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DELIVERABLE 2.2.4a: STORMWATER AS A VALUABLE RESOURCE WITHIN THE URBAN WATER CYCLE

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SWITCH Document

Stormwater as a Valuable Resource Within the Urban Water Cycle (Deliverable Task 2.2.4a).

J B Ellis and D M Revitt

Audience

The deliverable is primarily addressed at municipal drainage engineers and officers responsible for drafting and delivering surface water management plans (SWMPs) to mitigate the effects of stormwater discharges from impermeable urban areas and in the coordination of sustainable urban water resource management and delivery. It is also of relevance to urban water resource managers, regulatory agencies and consultant environmental engineering groups who have oversight of urban surface water drainage infrastructure in terms of statutory legislation and design implementation for surface water drainage systems. The document also provides an information base to identify the role and significance of surface water in the overall urban water cycle for development planning purposes and is thus of relevance to district and regional planning offices. In particular, the work is addressed at the role and potential re-use of impermeable surface runoff to the water resource capacity of the urban water cycle within the SWITCH demonstration city of Birmingham, and is of relevance to the Birmingham Learning Alliance (LA) in terms of both strategic and local policy and practice.

Purpose

The deliverable identifies and considers the potential contributions and benefits that urban stormwater management strategies can make in meeting the needs of, and reducing the stresses on, stakeholders involved in the management of other components of the urban water cycle. In particular, the deliverable examines the structures, processes, measures and organizational frameworks that facilitate or hinder the implementation of integrated urban stormwater management (IUSM) and associated sustainable integrating approaches for urban surface water drainage infrastructure provision.

It is intended to provide an appropriate methodological approach to analyzing the role of surface water discharges in the total urban water cycle and to develop a specific methodological approach for generic urban water cycle (UWC) studies.

Background

The basic working philosophy of stormwater source control is to maximize flood and water quality protection as well as to minimise water consumption and to create opportunities for community benefits that can arise from conjunctive, multiple use of surface runoff water. There is a general expectation in most developed countries of more adaptable future urban drainage systems, reducing not only flood and pollution risks, but also providing amenity/ecological benefits to local communities and decreasing the burden on existing sewer networks. Such Best Management

Practice (BMP) source controls can be implemented at plot, site and sub-catchment scales although there is little hard information or guidance available on the integration of stormwater recycling into the total urban water cycle (UWC) or on how such recycling might optimize water conservation objectives.

The strategic re-use of stormwater within the urban environment has considerable scope for relieving future pressures on water resource provision and management within the urban water cycle (UWC) as for example, identified in current Australian Water Sensitive Urban Design (WSUD) practice. Appropriate methodological approaches are needed to identify and quantify the potential benefits that might accrue from such rainwater harvesting and stormwater re-use. The report develops the concepts and principles of generic urban water cycle studies as an appropriate vehicle for guiding stakeholders in working-up and delivering sustainable strategies for the management and control of urban surface water runoff; the major objective being to identify tensions between development proposals and environmental requirements.

Such water cycle planning will provide a guidance framework for identifying potential contributions that surface water discharges can make to other components of the water cycle, whilst at the same time reinforcing legislative requirements, stakeholder participation mechanisms and community quality-of-life objectives. The generic UWC methodology is then applied to an initial scoping (Phase I) study undertaken for the SWITCH demonstration city of Birmingham as a basis for illustrating the pilot template approach.

Potential Impact

The potential contributions of urban stormwater runoff to the water cycle can only be accurately evaluated within the context of the distribution and balance of water uses for the overall urban water cycle (UWC). The application of a strategic UWC study in conjunction with drainage infrastructure masterplanning, such as surface water management planning (SWMP) and catchment management planning (CMP), will make clear the nature of the relationships between national, regional and local planning structures as well as strategic flood and pollution risk assessment procedures. It is imperative that there is joined-up thinking and planning approaches at both spatial and temporal scales in the planning and delivery of urban drainage infrastructure and that these consider the totality of the urban water cycle. This in turn requires the availability of an appropriate, user-friendly methodology to evaluate the components and interactions which characterize the urban water cycle.

This resource planning integration is of crucial importance in developing a continuum of coordinated, integrated planning for urban drainage infrastructure and in providing a logical linkage between strategic plan-making, development assessment and on-site infrastructure provision. It is only by a thorough quantification of the distribution of water use components within the UWC that the significance of stormwater contributions to future urban water resource management can be satisfactorily identified and achieved. Such quantification is

also necessary to provide stakeholder confidence in the control and mitigating measures being proposed for future sustainable urban drainage management.

Issues

The issue of urban stormwater management can be visualized as constituting a "wicked" problem primarily dominated by barriers at the institutional and social levels reflecting the diversity of responsibilities, expertise and attitudes of various stakeholders. This inherent "wickedness" recognizes the normative "lock-in" (or entrapment) associated with conventional departmentalized organizations/agencies on the one hand and the cognitive behaviours of disparate, vested-interest public/NGO groups on the other hand. Only a shared, stakeholder dialogue approach can address this "wicked" situation, and this requires an objective evidential base and an appropriate methodological framework to facilitate the stakeholder consultation process and serve as an acceptable information database to support the decision-making process.

Principal stormwater concerns for municipal local authorities include water demand and usage rates as well as ensuring sufficient capacity to meet requirements for new developments. In addition, there is a need to ensure operational reliability and sustainability of the drainage network resources being delivered and a need to ensure that mitigating controls cover the full spectrum of storm events, including extreme storm event exceedance flows. A further major concern is to develop an effective timetable for a staged and integrated planning framework to ensure "on-time" and appropriate delivery of drainage infrastructure controls.

Recommendations

Municipal local authorities need a procedure for identifying development constraints in respect of both existing and future water use in order to make preliminary determinations of water demand and usage rates for new development, together with a quantification of possibilities for water savings and re-use potential.

A two-stage urban water cycle (UWC) approach is recommended as providing an appropriate methodological framework for the identification and quantification of the contributing components of the urban water cycle. This UWC approach needs to draw together relevant supporting documentation and regulatory guidance from national, regional and local sources. This evidence base should also identify the key skills and expertise needed to carry out a successful UWC study as well as specifying the benefits accruing from the generic approach.

It is recommended that such an evidence-based approach should include reference to appropriate design standards (flood, water quality and ecology/amenity), adoption criteria, funding mechanisms and strategic stakeholder partnerships necessary to implement a sustainable urban drainage infrastructure. The use of a developer checklist for urban surface water management is therefore recommended as a support tool in facilitating the decision-making and development planning application process.

The application of a staged, evidence-based UWC study can specifically address development impacts on the water cycle, with particular emphasis on the consequences for the provision and maintenance of surface water drainage infrastructure and management. The outputs from the UWC study should provide a valuable basis for feeding into the masterplanning process and in strategic flood risk assessment as well as in the Water Framework Directive (WFD) requirements for SWMPs and Catchment Management Plans (CMPs).

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Abbreviations/Acronyms

ASR	Aquifer Storage Recovery
BMP(s)	Best Management Practice(s)
CFMP(s)	Catchment Flood Management Plan(s)
DPD(s)	Development Plan Document(s)
EA	Environment Agency
FZ	Flood Zone
IUD	Integrated Urban Drainage
IUSM	Integrated Urban Stormwater Management
IUWCM	Integrated Urban Water Cycle Management
GIS	Geographic Information System
LBAP(s)	Local Biodiversity Action Plan(s)
LDF(s)	Local Development Framework(s)
LID	Low Impact Development
LDS	Local Development Scheme
O&M	Operation and Maintenance
PPG	Planning Policy Guidance
PPS	Planning Policy Statement
RFRA	Regional Flood Risk Assessment
RI	Return Interval
RSS	Regional Spatial Strategy
SEA	Strategic Environmental Assessment
SFRA	Strategic Flood Risk Assessment
SRA	Strategic Risk Assessment
STW	Sewage Treatment Works
SPD	Supplementary Planning Guidance
SUDS	Sustainable Urban Drainage Systems
SWMP(s)	Stormwater Management Plan(s)
UDP	Unitary Development Plan
UWC	Urban Water Cycle
WCS	Water Cycle Strategy
WFD	Water Framework Directive
WSUD	Water Sensitive Urban Design

SUMMARY

This deliverable identifies and considers the contribution that stormwater management strategies can make in meeting the needs of, and in reducing the stress on, stakeholders involved in other components of the urban water cycle. In particular, the deliverable examines the processes and measures that facilitate or hinder the implementation of integrated stormwater management (IUSM) and associated sustainable mitigating approaches. These aims are explored within the context of the growing framework of urban water cycle (UWC) studies.

The stakeholder benefits of implementing sustainable stormwater management and BMP/SUDS controls are discussed for plot, site and sub-catchment (neighbourhood) scales. The advantages and limitations of plot scale rooftop disconnection, infiltration and rainwater storage, site scale re-use and storage and sub-catchment BMP application are discussed and the utility of this spatial scale approach to site design is demonstrated. There appears to be considerable potential scope for the strategic re-use of stormwater runoff at all spatial scales although the benefits for the urban water cycle largely remain to be realised in most countries.

