively high area and hence cost of land take, BMPs are more cost-effective drainage systems. Whole-life costing is a system for identifying and providing more accurate future costs.

6.1 BMP costs

Duffy *et al*. (2008) compared the costs of constructing and maintaining a stormwater drainage system based on BMP systems in comparison to the traditional drainage system and underground storage chambers at DEX, a 50 ha development of residential, retail, commercial, industrial, leisure and public open space which commenced construction in 1996 on a greenfield site on the eastern periphery of the Scottish city of Dunfermline. The systems investigated include four ponds and a constructed wetland.

The installed BMPs were designed to attenuate the 100 year event and the storage chambers to attenuate 50 and 100 year storm events respectively. The costs of the five BMP systems, that also provide treatment, were compared with the cost of the storage chambers, which provide minimal treatment. There were wide variations in the construction costs of the BMPs as a result of the different catchment sizes and site specific construction details. For example, one pond was fitted with an impermeable liner and excavation of rock was required at a series of three separate ponds. In all cases there was a significant difference between the costs of the traditional and BMPs solutions, with the latter always being lower. On average, the construction costs of BMP systems was 70% less than for the traditional drainage structures.

Duffy *et al.,* (2008) reported that the BMP maintenance regime was both well organised and intensive at DEX in comparison with other BMP maintenance regimes in existence in the UK as reported in parallel studies (Lampe *et al.* 2005). The average annual cost of maintaining BMP was 40% less than for the equivalent traditional approach. Because above and below ground maintenance of BMPs will probably be the responsibility of different organisations, the costs were separately determined. The BMPs with larger catchments had lower maintenance costs except for one pond with extensive barrier and amenity vegetation. The average cost of above and below ground maintenance was 6% and 85% less respectively for BMPs than for the storage chambers reflecting the limited below ground structures in BMPs.

Whole-life costing should be applied to BMP systems when selecting a drainage programme.

'Whole-life costing is about identifying future costs, such as those associated with operation and maintenance, and relating them to present day costs using standard accounting techniques. Determining an accurate cost of a system can help define long-term investment requirements and allow facilities to make more cost-effective decisions when selecting a programme (www.werf.org). A life-cycle cost calculation tool (LCCA-Tool) has been developed by Sieker *at al.* (2008). The tool is equipped with a web-based unit cost database that provides information which is often not available from other sources. It facilitates the life-cycle cost calculations and a comparison of the costs of different planning alternatives. The application of the tool promotes; the development and comparison of different planning alternatives as a prerequisite for finding sustainable and efficient solutions; the application of life-cycle cost calculations leading to cost efficient solutions and thus more ecological benefit for a given budget; sustainable, source control oriented approaches that are

not only more ecological, but are often also lower cost options than conventional (pipes, channels) solutions.

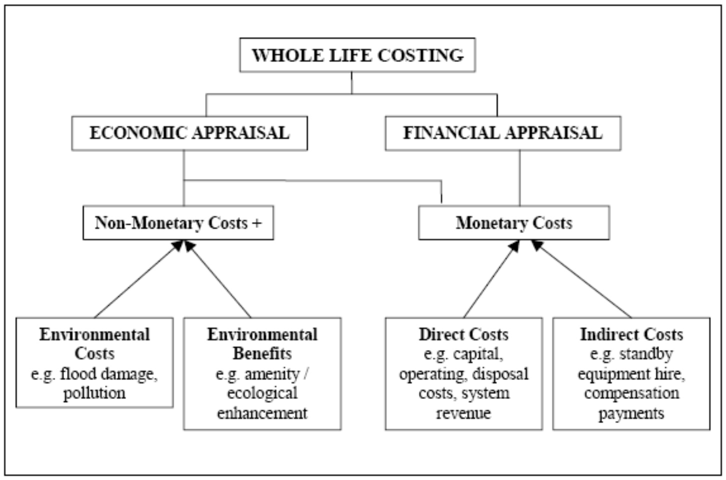


Figure 17 Different approaches to whole life costing (WLC) (Hydraulics Research, 2004)

Two approaches to assessing the Whole Life Costs (WLC) for BMPs were proposed by Hydraulics Research (2004). An economic appraisal aims to evaluate all the costs and benefits to a community influenced by a proposed development, whereas a financial appraisal is only concerned with the costs, earnings and revenue to the BMP owner and operator (*Figure 17*)

A financial appraisal of WLC for BMP ponds at DEX was found to be significantly more cost effective (67% less for a 100 year return period) when compared with traditional drainage storage chambers. The accounting procedure used was Present Value, the sum of money that needs to be spent today to meet all future costs as they arise through the life cycle of a scheme or structure (HR Wallingford, 2004). The discount rate to adjust future costs to 2005 was 3.5% and the discount period was 60 years (DTI 2002). Land take costs were excluded from the WLC analysis due to their probable variability although the BMPs were located in public open spaces and provided environmental, biodiversity and amenity benefits as well as a drainage function.

Capital and maintenance costs, and WLC at DEX were compared with the catchment area served by the BMPs and the results showed that the capital costs of traditional drainage were more than double those for BMPs, annual average maintenance costs per ha would be 20 - 25% greater for traditional drainage, and WLC per ha of traditional drainage were approximately double the costs for BMPs (Duffy *et al.,* 2008). The BMP system for the treatment of car park drainage at the M42 motorway Hopwood service station, UK, has been monitored since construction to evaluate performance and costs. Capital costs were estimated at £56,000, and the annual regular operation and maintenance activities at £5910 pa (CIRIA, 2005; HR Wallingford, 2004). The frequency at which irregular maintenance is required at this site and others is mainly dependent on site characteristics and the quality of system design and is difficult to predict (Woods-Ballard, 2007). The site can be accessed by the public and value of this benefit has been calculated as follows;

Benefits = number of visits x transfer value (per visit per year)

A conservative value of £0.10 per car per visit has been suggested by Woods-Ballard *et al.,* (2007) and with 500 car parking spaces and an assumed 1000 visitors per day of which 2 per cent visit the BMP, the environmental benefit is 0.02 x 0.1 x 1000 = £2 per day (or £730 per year).

The level of maintenance in relation to the size of the site should be carefully considered in whole-life cost assessments.

A Water Environment Research Foundation (WERF) (2009) study found that the level of maintenance specified had a pronounced effect on the whole-life cost for most BMP facilities. For instance, the level of maintenance for retention ponds had a much greater influence on whole-life cost than construction cost. Also, the model developed by the WERF study predicted that small sites with a high level of maintenance would have a greater whole-life cost compared with facilities that were 10 times as large, but maintained at low or medium levels. An example of the latter is the BMP treatment train system or bio-ecological drainage system (BIOECODS) at the Engineering Campus of University of Science, Malaysia The drainage components (i.e. ecological swales, on-line sub-surface detention and dry ponds) are integrated with the ecological pond components (i.e. a wet pond, a detention pond, a constructed wetland, a wading stream and a recreational pond) for further treatment of the stormwater runoff (Zakaria *et al*., 2003). The combination of these treatment systems increases runoff lag time and pollutant removal from settling, biofiltration and biodegradation and reduces the rate and volume of runoff by enhanced infiltration due to the increased area of impermeable soils. The vegetated ecological systems also provide an opportunity to enhance the landscape and provide habitats for wildlife within the university campus. The final discharge will significantly reduce the risk of pollution to the receiving river and of flooding downstream. Surface volumes are predicted to reduce by 65% and solids, nutrients and heavy metal loads by 85% to 100%. There will be substantial predicted cost benefits to developers and river management authorities from the operation and maintenance of such a system.

6.2 Costs and benefits of retrofitting BMPs

IUWRM strategies should encourage BMP retrofitting through the use of economic incentives and through highlighting positive benefit-cost ratios.

Gordon-Walker *et al*., (2007) noted that BMPs can be retrofitted under a number of conditions including; at the time of building refurbishment; during drainage improvement for large areas such as trading estates or where there are unsatisfactory combined sewer overflows (CSOs); and through incentives to property owners to “disconnect” roof or driveway runoff from the public drainage system. Among the identified benefits from retrofitting BMPs were that the extensive use of BMPs will reduce the runoff load at CSOs and sewage treatment works and the less diluted sewage may result in more efficient treatment of wastewater and reduce energy costs and the need to provide additional treatment capacity and also reduce flooding risks and incidents and their costs. BMPs provide a route for additional recharge of aquifers in areas under water supply stress and the extensive use of certain types of BMPs, such as water butts and rainwater harvesting, systems will help to meet water efficiency targets and reduce water bills.

The technical and economic benefits of retrofitting BMPs should be emphasised to developers.

The life cycle costs of the different types of BMPs were calculated by Gordon-Walker *et al*., (2007) who found that the cost of permeable paving is less than for traditional surfaces although the initial capital costs are higher. The maintenance cost of replacing worn out permeable paving is less than the cost of renewing a traditional tarmac surface. Furthermore, there will be no charge for permeable surface drainage from water companies that only charge for surface drainage from impermeable surfaces. The study estimated that the cost of retrofitting permeable paving to ‘approximately 50% of non-road hard surface areas in England and Wales would provide discounted economic benefits of nearly £1.7 billion.’ Water butts were estimated to provide potential economic benefits of nearly £1

billion for an initial cost of just over £325 million, to households through reduced costs of water, especially to those with water meters, if the butts were regularly used through the summer months. Although the financial benefits of installing water butts exceed their costs by a factor of two, retrofitting complete rainwater harvesting systems in existing properties was not shown to be cost effective (*Table 10*). The study found that the costs of retrofitting swales, infiltration trenches and filter drains considerably exceeded the financial benefits.

Table 10 Summary of cost-benefit analysis of BMPs in the UK

	Benefits (£'000)	**Costs (£'000)**	**Benefits minus costs (£'000)**	**Benefit to cost ratio**
Permeable paving	515,217	896,603	1,411,820	Very positive
Rainwater harvesting	8,647,965	13,702,282	-5,054,317	Neutral
Water Butt	733,075	325,824	407,742	Very positive
Swale	60,392	610,134	-549,742	Negative
Infiltration trench	105,687	8,739,055	-8,633,368	Very negative
Filter drain	60,392	7,212,069	-7,151,676	Very negative

(Gordon-Walker *et al*, 2007).