The concepts and working principles of an UWC study are developed with the major objective being to identify tensions between development proposals and environmental requirements. The UWC approach aims to confirm whether the existing infrastructure can support the developments identified within the spatial planning strategies and local development schemes. Such water cycle planning provides a guidance framework for identifying potential contributions that surface water discharges can make to other components of the cycle, whilst at the same time reinforcing legislative requirements, stakeholder participation mechanisms and community quality-of-life objectives.

The intersection of surface water management plans (SWMPs) and strategic UWC studies at both Outline Phase 1 and Detail Phase 2 levels are considered, together with their relationship with national, regional and local planning structures as well as strategic flood and pollution risk assessment procedures. The crucial importance of a continuum of coordinated, integrated planning for urban drainage infrastructure is stressed, providing logical linkage between strategic plan-making, development assessment and on-site infrastructure provision. The issue of stormwater management is visualised as a “wicked” problem dominated by barriers at the institutional and social levels reflecting the diversity of responsibilities, expertise and attitudes of various stakeholders. There are no right or wrong solutions and every solution throws up new problems. This inherent “wickedness” recognises the normative and cognitive “lock-in” respectively demonstrated by conventional, departmentalised professional institutions on the one hand and disparate, vested interest public groups on the other. A shared, stakeholder dialogue approach is recommended to overcome this “wicked” situation,

Details of the stages of a typical UWC study are presented together with a working brief. This is then illustrated in the context of the development of an UWC strategy for the Eastside development area of the SWITCH demonstration city of Birmingham, UK. The background to drainage infrastructure within the development area is described together with the main concerns of the regulatory and local authorities and other stakeholder groups. A development

constraint matrix for use in an Outline Phase 1 UWC study is shown and a preliminary determination of water demand and usage for the development area is made together with possibilities for water savings and re-use.

The application of a GIS-based BMP/SUDS modelling approach to predict storm runoff and source mitigating measures for a 4.5 ha sub-catchment within the development area is demonstrated using the STORM hydrological model and a BMP/SUDS location tool developed within the SWITCH project. It is shown that BMP/SUDS application (using green roofs and porous paving) to the drainage infrastructure could reduce peak flow volumes of surface runoff by between 70% - 90%.

The deliverable identifies the key supporting documentary evidence available for a UWC study at the local municipal, regional and national levels. A representative stakeholder steering group for the UWC study is proposed (largely following the established SWITCH Learning Alliance (LA) consortium), to be led by the Birmingham City Council and the outputs and benefits of the UWC study are identified together with the key skills and expertise needed to carry out a successful UWC study. Consideration is also given to the financial resources necessary to undertake such a study and possible funding mechanisms that might be adopted to deliver an integrated, strategic approach for implementing a sustainable drainage infrastructure. An annex to the deliverable outlines a potential developer checklist for urban surface water management that might be required under the development planning application process.

BRIEFING NOTE

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INTRODUCTION

1.1 Integrated Urban Stormwater Management (IUSM)

The aim of integrated urban stormwater management (IUSM) is to bring together all the issues and stakeholders surrounding the effective drainage of the urban area, taking into account both the quantity of flows to be dealt with and the quality of the receiving waterbodies. In view of future challenges including urban expansion, climate change and more stringent regulations, effective integration is a clearly desirable objective for sustainable water resource management for the city-of-the-future. However, it must be expected that various aspects of existing practice, institutional organisation and governance arrangements will need to be addressed if such integration is to be achieved. Figure 1 illustrates the various components of the urban water cycle which need to be cost-effectively managed and the operational framework within which generic decision-making processes must be brought together to resolve the disparate issues associated with IUSM and to bring about a shift in the prevailing urban water paradigm.

Successful integration of the surface water, wastewater, groundwater and drinking water components of the urban water cycle shown in Figure 1 will only be achieved through a shift in the current urban water paradigm which is based on an "all-to-the-sewer" approach operated in semi-autonomous compartments and separately managed by a mix of public and private organisations. These variable institutional and governance arrangements, in turn, operate within planning and regulatory frameworks normally structured by national and/or state guidelines but frequently delivered at local authority or municipal level.

1.2 WP2.2.4a objectives and relation to other SWITCH WP themes

Theme 1 of the SWITCH project has recognised the basic components of the urban water cycle and the role of stormwater in the cycle together with the significance of utilising a risk management approach to IUSM. Theme 1 has also identified a suite of sustainable indicators that need to be adopted in future water resource decision-making and planning processes if a paradigm shift is to be achieved in IUSM. These indicators embrace flood risk, receiving water quality/ecology, source control and BMPs/SUDS, stormwater re-use/recycling and enhancement of the urban water balance (Theme 1. P van de Steen, "*Draft Strategy Paper*", 26 August 2008 version; www.switchurban water.eu). Theme 2 Deliverable 2.2.3a has incorporated these sustainability indicators in a Vision Statement for future IUSM for the Eastside development area within the city of Birmingham, UK (Ellis *et al.*, 2010).

The significance of stormwater as a potential supply resource rather than a "waste" water is central to the strategy for sustainable urban water resource management as visualised in Theme 3 of SWITCH (Kayaga and Smout, 2006). The meaning and significance of stormwater re-use for IUSM and as a source of alternative resource capacity at both household and municipal levels, has also been considered by Scholes and Shutes (2007), as well as in a Theme 2 Workshop held during the SWITCH 1st Scientific Meeting in Birmingham on 8 January 2007 (www.switchurbanwater.eu). The SWITCH Deliverable 2.1.1b outlined national guidelines, concerns and public perceptions of, as well as the economic benefits to be gained from, stormwater re-use (Scholes and Shutes, 2007).

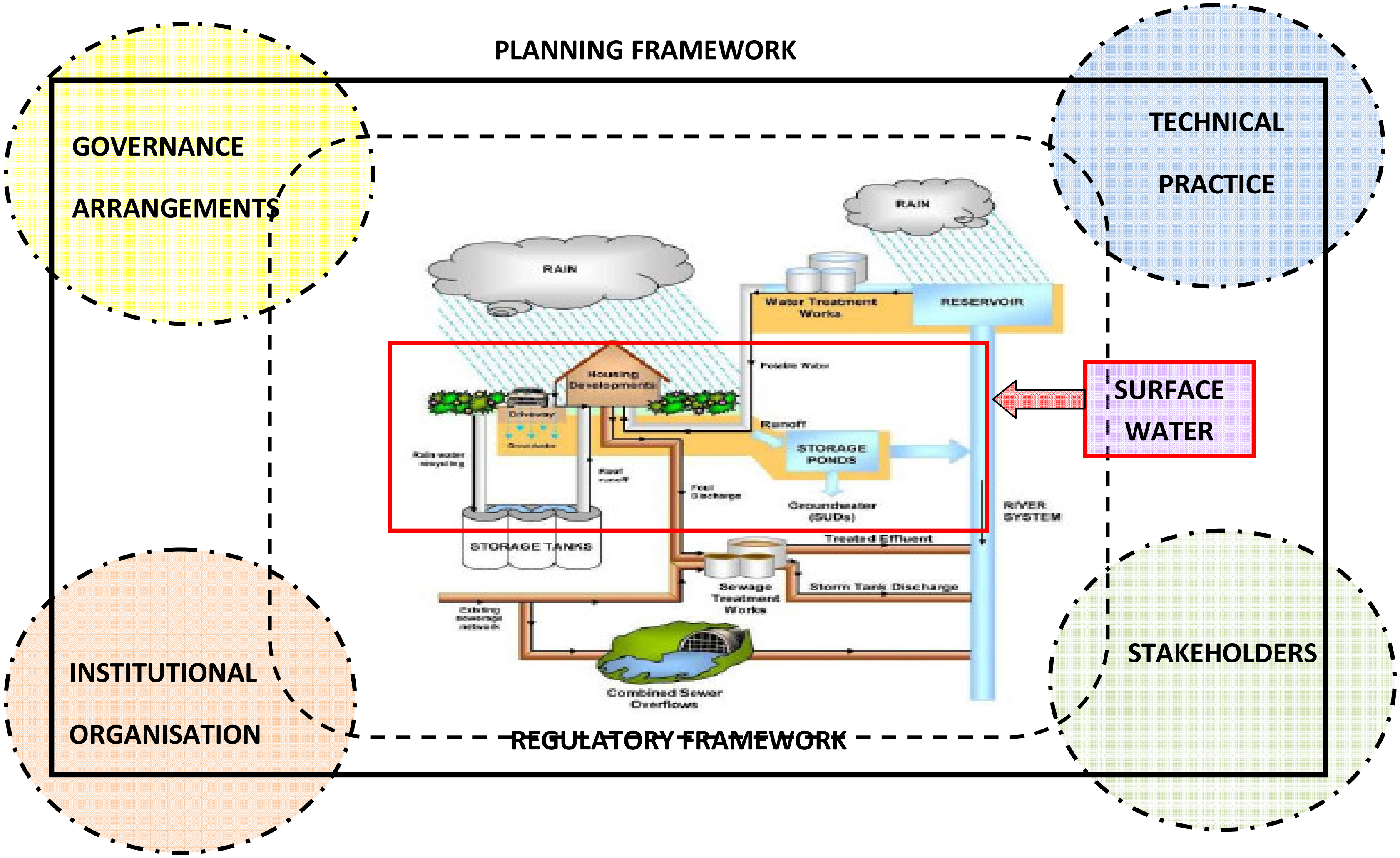


Figure 1. A sustainable framework for IUSM.