The EU Interreg 111B Programme project "Floodplain Landuse Optimising Workable Sustainability" (FLOWS) suggests from demonstration sites in Cambridgeshire UK, that most infiltration BMPs are not affordable in the long term as:

- they are susceptible to siltation either during construction or through the design life of the structure.
- they are also very unlikely to be monitored or restored in case of failure within most urban developments.

In spite of its long term value, permeable paving is less used than traditional surfacing methods and the reasons proposed include the following:

- decisions on resurfacing parking are not considered of sufficient importance for organisations; awareness of the existence of permeable paving and suppliers is likely to be low due to its lack of market penetration;
- property owners and managers may perceive higher initial costs and greater risks with an unfamiliar (though not unproven) technology;
- lack of knowledge of permeable paving by architects and planners advising property owners; preference for selecting non-road surface type consistent with other parts of a site when retrofitting (Gordon-Walker *et al.*, 2007).

6.3 Strategy for Retrofitting BMPs

Incentives are required for property owners to encourage them to adopt BMPs, and governments should work with professional services associations to reinforce best practice in BMP implementation including retrofitting.

As a solution to the lack of implementation of permeable paving and other BMP types, one of the recommendations of the Pitt Review (2008) following flooding in the UK in 2007, includes the interim conclusion (IC9) "….that householder and business owners should no longer be able to lay

impermeable surfaces as of right". The need to improve public understanding of the factors that exacerbate flooding and the role of BMPs in its reduction is discussed in *Section 5.1* of this report. Gordon-Walker *et al*. (2007) recommend addressing urban flooding and CSO problems due to a lack of drainage system capacity with a combination of traditional and BMP solutions and setting the conditions for an overall reduction in pressures that might increase flooding and pollution risk including the use of permeable paving as a required first preference for new or replaced surfaces. As property owners are responsible for many of the decisions on BMP retrofits, there need to be incentives for them to change their behaviour.

Government could collaborate with professional services associations, perhaps through professional accreditation schemes, to reinforce best practice in BMP implementation, including retrofitting. This would show leadership by example, demonstrating to the public that governments are committed to the adoption and implementation of sustainable urban drainage.

Sewerage companies should be required to charge commercial companies for surface drainage

Sewerage companies should consider the potential for BMP retrofitting to help drain catchment areas, provide drainage services, prevent sewage flooding and reduce CSOs. They should also be required to charge commercial properties for surface water drainage on the basis of area drained. This will provide incentives for property owners to replace hard surfaces with permeable ones. Property owners should be provided with more information about options for disconnecting surface water drainage.

6.3.1 BMP Insurance costs

Whole-life costing should consider BMP drainage system insurance indemnity as future flood risks may exceed the drainage system capacity.

Ellis (2005) noted that long term affordability must also consider insurance indemnity with flood risks exceeding the drainage system capacity being increasingly liable to excess premiums or even to non-insurance. This will be an increasing problem for many BMPs given the trends of climate change especially given that above-ground drainage infrastructure can be mapped and monitored directly by insurance company airborne radar (SAR) and satellite technology. In the UK, there are indications that the insurance industry will be expecting a minimum 200 year return period (i.e. 0.5% annual flood probability) level of protection by 2050 after taking climate change into account for the purposes of normal residential insurance cover. Ground floor apartments, basement accommodation, schools and other special housing types with no flood warning systems, will require 1:500 to 1:750 return period standards in order to qualify for normal long term insurance coverage, which few if any BMPs are capable of satisfying. This would make adoption and liability coverage of public open space containing BMPs much more difficult for potential adopting authorities having statutory duties as well as for developers requiring professional indemnity insurance. This may be a particular problem in low lying areas especially where rising groundwater might also present a long term problem. Such conditions would also reduce the residual benefit of the BMPs in terms of end-of-life disposal value and thus impact upon long term affordability.

In the UK, flood damage from rising groundwater is not covered as an insurable loss and pollution liability from infiltration facilities only covers accidental pollution and not progressive operating causes. This might become liable to compulsory pollution liability insurance under the EU Environmental Liability Directive. Subsidence of BMP structures is also likely to become an expensive insurance item and difficult to avoid especially given that satellite technology can enable insurers to monitor and map sub-millimetre subsidence and heave. Defective BMP O&M is also likely to lead to insurance difficulties as well as property value blight and increasing litigation against BMP

designers. Blocked screens and other operational defects to BMP structures which either cause or exacerbate flooding can provide a basis for householders and developers to sue local authorities.

7 Legal and Urban Planning

Legal and urban planning issues with regard to water resource management are complex and varied. Central to good governance is the agreement over the responsibilities of the various stakeholder organisations and authorities, clear and achievable management strategies, and total transparency and accountability. The main indicators for legal and urban planning performance, as described by the DayWater project are adoption status, building development issues and stormwater regulations. The following principles define how BMPs should be governed within an IUWRM approach and the ways in which they are integral to the good performance of sustainable urban water resource management strategies.

7.1 Principles regarding legal responsibility

Clear and thorough governance that includes the promotion of BMPs and the distribution of responsibility are essential to effective IUWRM.

The SWITCH Learning Alliance Briefing Note 14 (Water governance for integrated urban water management) (da Silva *et al*., 2008) outlines the concept of water governance and its importance to the effective implementation of IUWRM. The key messages are that governance is not synonymous with government although it naturally involves a number of governmental or managerial players, and that it can be characterised by openness, participation, legitimacy, equity, accountability, effectiveness and coherence. These principles apply to the good governance of stormwater issues around the globe and in order to apply innovative BMPs that will contribute to improved stormwater management in any area it is essential that there is clear institutional mapping with the responsibilities detailed coherently.

The Belo Horizonte case study described in SWITCH deliverable 2.2.1a provides an example of a city that does not have good autonomy between the various authorities and that struggles to clearly define the distribution of the institutional responsibilities that will enable a successful IUWRM strategy if upheld. The result is that the water supply system is poorly moderated and is subject to abuse with consequences for public and receiving water health and flood potential.

Surface Water Management Plans (SWMPs) are integral to an effective IUWRM strategy by identifying and quantifying the infrastructure and water resources available and the demands on them. SWMPs are required at local, regional and national scales in order to unify governance of all IUWRM related issues. They should be structured in line with demands made in the WFD and other European legislation and they should make provision for sustainable water management technologies such as stormwater BMPs within new legislation as their omission can act as a barrier to their implementation (CIRIA, 2009).

It is important to designate responsibility for all aspects of IUWRM in order that all stakeholders know who to approach for information and data. The modelling and mapping of meteorological and hydrological data for example, may be conducted on a local scale by a number of organisations. However, a national organisation should be allocated the responsibility for either ensuring that all data is compiled to aid wider strategic planning, or that a centralised system is developed such as the UK Flood Forecasting Centre that provides a nationwide mapping and forecasting service.

The designation of responsibility for the development, operation and maintenance of BMPs in urban areas must be clear and sufficient resources must be provided at a national, regional and local level.

The designation of responsibility must be clear in relation to the ownership and maintenance of BMPs. Funding will be provided where necessary (see *Section 6*) and local authorities in particular need to be provided with sufficient resource capabilities and organisational capacities that they can meet the demands of the WFD. It will be their responsibility to ensure that BMPs are appropriately implemented in their areas.

7.2 Principles regarding the legal setting

The management unit should be set at the catchment or river basin scale.

For governing bodies to effectively work towards improved IUWRM, the management units and associated distribution of responsibilities must be clear. Water resource management in Europe is governed under the auspices of the Water Framework Directive (2000/60/EC) (WFD), which uses the River Basin District (RBD) as its adopted management unit. The reason for this choice is that it enables planners and decision makers to consider the complex catchment-wide interrelationships between surface and groundwater flows and other environmental processes such as the transfer of pollutants through the environment. With the aim of ensuring a holistic and integrated approach to water resource management, the RBD approach highlights priority areas for improvement and emphasises the importance of both upstream and downstream solutions. It also provides for the simultaneous consideration of multiple water bodies in relation to the three pillars of sustainable development (social, economic and environmental considerations). This is an important principle for ensuring that all aspects of the water environment are accounted for in a decision-making process regarding which strategies and BMPs to put in place in an urban area.

RBMPs will be implemented through a mix of regulation, incentives, and voluntary measures in England and Wales (POST, 2008) and this multi-faceted approach ensures that the many varied stakeholders can contribute in different ways thereby increasing the likelihood for beneficial change.

There are usually a variety of land uses within a given RBD including a variety of water bodies, developed urban areas, and rural space. Urban areas pose quite specific water resource management issues due to high population densities and significant areas of largely impervious land cover that alter natural drainage patterns. The key components to urban water resource management are the reliable provision of freshwater supplies, the hygienic disposal of wastewater, and the management of stormwater flows. The good governance and management of these issues on an urban scale will benefit the RBD as a whole, and urban areas are therefore considered to be useful management units if designed and implemented in harmony with wider RBD strategies. This is important alongside the RBD approach of the WFD because local decision-makers require a localised management framework from which to work that accounts in detail for all the issues and systems that are particular to the locality.

Within the scope of EU IUWRM, the founding principles of the Water Framework Directive must be adhered to.

The monitoring and control of diffuse pollution into surface waters is a key component of the Water Framework Directive (WFD), including that caused by urban runoff and stormwater flows. Some BMPs act as effective sinks or filters for some of the major pollutants that occur in urban runoff and

stormwater flows including the priority substances (PSs) and priority hazardous substances (PHSs) that are in particular focus in the Directive. The relative benefits of the various BMPs are described in Deliverables 2.1.1a, 2.1.2 Part B and 2.1.4 and their implementation should be considered as a significant contribution to the achievement of "good surface water quality" as required by the WFD. The RBMPs are each to include a "Programme of Measures" that will set out practical ways of facilitating the requirements of the WFD. The benefits of BMPs should be promoted to RBMP decision-makers and they should be included in these programmes to ensure their inclusion in the overall IUWRM strategy.

New legislation and regulation should consider the long-term funding of BMP development and maintenance.

Decision-makers will fail to include BMPs in new urban development plans if they are not considered to be financially viable or if they are inadequately funded in the long term. Details of the economic aspects of BMPs within the IUWRM approach are included in *Section* 6 but it is important to note here that new legislation and regulation regarding the implementation of BMPs should consider funding issues, particularly for the operational maintenance of BMPs once constructed. This is particularly important for BMPs owned privately or located on private land as the incentive to properly maintain them so that they are able to perform optimally may be compromised in these cases.