A further report (Deliverable 2.1.2, Part B) also examined the potential of retrofit and hybrid stormwater BMPs/SUDS to integrate with existing drainage infrastructure as a means of contributing to other sectors of the urban water cycle shown in Figure 1 (Shutes, 2008).

SWITCH Theme 5 has focussed on stormwater management and urban design with particular reference to spatial planning strategies for water-sensitive urban design (WSUD) approaches in terms of urban ecology, recreation and social inclusion (Langenbach *et al*., 2007). The need for an integrated, holistic approach to functional urban design, developed within a multi-disciplinary context, is considered to be a pre-requisite for successful IUSM. Deliverable 5.1.3R (Parts I – III) examines potential approaches and solutions to integration of the parameters of WSUD within the planning system (Langenbach *et al*., 2009). Within SWITCH Theme 2, Deliverable 2.1.1a identified the need for regulatory approaches to planning for IUSM at both site and catchment scales as illustrated by reference to the situations in Birmingham, UK and Belo Horizonte, Brazil (Ellis *et al*., 2007). Deliverable 2.1.2, Part A reviewed national design guideline manuals for stormwater management best practice and particularly examined their vulnerability under extreme wet weather conditions (Ellis *et al*., 2008a).

Deliverable 6.1.1 of SWITCH Theme 6 has provided a series of briefing notes on governance principles and protocols to deliver IUSM and has developed the potential contributions that institutional mapping can make to achieving sustainable objectives (Da Silva *et al*., 2008). A case example of institutional arrangements and mapping protocols for Birmingham, UK has been separately developed by Green *et al*, (2007). This Theme 6 contribution has been complemented by Deliverable 2.2.3b (Ellis *et al*., 2009a) which provides guidelines to stakeholders in preparing and understanding institutional mapping protocols and approaches for IUSM based on the principles and protocols of Theme 6, using the SWITCH demonstration city of Birmingham as the working example. The deliverable identifies governing hierarchies and responsibilities, underlying social norms and prevailing socio-economic conditions. The range of potential stakeholders in IUSM and their "action spaces", particularly with respect to the implementation and operation of stormwater BMPs/SUDS, has been discussed together with the importance of achieving behavioural change in institutional outlooks. The interactions between SWITCH Themes 6.1 and 2.2 have been further explored in a paper presented at the 4th SWITCH Scientific Meeting in Delft in October 2009 (Ellis *et al*., 2009b).

There has therefore already been considerable complementarity between the core of Theme 2 (Stormwater Management) and Theme 1 (Urban Water Paradigm Shift), Theme 3 (Efficient Water Supply and Water Use), Theme 5 (Urban Water Environments and Planning) and Theme 6 (Governance and Institutional Change). A number of the deliverables developed within the stormwater management Theme 2 have considered cross-thematic SWITCH issues and adopted principles, approaches and protocols developed in companion workpackages. The objective of the current deliverable (Task 2.2.4a) is to further identify and consider the contribution that stormwater management strategies can make in meeting the needs of, and in reducing the stress on, stakeholders involved in other components of the urban water cycle. In particular, the deliverable is intended to identify and examine processes and measures that facilitate or hinder the implementation and operation of IUSM and associated sustainable mitigating approaches. These aims will be delivered in this paper within the context of the growing framework of urban water cycle (UWC) studies.

1.3 Benefits of Stormwater Management within the Urban Water Cycle

The philosophy of stormwater source control is to maximise flood and water quality protection as well as to minimise water consumption and to create opportunities for community benefits that can arise from conjunctive use. The UK government for example, has recently acknowledged that the future vision for surface water management must include more adaptable drainage systems delivering reduced flood and pollution risks, decreasing the burdens on existing sewage networks and providing amenity/ecological benefits to local communities (Defra, 2008). It has been argued by Campbell *et al* (2005), that there is a significant substantive difference between source control and sustainable (water sensitive) urban drainage systems (SUDS or WSUD). The latter, it is asserted, essentially refer to drainage control options that include specific reference to flow quantity, quality and amenity/ecology. Source control on the other hand can be regarded as a generic term covering both BMPs (such as SUDS/WSUD controls) and general housekeeping (road sweeping, car parking ordinances, hard standing etc.,) and other external options such as product substitution or financial incentives. Such strict terminological separation has not been applied in the current document.

BMP source control can be implemented at plot, site and sub-catchment (neighbourhood) scales to achieve these multi-purpose benefits, although relatively little detailed work has been undertaken to quantify the economic benefits accruing from such source control/BMP implementation. Andoh and Declerck (1999) have asserted that the application of roof disconnection with distributed surface and in-pipe storage measures can result in cost savings of between 30% and 80% over traditional drainage methods. Stahre (2000) has also illustrated the positive hydrologic, amenity and aesthetic benefit values to the total urban water cycle accruing from source detention and disposal of stormwater runoff in the city of Malmo, Sweden. The agreement between the State Ministry, the regional water authorities and local municipalities in Germany for the 266 km^2 Emscher catchment to achieve 15% roof disconnection over the next 15 years (the 15:15 project), will reduce some 26.4 billion m^3/annum from the surface water drainage system (Seiker *et al*., 2006). This catchment-scale disconnection will release and divert valuable rainfall-runoff to recharge groundwater and also provide harvesting opportunities for plot-level rainwater storage and re-use. This German agreement has been stimulated by a stormwater tax on impervious surface coverage averaging €0.80/m^2.

At the plot scale, rooftop disconnection and rainwater storage are feasible options and there are over 3 million people in Australia currently using rainwater tanks for drinking water supply with very few reported health problems, and there are national standards providing guidance for stormwater and rainwater re-use (*AS/NZS 3500.1.2 National Plumbing and Drainage: Water Supply-Acceptable Solutions, 1998*). Coombes *et al* (2000a) have reported that such tanked roof rainwater is of acceptable quality not only for hot water, toilet flushing and outdoor uses but also for drinking water. Nevertheless, there is still substantial reluctance to the wider household adoption of harvested rainwater for drinking water use, with most consumers preferring that tanked rainwater be restricted to outdoor uses. However, it would be erroneous to assume that using rainwater to only supply outdoor uses would result in substantial mains water savings given the potential mis-matches between rainfall incidence and water use patterns. It is only by combinations of different water use types that optimum household water savings can be achieved. Roof water re-use can provide

substantial savings estimated at 1% - 3% of drainage infrastructure cost as well as reducing annual maximum daily peak demands by 40% for domestic dwellings and reducing peak stormwater discharges by up to 80% for the 1:1 RI storm event (Coombes and Kuczera, 2001). Reductions in stormwater discharge of between 14% to 30% were reported for the 3 month RI storm event, although Andoh and Declerck (1999) predict a lower average 21% saving. 3 – 5 kL capacity rainwater tanks offer a mains water saving of around 90 – 110 kL per annum for an average Australian household; 18% of households in Queensland use such rainwater tanks and of this, 15% use rainwater as the main source of drinking water supply (Australian Bureau of Statistics, 1994 – 2001).

At the site scale, both rooftop water and other impermeable surface runoff can be captured and re-used for a variety of outdoor uses (irrigation, vehicle washing, fire-fighting), as well as for drinking water, toilet flushing, laundry etc. In addition, surface storage in raingardens/pocket wetlands can provide landscape enhancement as well as improving the urban water budget in terms of increased evapo-transpiration rates (Ellis, 2010). Indoor use of stormwater in the form of rainwater tanks can be used alongside water saving appliances to reduce the demand on the public water supply system, whilst at the same time the demand can be reduced in gardens and public open space by using stormwater in conjunction with treated greywater for irrigation and other outdoor uses. However, there are very few examples that can be referred to where all these applications and benefits have been concurrently tested in the field.

At the sub-catchment (neighbourhood) scale, the use of larger conveyance and storage BMP facilities such as ponds/wetlands and dry basins provide additional community and ecological benefits as well as opportunities for industrial re-use (cooling, boiler or wash-down process water) and groundwater recharge. For example, a joint venture in the city of Salisbury, South Australia, stores and treats 1 GL/year of stormwater runoff to be used for wool processing with 36 other wetlands in the city diverting stormwater for aquifer storage recovery (ASR). Coombes *et al* (2000b) estimate that the catchment scale application of rainwater harvesting can delay augmentation of water supply infrastructure by 8 to 30 years, even given predicted increases in urban growth and climate change. Regional reductions calculated for the Hunter Valley catchment in New South Wales indicated an average 50% reduction in mains water use by residential households following the introduction of rainwater tanks on a neighbourhood scale (Hatt *et al*., 2006).