7.3 Principles regarding effective planning and implementation

Stakeholder engagement opportunities should be provided for and the benefit from their outputs should be maximised.

The 2nd principle of the "Bellagio Statement", presented by the Environmental Sanitation Working Group in 2000 is that decision-making should involve participation of all stakeholders, especially the consumers and providers of services. The issue of multi-stakeholder engagement is discussed in relation to community and urban benefits in *Section 5.1* but it is important to note that communication and cooperation with all stakeholders is also important to good governance. Stakeholders are often the bearers of information relating to water use and the severity of local stormwater related problems such as flooding. The exclusion of any stakeholder group in the discursive process leads to the exclusion of important information that could assist in improving the management of urban stormwater. Furthermore, the citizens of an urban area are engaged in the localised management of water resources that contribute to the wider success of IUWRM on a larger scale. An important principle therefore is the need to engage stakeholder involvement in as many aspects of the decision-making process as possible.

The SWITCH Deliverable 2.2.1a (Evaluation of current stormwater strategies) identified national, regional and local levels of the regulatory and administrative frameworks that serve good governance. It is important that the use of BMPs be included in the highest level of governance for any given urban area in order that those planning stormwater management strategies may see them as a feasible instrument for implementation

BMPs should be included as measures for implementation in guidance and governance documents wherever they are able to contribute to the achievement of the IUWRM objectives.

BMPs can play a role in the effective management of several aspects of urban stormwater management. BMPs can have a positive impact on drainage, flood risk, surface and ground water quality and pollution control, water saving and reuse, and the protection of habitats species and

natural processes. It is therefore important that BMPs are included in documents produced for guidance and governance where measures for implementation are suggested in relation to the various aspects of urban stormwater management.

The use of BMPs in landscape planning is an effective way of integrating urban drainage, flood risk management, pollution control, wildlife habitat creation and aesthetics.

SWITCH Deliverable 2.2.1a describes how a system of landscape planning was developed in Germany in parallel with spatial planning. Certain BMPs such as constructed wetlands and swales have the potential to have an attractive appearance and attract wildlife within an urban landscape whilst simultaneously providing drainage, settlement and filtration services to urban runoff and stormwater flows. BMPs should therefore be considered as having an integral part in successful urban planning and urban landscape regeneration as they provide a mutual benefit.

In the UK, guidance is currently being written that will encourage the implementation of BMPs through Catchment Management Plans (CMPs). This will occur across Europe as CMPs are designed and implemented. It is essential that the planning process is coordinated and integrated thoroughly in order to maximise the benefits for each of the components.

BMPs should be integrated into flood management planning as storage and flow regulation mechanisms.

Urban areas require careful flood management in the EU and further afield in order to protect the population, property and businesses. BMPs have the potential to offer storage and flow regulation services as described in SWITCH Deliverables 2.1.1a, 2.1.2 Part B and 2.1.4 and should therefore be promoted by the authorities as feasible development options for increasing the stormwater holding capacity of urban areas. This can reduce pollution events caused by CSOs following a storm event and can reduce the pressure on existing urban water storage and flow regulation mechanisms.

Legal barriers and deterrents to BMP developments should be removed from existing drainage legislation and regulation and a clear adoption and maintenance process should be defined.

Each EU member state and other countries wishing to integrate BMPs into their IUWRM strategy should examine their existing legislation and remove any clauses that may prevent or deter decision-makers from implementing BMPs. In the UK for example, Section 106 and Section 115 of the Water Industry Act 1991 provide a right to connect surface water drainage from buildings and related property to public surface water and combined sewers where they exist. This tends to deter developers from considering alternative drainage technologies, opting instead for conventional methods that put further loading on public sewerage systems and WWTPs. The UK government intends to amend these Sections such that new developments must meet national standards for the application of BMP techniques before they are permitted to connect any surface water drainage to the public sewer (Defra, 2009). IUWRM strategies should include a clear adoption and maintenance process for the development of BMPs. This is particularly important for BMPs owned privately or located on private land where their level of maintenance is more difficult to control.

The extension of impermeable surfaces and urban "creep" should be understood and governed.

In urban areas where free parking is scarce, residents often pave over their front gardens to provide an off-street parking bay. In London, the scale of paved front gardens was calculated as covering an area of approximately 32 km^2 by 2003 (Greater London Authority, 2003). Since October 2008, planning policy has changed in the UK to prevent the further paving of front gardens with impermeable surfaces such as concrete. Planning permission is now required for laying 5 m^2 or more of traditional

impermeable driveways that do not allow water to drain to a permeable area. No planning permission is required if permeable surfaces are installed such as gravel or porous asphalt, or if rainwater is directed to a permeable area such as a lawn or border (Planning Portal, 2009). This legislative measure can only be effective however, if the public are made aware of their responsibility and if policy breaches are regulated.

New developments should be encouraged to use surface water systems for their drainage instead of connecting to the public sewer.

New developments will often incorporate their drainage direct to the public sewer as standard practice. Developers should be encouraged to assess the potential for BMPs to provide surface water drainage on their sites and should be given incentives to include them in their plans. It takes time and resources to convince developers of the potential benefits, particularly if they are more costly to implement than installing standard public sewer connections. If a voluntary approach is taken then it will be necessary to invest in information campaigns to educate developers. Alternatively, it may be possible to implement change through legislation.

In the UK, Section 106 of the Water Industry Act introduces the "right to connect" new building drainage to the public sewerage system. The UK Water Regulator, OFWAT is currently considering the possible re-definition of a "sewer" and "drain" to include surface water systems such as swales, infiltration trenches and wetlands as "sewerage assets". This is intended to encourage developers to carefully consider all the available options for their surface water drainage requirements. A Europe-wide redefinition of what may be considered as "sewer" would be beneficial to the implementation of this principle, with the relevant BMPs included within a new standard definition.

A GIS approach should be developed for widespread use in relation to BMPs and IUWRM.

A GIS approach should be developed and implemented that enables the identification of BMP installation sites within a catchment and the selection of the most appropriate BMP for any given location. This could be associated with urban runoff and stormwater flow modelling and prediction. It would simplify the procedure for local authorities wishing to implement BMPs. It would have the potential to reduce planning costs and could be designed such that the system could be used in EU countries and elsewhere. It could also be used in relation to assessments of the removal potential of pollutants by BMPs such as WFD priority pollutants (PSs and PHSs). This would benefit planners in terms of their continued work towards the achievement of WFD water quality objectives.

A number of GIS and modelling approaches are already in use within the field of urban drainage and urban stormwater management, including the MOUSE system that simulates surface runoff, flows, water quality and sediment transport in urban catchments and sewer systems. Other urban stormwater model examples are SWMM, MIKEII, Hydroworks, and STORM. They provide a good representation of the physical phenomena but are limited to technical issues and they are not very user-friendly. A GIS method would allow spatial data to be collected and managed in a user-friendly manner by providing visual representations of the results that can be easily understood by stakeholders. This type of approach has been identified as having great potential for planning and the implementation of WFD objectives and the SWITCH project is currently developing a GIS system of this type that aims to fill this role. The tool uses site criteria to assess the suitability of locations for BMP installation using indicators of site characteristic (land-use, soil type, slope etc.) and the relative potential for a particular pollutant or pollutant group to be removed by specific BMPs (Viavettene *et al.*, 2008). The tool is currently being tested and applied within the Eastside urban regeneration area in Birmingham, UK but it has the potential for a much wider application nationally and internationally providing sufficient background data can be collected.

8 Summary of Generic BMP Principles within a IUWRM Strategy

Table 11 Summary of BMP Principles

	BMP Principle
Technical	• Stormwater should be prevented from reaching receiving waters unless it has first been treated by an appropriate BMP or by a wastewater treatment plant. • Both structural and non-structural BMPs have the potential to prevent receiving water pollution and both should therefore be considered in an effective IUWRM strategy. • Impermeable surfacing should be minimised in urban areas. • BMPs should be used to expand existing stormwater drainage and storage systems where climate change predictions forecast increased precipitation and associated flooding. • BMP technologies and visions should be carefully integrated into existing urban water policies and retrofitted into existing urban and rural area infrastructures, with necessary concessions made for local characteristics and public awareness. • BMPs should be implemented in new road developments as storage, settlement and filtration techniques and should be used to divert road runoff from public sewerage systems. • The physical circumstances of urban areas should be carefully considered when selecting the most appropriate BMPs. • BMPs offer a means of storing urban runoff and stormwater flow and of regulating the post-storm event discharge into receiving waters with benefits to flood and pollution control. • A cleaner production approach should be applied to IUWRM by the development of stormwater BMPs in urban areas.
Environmental	• BMPs should be implemented to protect and maintain water volumes in receiving water bodies such that natural physical and biological processes are unaffected. • BMPs that store water should be encouraged and facilitated in water scarce areas. • BMPs can offer settlement and filtration treatment to urban runoff and stormwater flows with a benefit to the water quality in the receiving water environment. • BMPs should be implemented in order to provide wildlife habitat in urban areas for the benefit of local ecology and aesthetics. • BMPs should be integrated into the existing urban landscape to provide an aesthetic benefit where possible.
Operation and Maintenance	• Establish stakeholder responsibility for funding and implementing a BMP O&M programme at the planning stage • Standard agreements need to be developed to clarify responsibilities and costs between stakeholders • An O&M management plan should be prepared prior to the construction of BMPs, including consideration of major remedial activities and its funding in the long term. • Maintenance activity frequency should be determined in the O&M management plan giving consideration to the requirements of the BMP facility. • A record should be provided for each visual inspection and remedial task that is performed
Social and Urban Community Benefits	• Education, information and training programmes for the local community should be employed throughout the lifetime of a BMP facility. • Stakeholder consultation can influence BMP planning decisions so must be valued and conducted with care. • The public perception and acceptability of water reuse should be improved. • Amenity and aesthetic qualities of BMPs should not be undervalued. • BMPs can be located at educational facilities for the mutual benefit of urban stormwater management and environmental education. • The health and safety risks of any BMP scheme should be carefully assessed and made known to the public. • Signboards can offer a simple and effective method of informing the local community of BMP benefits.