Figure 2 illustrates the average end-use for stormwater recycling schemes identified in a review of Australian practice within 17 selected municipalities which show outdoor irrigation and associated uses to be by far the most common end-uses (~60%) followed by toilet flushing (Hatt *et al*., 2006). There does not appear to be any influence of plot, site or sub-catchment scale on the reported end-use type, although it is notable that the large majority of end-uses were restricted to plot/site scale and mainly applied for purposes having a low potential for human contact. It is also notable that most end-use schemes also used the same design controls developed for BMPs/SUDS which are not intended to produce the highest quality water outputs. This could be a major consideration for the future expansion of stormwater re-use schemes with a need to develop robust control options capable of consistent high-quality water production. This may require resorting to more complex, smart technology solutions for water treatment.

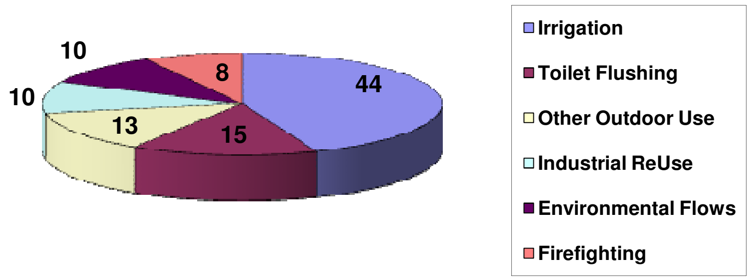


Figure 2. Stormwater recycling end-uses in Australia.

Little information is available regarding the integration of stormwater recycling into the total urban water cycle. It would seem that limited consideration is being given to how stormwater recycling can be integrated into the UWC or to objective assessments of whether it is an appropriate or optimal tool in all circumstances. In addition, little consideration has been given to how such integrated stormwater recycling might meet and optimise energy and water conservation objectives, although Kloss (2008) has estimated that reducing drinking water demand by 10% could save about 300 billion kWh of energy each year. Rainwater harvesting becomes more economically attractive when both water and energy savings are addressed collectively as they have been, to some extent, in the case of the SWITCH UK Birmingham Learning Alliance (LA) studies of utilities provision (Coyne *et al*., 2008).

Nevertheless, there would appear to be considerable potential scope for the strategic re-use of stormwater runoff in other sectors of the urban water cycle, particularly for secondary quality domestic/commercial uses ranging from toilet flushing, fire-fighting, vehicle wash-down, garden irrigation as well as for groundwater recharge. These potential uses are yet to be realised although progress is being made in the re-use of stormwater to supplement mains drinking water supplies as well as in re-structuring the urban water budget through BMP amplification of evapo-transpiration and infiltration processes (Ellis, 2010). Such strategic re-uses have the potential to provide substantial benefits across the entire urban water cycle. Rooftop disconnection also appears to be a common strategic approach at the pilot scale as evidenced by the German Emscher 15:15 project, although not necessarily accompanied by the introduction of green roof technologies.

2. URBAN WATER CYCLE (UWC) STUDIES

2.1 What is an Urban Water Cycle study?

The concepts of total water cycle management within urban catchments are now reasonably well versed emerging from practice first implemented in Florida and California in the 1980s (Marsalek *et al*., 2007). This more integrated approach to urban water resource management was also adopted and further developed in Canada and Australia during the early 1990s (Lawrence *et al*., 1999). However, the specific principles and approaches associated with urban water cycle (UWC) studies as part of a total water cycle management approach formally emerged from practice in New South Wales (NSW), Australia (Gilmour *et al*., 1999). The role of stormwater in the urban water cycle and its role in strategic infrastructure policy formulation and evaluation has now been formalised into NSW legislative and administrative structures (Dept. of Energy, Utilities & Sustainability, 2004; Langdon, 2006). A number of papers outline the strategic policy and planning implementation of UWC management within various NSW urban areas, the importance of community participation and the need for institutional "shaping" as given in Phillips (2003) and Ryan *et al*., (2003). In the UK, the regulatory Environment Agency has recently issued a draft document prepared by Halcrow plc (2009) outlining the concepts and structure of Water Cycle Study approaches (www.publications.environment-agency.gov.uk) and the UK government has also issued a consultation guidance document which encourages local authorities to adopt Water Cycle Strategy studies as a preliminary methodology to the development of Surface Water Management Plans, SWMPs (Defra, 2009a). At the present time over 39 individual Water Cycle Studies are being undertaken within England, including one commissioned by Birmingham City Council, all of them following the Halcrow plc (2009) template.

Urban water cycle (UWC) studies are intended to identify tensions between development proposals and environmental requirements as a means of facilitating potential solutions in order to address them in an integrated, sustainable and cost-effective manner. The UWC approach aims to confirm that the urban water cycle infrastructure can support the developments identified within regional spatial planning strategies and local/municipal development frameworks. Water cycle planning represents a relatively new approach for urban drainage which supports the provision of a sustainable water cycle infrastructure for both new and existing urban areas, and adopts an integrated approach to total water cycle infrastructure provision. In this respect, the UWC approach provides a guidance framework for identifying the potential contributions that stormwater discharges can make to other components, and to the concerns of differing stakeholder groups, within the total urban water cycle.

UWC studies can thus provide the basis for developing a holistic strategy for the provision and operation of water infrastructure, including stormwater, as required under future growth scenarios and which are appropriate to local, regional and national planning and regulatory strategies. Effective planning and close cooperation between all stakeholders is essential to the success of a water cycle study. A water cycle study is able to support planning approaches for urban water resources provision and IUSM in an integrated fashion and help identify the contribution that individual components of the urban water cycle such as stormwater, can make towards other aspects of the water cycle. A water cycle study provides a strategy to deliver the most sustainable water services infrastructure at the right time and location to enable and optimise existing and future development. Such an approach not only

requires effective stakeholder partnerships but also requires data sharing in terms of technical knowledge of the urban water resource cycle embracing water supply, wastewater, surface water, flood risk and receiving waterbody quality and ecology.

UWC studies can therefore help to plan for integrated urban water cycle management (IUWCM) by:

- bringing together organisational and stakeholder knowledge, understanding and skills, supporting "joined-up" approaches and attitudes leading to decisions on strategic growth planning,
- bringing together water, planning and regulatory evidence into a single framework,
- supporting the understanding of technical, environmental, socio-economic and institutional constraints to development,
- working with "green infrastructure" planning principles to identify opportunities for enhanced sustainable urban planning and ecological design, including low impact development (LID) approaches for high-density urban development (Ellis *et al.*, 2004),
- identifying water cycle planning policies and developing a water cycle strategy to help all stakeholders make decisions for a sustainable future water environment.

Figure 3 illustrates the environmental, community, organisational and economic components of the urban area which, as stated above, need to be brought together in a new integrated urban water cycle management approach to achieve future water resources sustainability and to obtain the benefits from stormwater contributions to the urban water cycle. However, an effective stormwater strategy and drainage infrastructure can only be achieved within the context of the wider UWC stakeholder framework implied in the IUWCM framework shown in Figure 3. Within this wider and catchment-based context, urban surface runoff water and

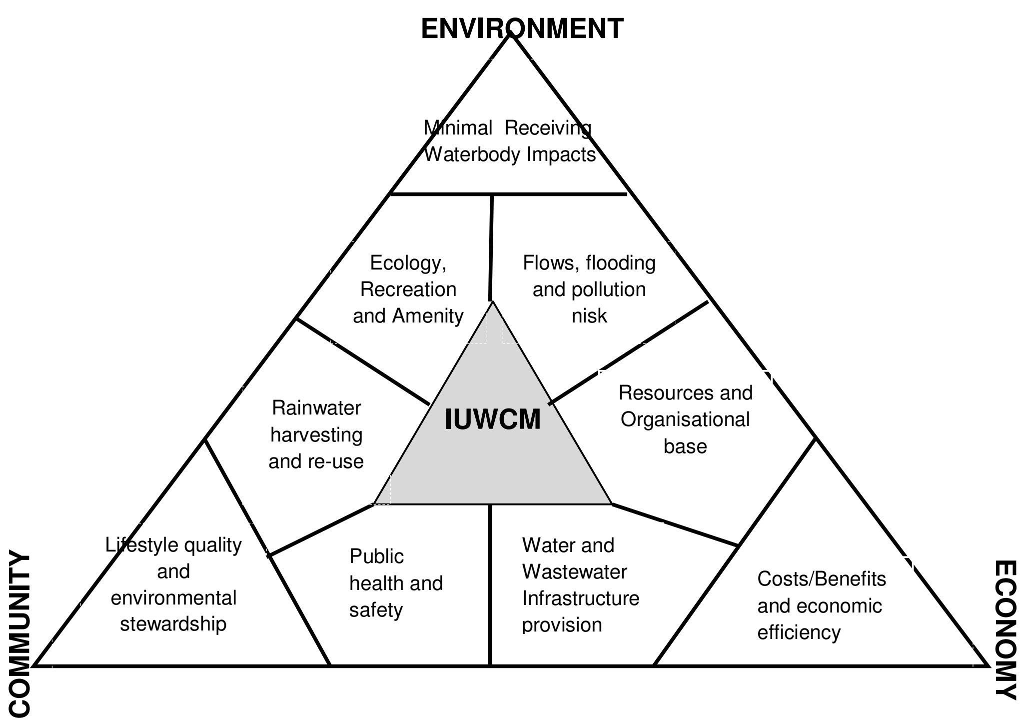


Figure 3. Integrated Urban Water Cycle Management (IUWCM)

best practice drainage can make substantial contributions to meet the future stakeholder objectives and aspirations embodied in the concept of total integrated water cycle management (IUWCM).

Expressed in these terms, an UWC study can be regarded as being:

- a methodological approach for determining what water resource infrastructure is required, as well as where and when it will be needed,
- a risk-based approach ensuring that the planning process makes best use of environmental capacity and is adapted to environmental, technical, costing and other major local/regional constraints
- a structural framework for stakeholder engagement and collaboration,
- a process procedure whereby diverse and disparate knowledge and information is brought together to make better and more integrated risk-based decisions with respect to the urban water environment,
- a basis for developing stormwater management plans (SWMPs) and preliminary strategic flood and pollution risk assessments (SRAs) as well as ensuring compliance with other regulatory requirements such as those required under the Water Framework Directive (WFD) and with local/regional development planning policies and regulations.

An effective UWC study acts as a vital evidence base for local/regional development plans, showing how water services and the water environment have been considered in the strategic planning process. As such it can facilitate a water-based comparative assessment of development option designs and locations and can feed into and underpin core planning and regulatory control strategies. It also ensures that both new and retrofit urban developments comply with current and future legislative requirements such as those required under the Water Framework Directive. In this respect, UWC approaches are a means which will enable compatibility to be achieved between local authority/municipal Stormwater Management Plans (SWMPs) and regulatory authority Catchment Management Plans (CMPs) in respect of effective surface water drainage. UWC studies can also provide an evidence base for setting out priority allocations, development phasing, assessing developer contributions to drainage infrastructure and supporting BMP implementation and operational guidance. Active stakeholder participation is also likely to make each partner more committed to delivering the agreed water cycle strategy.

2.2 Stormwater in the Urban Water Cycle

Surface water management in the urban water cycle is essentially concerned with identifying and mitigating pluvial flood and receiving waterbody pollution risks associated with the drainage of urban surfaces (Figure 4). As indicated in the figure, effective stormwater management can also make substantial contributions to environmental water quality (surface and groundwaters), and to reducing the stress on wastewater and water supply infrastructure through control of surface flows to sewers, stormwater re-use and enhanced infiltration to groundwater capacity. In addition, integration of surface drainage design into "green infrastructure" planning within the urban area offers contributions towards more natural

urban water balance and water recycling processes, as well as opportunities for community leisure/amenity, open space and environmental stewardship.

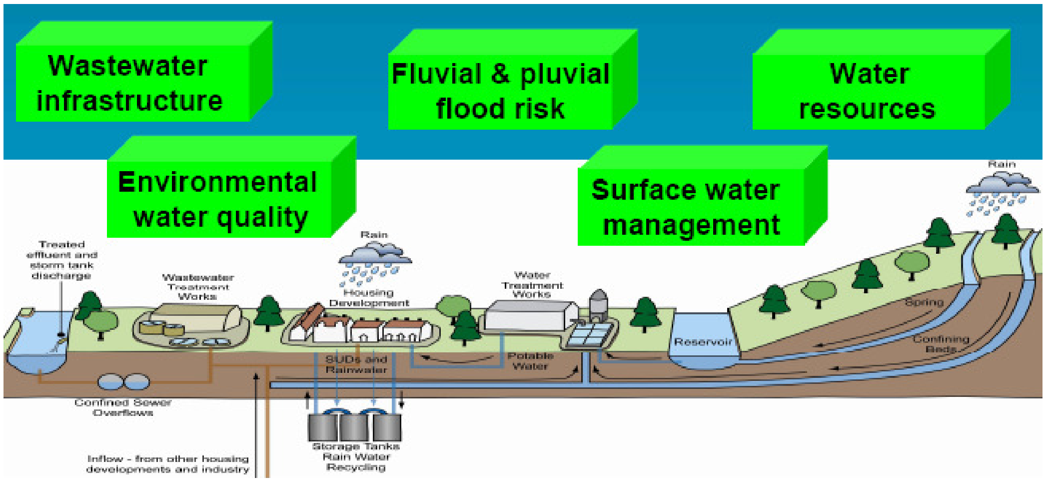


Figure 4. Stormwater management and the Urban Water Cycle.

Stormwater best practice infrastructure within such an IUWCM framework as shown in Figures 3 and 4, can provide a basic design model for future surface water drainage planning approaches. The landscape design approach indicated in Figure 5 offers opportunities for source control, treatment train and infiltration/storage BMPs to combine with conventional drainage assets whilst creating linkages between plot, site and sub-catchment scales in addition to providing contributions to other water cycle components. The drainage infrastructure model shown in Figure 5 can be implemented for both low and high housing densities as well as for greenfield, brownfield and retrofit situations (Ellis *et al*., 2004; Bray, 2007). Excess flows from any part of the source control or BMP treatment train stages can be routed directly to the receiving watercourse via overflow pipes or "grilled" surface channels.

The contributions of surface-derived stormwater to other uses within the urban water cycle are also indicated in Figure 5 with the integrated management planning providing an alternative approach to landscape urbanism infrastructure. The design approach retains existing watercourses and gravity flow routes based on self-contained but inter-connected sub-catchments (Bray, 2007), with emphasis on managing rainfall-runoff as much as possible "at-source". This can be done by the introduction of micro- and meso-vegetative BMP systems at both site and sub-catchment scales, by integrating street "greening" drainage infrastructure with optimised biofiltration BMP solutions together with plot controls such as green roofs and downspout disconnection. These vegetative-based approaches can be further integrated into sub-regional catchment riparian corridors to achieve a minimum overall 30% - 40% canopy cover level to maximise evapotranspiration and infiltration processes (Ellis, 2010). It has been demonstrated that such urban BMP "greening" can be compatible with high development densities and achieved within a reduced urban footprint (Ellis et al., 2004; Jacobs and Lopez, 2009). However, successful implementation requires careful planning and stakeholder consultation as well as supporting costing and institutional arrangements. The convergence of sustainable stormwater and community quality-of-life objectives in high density developments can offer benefits of service/retail proximity, traffic controls,

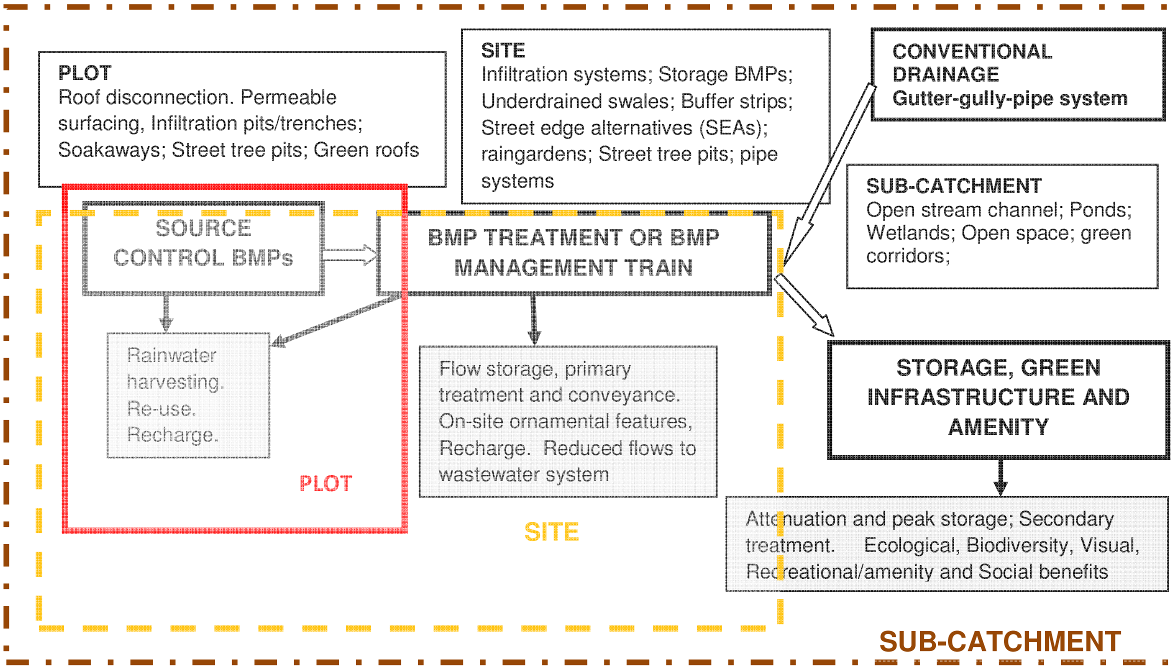


Figure 5. IUWCM landscape drainage design.

pedestrianisation and access to local "blue-green" facilities. A US EPA (2005) study concluded that higher densities contain less impermeable cover and generate less stormwater and contaminant loadings per dwelling/premise at all scales from plot to sub-catchment levels.