	• Health and safety risks of BMPs should be mitigated at the planning stage, particularly of those that involve standing water. • Risk assessments should be conducted at the design stage of BMP planning. • BMPs have the potential to contribute to the implementation of sustainable development strategies.
Economics	• Whole-life costing should be applied to BMP systems when selecting a drainage programme. • The level of maintenance in relation to the size of the site should be carefully considered in whole-life cost assessments. • IUWRM strategies should encourage BMP retrofitting through the use of economic incentives. • The technical and economic benefits of retrofitting BMPs should be emphasised to developers. • Incentives are required for property owners to encourage them to adopt BMPs, and governments should work with professional services associations to reinforce best practice in BMP implementation including retrofitting. • Sewerage companies should be required to charge commercial properties for surface water drainage. • Whole- life costing should consider BMP drainage system insurance indemnity as future flood risks may exceed the drainage system capacity.
Legal and Urban Planning	• Clear and thorough guidance that includes the promotion of BMPs and the distribution of responsibility are essential to effective IUWRM. • The designation of responsibility for the development, operation and maintenance of BMPs in urban areas must be clear and sufficient resources must be provided at a national, regional and local level. • The management unit should be set at the catchment or river basin level. • Within the scope of EU IUWRM, the founding principles of the Water Framework Directive must be adhered to. • New legislation and regulation should consider the long-term funding of BMP development and maintenance. • Stakeholder engagement opportunities should be provided for and the benefit from their outputs should be maximised. • BMPs should be included as measures for implementation in guidance and governance documents wherever they are able to contribute to the achievement of the IUWRM objectives. • The use of BMPs in landscape planning is an effective way of integrating urban drainage, flood risk management, pollution control, wildlife habitat creation and aesthetics. • BMPs should be integrated into flood management planning as storage and flow regulation mechanisms. • Legal barriers and deterrents to BMP developments should be removed from existing drainage legislation and clear adoption and maintenance processes should be defined. • The extension of impermeable surfaces and urban “creep” should be understood and governed. • New developments should be encouraged to use surface water systems for their drainage instead of connecting to the public sewer • A GIS approach should be developed for widespread use in relation to identifying BMP location and type and informing on the impact for IUWRM.

9 Implementation of IUWRM

9.1 IUWRM and SWITCH

The SWITCH project aims to develop a new approach to Integrated Urban Water Resource Management which will result in new ways of planning the urban water system for the future while addressing global change pressures. It also aims to increase the sustainability of the urban water system and reduce the risks by selecting physical system boundaries as in Lundin and Morrison (2002), in order to ensure that positive and negative impacts that traditionally are seen as 'external' will be included in the analysis, and in the decision making. Lundin and Morrison's (2002) view of the urban water system includes the entire urban water cycle, as well as sludge disposal, materials consumption, energy consumption and agriculture (*Figure 18*).

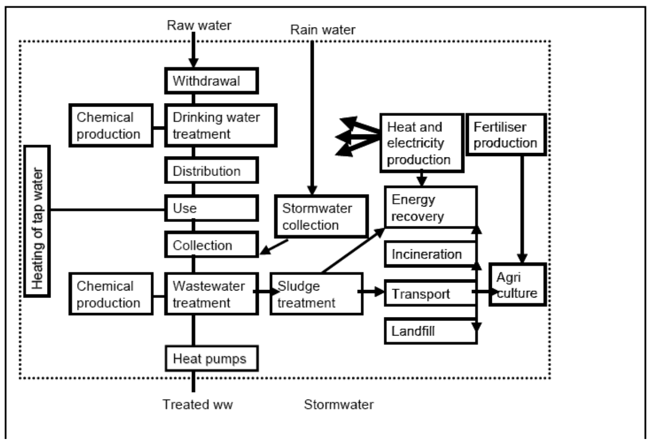


Figure 18 Urban Water System

(Lundin and Morrison, 2002)

The strategies for implementing sustainability in the urban water system range from predominantly technical options to economic and institutional instruments (*Figure 19*). The United Nations Millennium Development goal No 7, Environmental Sustainability, recognises that social, economic and regulatory instruments are changing inappropriate water allocations and uses (Hassing *et al.*, 2009).

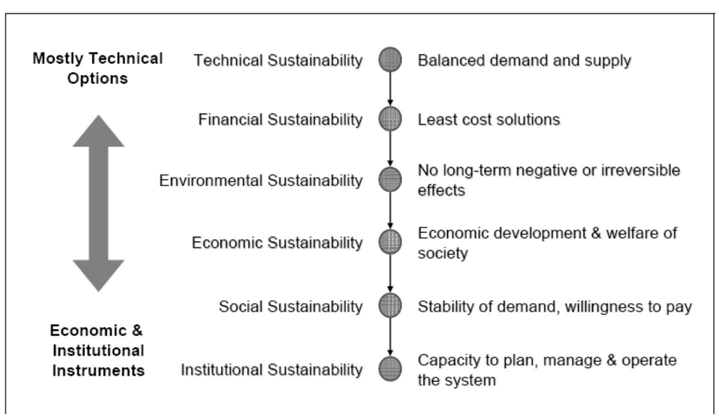


Figure 19 Components of Sustainability

(Katsiardi *et al.*, 2005)

The assessment of the sustainability of the urban water system is based on the identification (by all stakeholders) of a set of 'sustainability indicators' (van der Steen, 2006). The scoring of the indicators can then be used to decide on different water management options. The application of a Multi Criteria Analysis can define the best option, by giving weights to the different criteria and indicators. Models can be used to assess the sustainability of the different options and to develop strategies for the planning of urban water management (Malmqvist *et al*., 2006).