The evidence provided by an outline Level 1 UWC study will help to determine whether a SWMP is required in the first place to provide a strategic approach to surface water drainage, flood risk and pollution management as well as groundwater flooding. It also allows the regulatory agency to agree in principle that local development planning strategies are likely to be in compliance with legislative requirements. The options for potential multiple-use benefits of drainage best practice can be identified and the UWC study can take into account the likely impacts on spatial planning of future climate change with respect to surface flooding and pollution risks. The UWC framework therefore provides appropriate methodology and protocols for analysing the contribution of stormwater management strategies in meeting stakeholder needs and interests in other parts of the urban water cycle.

2.3 The Urban Water Cycle and "source" control

The management of stormwater runoff at the plot (or site) scale is frequently referred to as "source" control which aims to cost-effectively minimise the production of stormwater runoff and wastewater effluent (and contribute wherever possible to reducing water demand). As shown in Figure 6, the three principal components of the urban water cycle (water supply, stormwater and wastewater), intersect at the plot scale with domestic consumption and disposal. At this scale, mains water is consumed, wastewater is produced and stormwater runoff is generated. Stormwater source (plot/site) contributions can therefore be directly made to other sectors of the UWC through retention of roof rainwater (green roofs, rainwater

tanks), on-site infiltration and aquifer recharge, on-site treatment of greywater (bath/kitchen waters, laundry waters etc), and blackwater (toilet flushing), together with the application of water efficient appliances and practices. Such plot/site level applications could well offer the most beneficial and tractable opportunities for cross-sectoral allocations within the urban water cycle. There have been very few attempts to optimise the water cycle at the plot/site

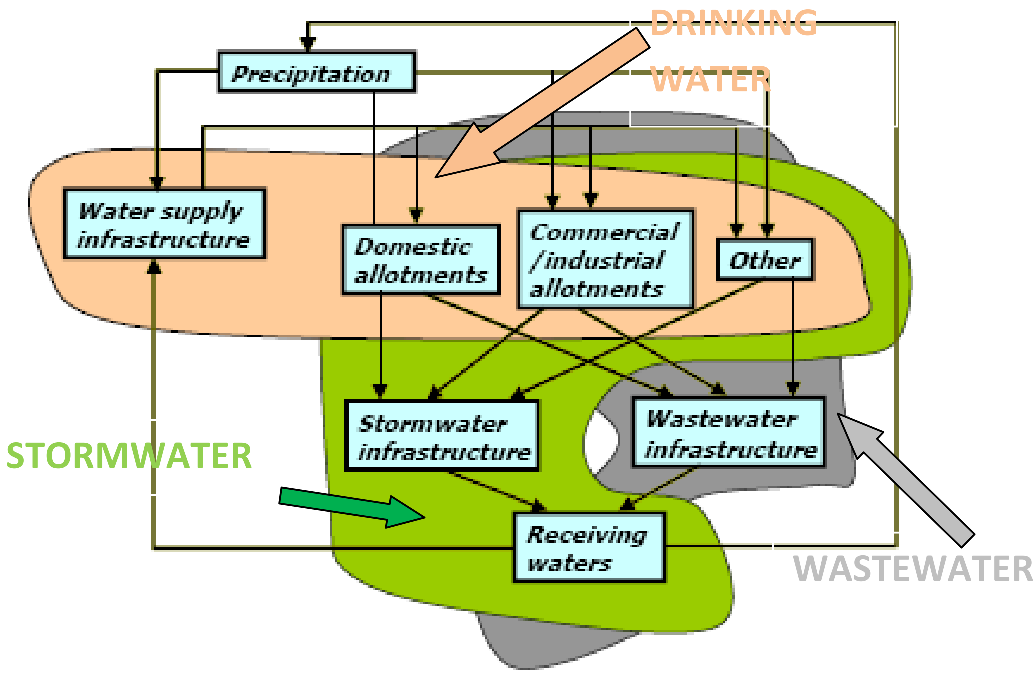


Figure 6. UWC sub-system spheres of influence.
[After: Kuczera and Coombes, 2002)

scale with the objective of minimising lifecycle costs through balancing water cycle service provision to household/commercial properties on a sustainable 50 to 100 year scale. Given the intersection of the three water cycle sub-systems at the plot scale shown in Figure 6, it is clear that any "source" control implementation will require the involvement of two or more sectors of the water industry (and associated regulatory agencies). These organisations are quite likely to have differing perspectives, policies and priorities as well as funding budgets, and thus the prospect for missed IUWM opportunities are abundantly clear even given the obvious performance benefits to be gained for cross-sectoral water distributions.

2.4 SWMPs and the Urban Water Cycle

A Surface Water Management Plan (SWMP) can be considered as an essential element in the strategic planning process for urban water infrastructure (Figure 7). SWMPs should carry a mandate for a partnership approach between the principal stakeholders which normally comprise at least local/state government, regulatory agencies, wastewater and water utilities. The initial SWMP outline is likely to follow a conventional source-pathway-receptor survey for the local government administrative area/district, but will need reference to the wider parent catchment region which will usually require collaboration and networking between

adjacent local authority/municipal districts as well as state/national regulatory agencies. However, the evidence and modelling outputs emerging from the outline Level 1 UWC study are likely to focus on critical drainage areas within the local administrative district(s) requiring further detailed risk assessment and mitigating solutions to be worked out in a more detailed Level 2 UWC study (Figure 7). In addition, the detailed Level 2 study should also address the uncertainties associated with the initial designation of moderate and low risk areas identified in the outline lower-level UWC study.

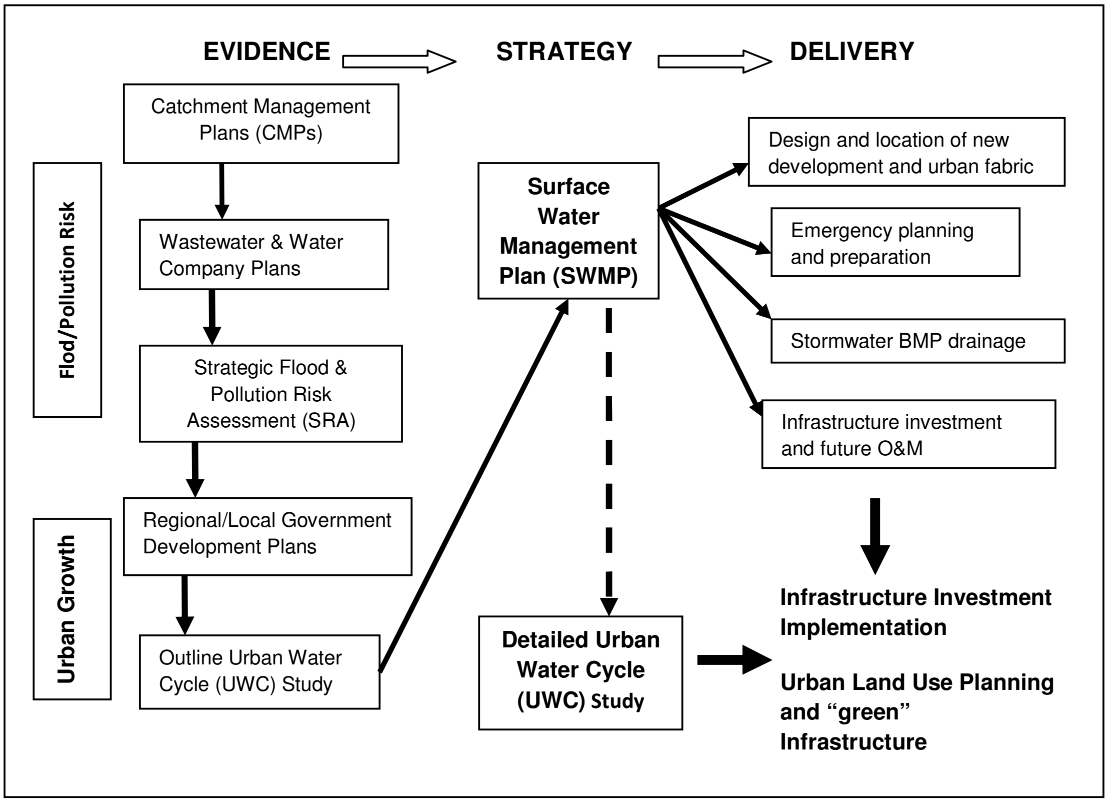


Figure 7. SWMPs and Urban Water Cycle studies.

SWMP production must involve existing organisational groupings and institutional arrangements as well as providing a clear structural framework which is consistent with other related methodological approaches such as CMPs, government project appraisal guidance etc. The framework should facilitate various stakeholder organisations to work together in compatible and reinforcing institutional arrangements in order to develop a shared understanding necessary to approve and implement appropriate drainage infrastructure solutions to address the identified risks. However, it is not for the SWMP to specify detailed requirements and mandatory options for site drainage, but to provide a framework of options and a set of standards for developers to work with and which are acceptable to the stakeholders. This may well incorporate conventional below-ground sewer assets with alternative BMP approaches to offer a hybrid solution for future drainage infrastructure.