9.2 Principles of IUWRM

The principles of IUWRM developed by the GDRC that were discussed in *Section 1.1* and the BMP principles developed throughout this report are to guide the management of stormwater as part of an IUWRM strategy and need to be carefully and strategically implemented if they are to have any value. Different styles of implementation will be required at different locations, with rates of implementation and BMP choices depending largely on the local conditions and government priorities.

The majority of the barriers listed in *Table 1* (*Section 1.3*) relate to legal and urban planning issues. This highlights the importance of developing clear strategies within administrations and governments and of ensuring that responsibilities are made clear and upheld.

In some areas a top-down approach is appropriate whereby the government defines a strategy for regions to adhere to. The UK is currently undergoing a policy update through the introduction of a new Floods and Water Management Bill (in draft form at the time of writing) that adopts this approach. One of the Bill's main objectives is clarify and designate the various responsibilities for urban water management issues to enable better accountability.

Local authorities that are required to implement IUWRM strategies on the ground need clear guidance on how to select BMPs and how to operate and maintain them as the specialist knowledge required is unlikely to be found within an average city council or authority.

Other parts of the world may be better suited to a bottom-up approach whereby local people instigate change and implement BMPs on a local level to improve their urban environment. Charities and NGOs may have a role in assisting this process by introducing local people to BMP ideas and educating them in how best to install and maintain them.

Srinivas (2005) states on the GDRC website that a coherent water strategy for urban areas must develop the following key themes:

Water Audits: Water audits provide a comprehensive appraisal of the natural and urban water resource base. They assist in water policy assessment and development, investment decisions, monitoring and evaluating programme and policy performance; and direct resource management, particularly by local government.

Demand Management: To effectively mitigate water crises where they may occur, it is essential to implement demand management. This can be achieved by understanding water usage in urban areas, by developing tools and strategies for a deeper and broader reduction, and through the reuse and recycling of water for different purposes. Community education and awareness-building is a critical component in water demand management, as is effective stakeholder participation in decision-making and policy development. Water pricing issues are also of paramount concern.

Urban watersheds: The issues of managing urban water supply, wastewater and stormwater can be viewed in an integrative manner by looking at urban areas as watersheds. Such perspectives incorporate issues such as the pollution of water resources, surface run-off, rainwater harvesting from urban structures, etc. It includes the perspective of cities as 'metabolic units' that can be defined in terms of inputs/outputs and material balance as well as life cycle cost (Srinivas, 2005).

Integrated urban water resource management (IUWRM): IUWRM is an emerging concept that covers the entire urban water cycle, including rainwater, desalination, ground and surface water, etc., as well as storage and distribution, treatment, recycling and disposal, and the protection, conservation and exploitation of water resources at their origin. It also covers empowering local communities to decide on the level of access to safe water and hygienic living conditions, the need to produce more food, and the need to create more sustainable livelihoods per unit of water. The need to manage human water use to conserve the quantity and quality of freshwater and terrestrial ecosystems that provide services to humans and all living things is an important component of IUWRM.

9.3 IUWRM and Stormwater Management

Urban stormwater and treated effluents will be reused for landscape irrigation, and groundwater recharge in the Cities of the Future. All three components, i.e., water supply, stormwater, and wastewater will be considered and managed in a closed loop (Novotny and Brown, 2007). One of the features of future cities is localised drainage networks comprising more surface rather than underground systems. The introduction of stormwater reuse contributes to integrated management within the urban water cycle through:

- Directly reducing the impact on the volume and quality of generated stormwater runoff;
- Indirectly impacting on sanitation (through reduction in flows to wastewater treatment plants);
- Conserving drinking quality water supplies (by using the lowest quality of water for lowest quality needs); and
- Generating water supplies for urban agriculture/other uses.

The benefits to an IUWM programme of introducing or retrofitting a drainage system comprised essentially of BMPs are summarised in *Table 12.*

Table 12 IUWM benefits of BMP drainage system development

Technical	**Environmental**	**Community**	**Costs**	**Planning**
↓Pollution and flooding ↓Runoff volumes to CSOs, WWTPs ↓Impermeable surface area ↑Stormwater storage volumes	↑Maintaining receiving water volumes ↑ Water quality ↑Wildlife habitats ↑ Biodiversity and landscape	↑Environmental education, information and training ↑Stakeholder Consultation ↑Community participation	↓Drainage system costs ↓O&M costs ↓WWTP runoff treatment costs ↓Retrofit costs	↑Landscape & flood management planning ↑Control of impermeable surfaces ↑Surface water drainage

Key: ↑= increase; ↓= decrease

The cost of developing or retrofitting, operating and maintaining a drainage system are normally lower for BMPs than for a traditional system. The increase in stormwater storage volumes and infiltration volumes provided by BMPs reduces the volumes of stormwater discharged to the sewer system and to wastewater treatment plants (WWTPs), thus lowering the energy costs of operating WWTPs. Cost-benefits will also accrue from a reduction in water pollution and flooding. The enhancement of urban biodiversity and the landscape from larger BMPs (wetlands, ponds and basins) will also have a cost-benefit in terms of increasing property values. Direct and indirect improvements in the quality of life and health of the urban population will result from an integrated programme of stormwater, wastewater, water supply and demand management and environmental education.

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