Figure 8 illustrates the principal institutional and evidence phases that might be considered within the four key SWMP stages of plan preparation, risk assessment, mitigating options and implementation as contained in the UK Defra (2009a) SWMP technical guidance wheel chart

of these key elements. A successful SWMP should normally target for a 25 – 30 year planning horizon and take into account allowances for future climate change and urban growth. As indicated by Figure 7, the production of a SWMP must be linked to a variety of spatial planning, institutional investment planning and flood/pollution risk management procedures and organisational arrangements, many of which themselves will provide input to the SWMP procedure as well as being influenced by the outputs of the SWMP. Ideally SRAs for flood and pollution should be completed prior to the SWMP as part of the outline Level 1 UWC study and comprise key "trigger" indicators in the need for, and options identified by,

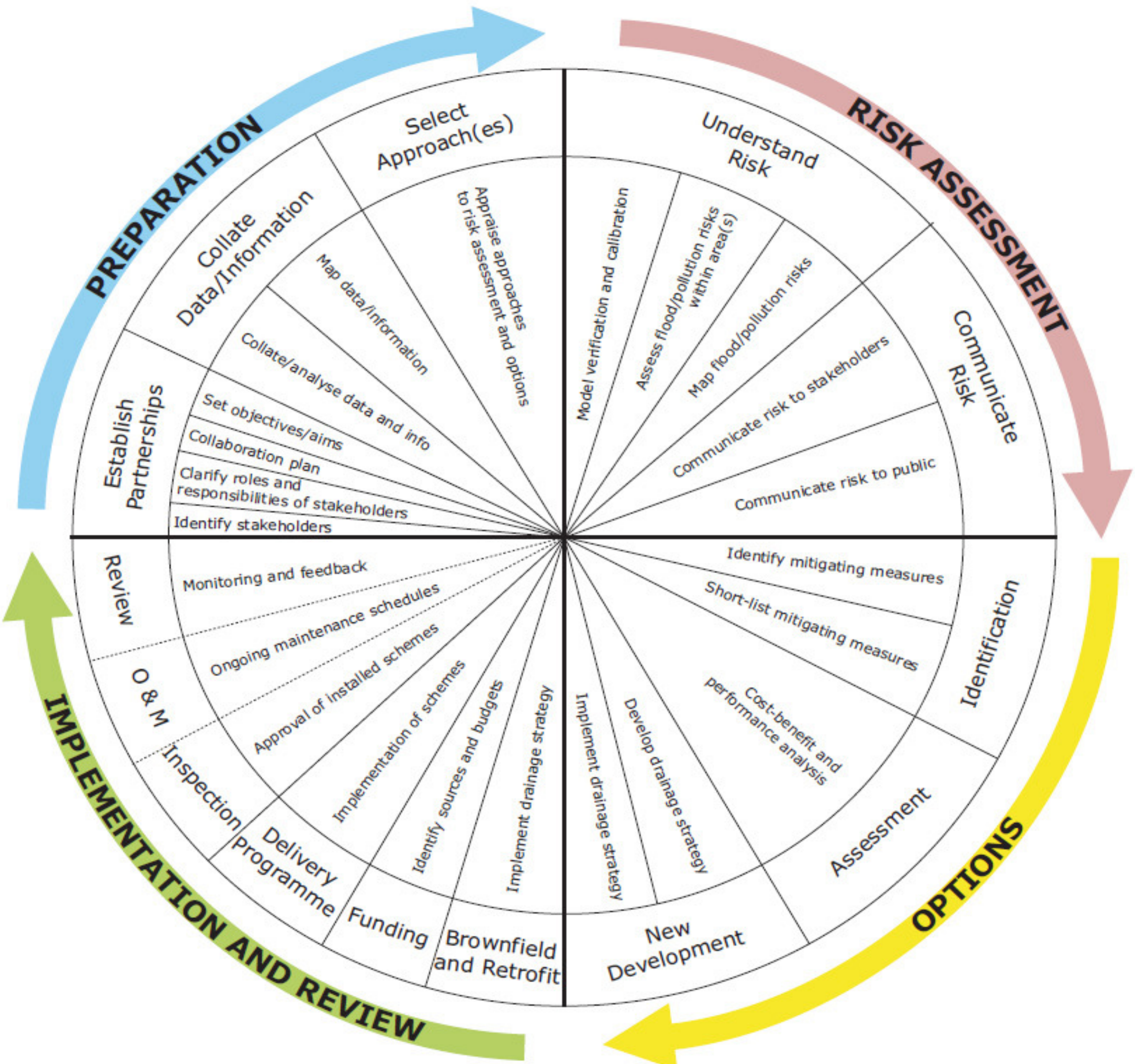


Figure 8. The production of a SWMP.
(After: Defra, 2009a)

the SWMP procedure. Clearly there must be a degree of interaction in the activities and data sharing between the surface water SRAs and the SWMP with the former informing the latter. Outputs from the SWMP may also be fed back into and better inform any Level 2 detailed UWC study. Following the publication by Defra (2009a) of the SWMP technical guidance document, six pilot studies were commenced in England which will follow the Defra

template. The Birmingham Water Group, chaired by Birmingham City Council has received the largest share (£300K) of this national pilot study funding.

Figure 9 shows how the activities and data sharing between the Level 1/2 SRAs can be related to the phases of the SWMP methodology. The Level 2 SRAs and the SWMP need to address two key questions in relation to stormwater flood and pollution risks:

- identify and define appropriate strategies to manage surface runoff from urban surfaces to control flood and water quality risks to collector drainage and/or downstream river systems and their ecological habitats
- identify and define appropriate strategies to manage and mitigate surface runoff generated from differing urban land uses within and immediately outside the development site, and particularly for extreme wet weather conditions.

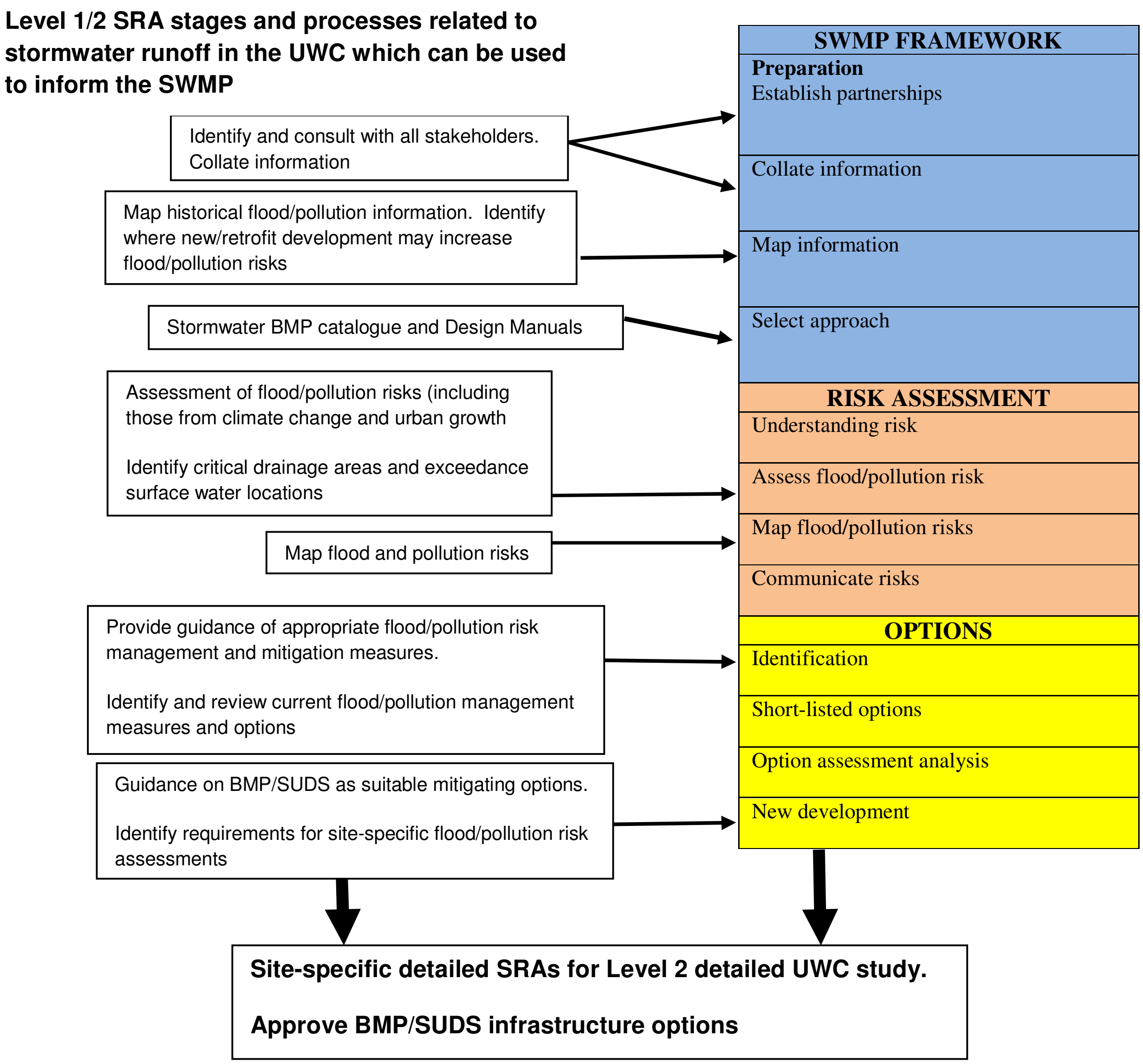
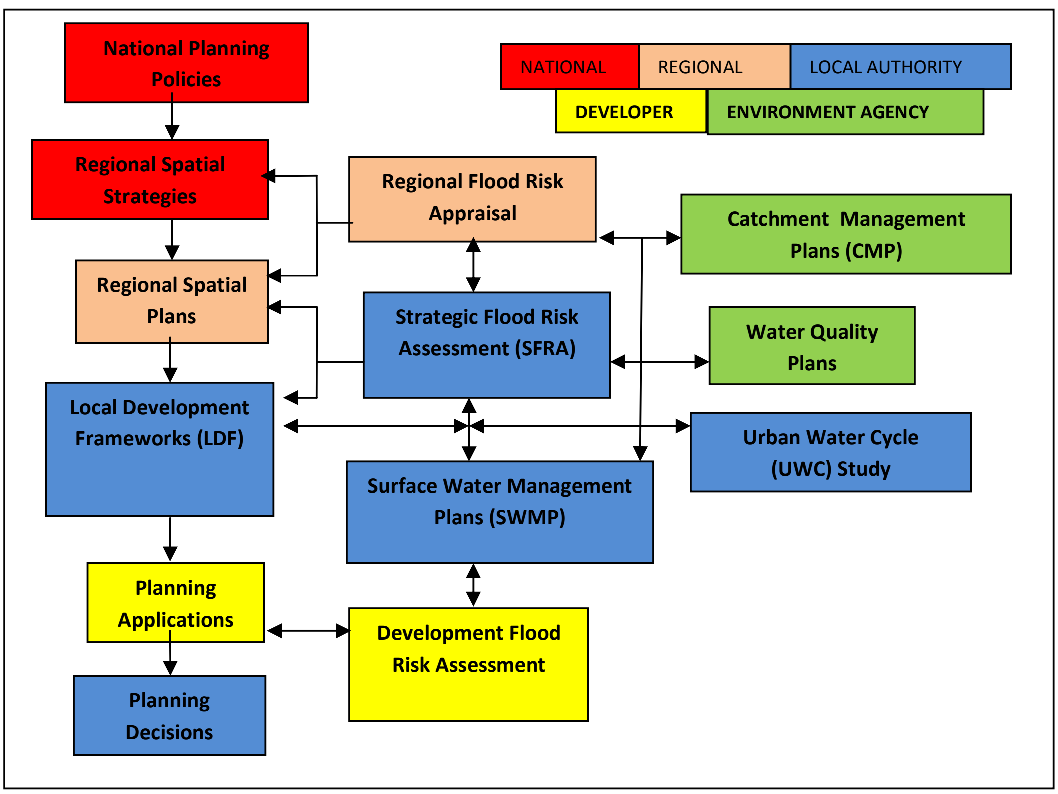


Figure 9. Relations between UWC study SRAs and SWMP processes.
(After: Defra, 2009a)

Gross storage (and/or infiltration) requirements for development runoff rates and volumes should match existing values for up to the 1:100 (1% probability, 6 hour duration storm rainfall event) with suitable uplifting e.g. + 10% to 20% for climate change. Minor drainage systems such as swales, infiltration trenches, soakaways, sewer pipes etc., should be designed to convey (and treat) flow up to the 1:30 event. It is UK Environment Agency policy that site discharge can occur at rates of 2 l/s/hectare beyond the 1: 100 design level, and SWMP partnerships are required to agree on this set of standards to size BMP facilities although these standards may vary nationally across Europe as well as further overseas. The persistent recurrence of serious pluvial flooding in UK urban areas over the period 2006 – 2009 is calling into question these design standards, with suggestions that the upper catchment-scale flow rates and volumes should be more realistically aimed at containment of the 1:1000 storm event. Whilst this might be feasible for strategic coastal flood protection, it is questionable as to whether such a high return period standard could be cost-effectively adopted for general urban pluvial flood protection.

There are clearly close and overlapping relationships between planning policy and flood/pollution risks which arise from co-consideration of national, regional and local policy guidance and objectives for surface water drainage provision and management. Figure 10 identifies the key documents guiding the spatial planning process in the UK and their links with key flood/water quality risk strategies. There is clearly a mix of national, regional and



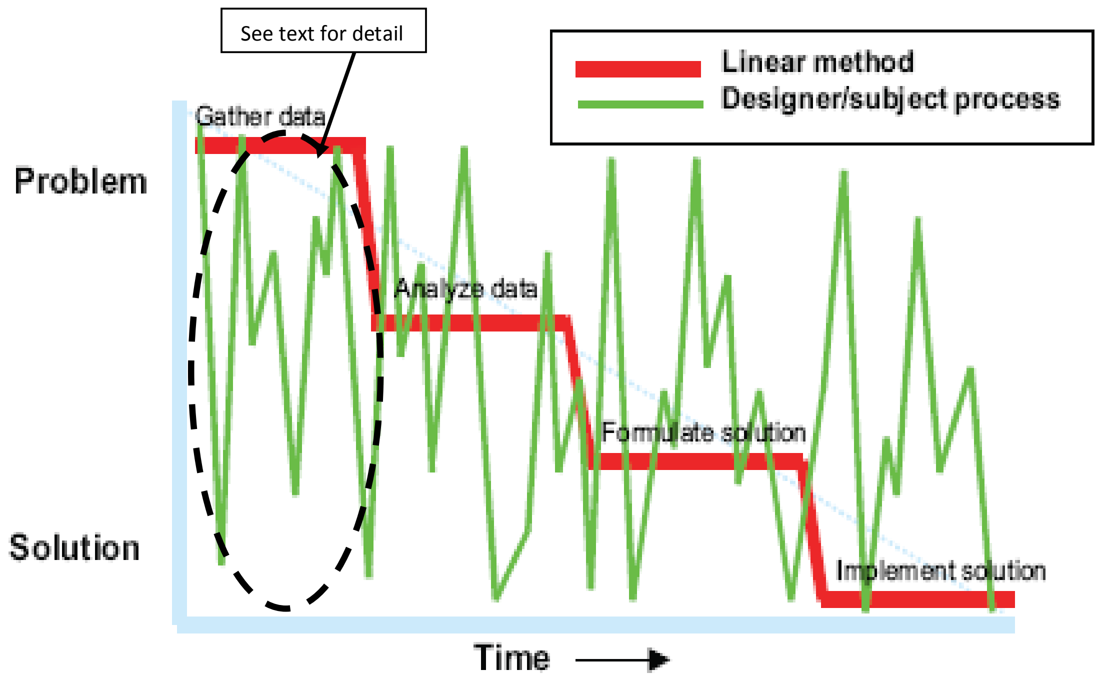
[After: Defra and EA, 2005]

Figure 10. Planning and Flood Risk Strategy documents at national, regional and local levels.

local government guidance involved in the planning and flood management process which adds considerable complexity to decision-making requiring stakeholders such as developers to "read-across", to interpret, and then to apply the hierarchical guidance. It is not surprising that incompatibilities can arise as a result of differing functional interpretations and administrative perspectives of roles and objectives. However, there should be a continuum in strategic planning for urban drainage infrastructure between the various policies/plans shown down the left hand side of Figure 10 which connect and integrate stormwater management approaches from national, regional to local level. In this way, water planning will be coherently integrated into the land planning process such that there will be logical links between strategic plan making, development assessment and on-site infrastructure provision.

2.5 Stormwater management as a "wicked" problem

A "wicked" problem is one for which each attempt to identify and develop a solution, changes the nature and understanding of the problem. Such problems cannot be readily resolved in the traditional linear fashion as indicated by the line (identified as 'linear method') in Figure 11, because the problem definition evolves as new possible solutions are considered and/or implemented. The traditional rigid, semi-autonomous structure of local government and regulatory agencies, based on hierarchical and beaurocratic systems, normally follow this linear "waterfall" decision-making path, and their administrative, budgetary and institutional structures inhibit their ability to deal effectively with such wicked problems.



[After: Conklin, 2005]

Figure 11. The cognitive pattern in resolving a wicked problem.

The majority of "wicked" problems occur in a social and institutional context where the problem reflects a diversity in responsibilities, opinions, expertise and expectations in the various stakeholders involved in the problem. The stakeholders bring multiple and often conflicting interests and solutions, which can create problems for others, and there are no rules for determining when the problem(s) can be said to be resolved. It is frequently the social/institutional complexity rather than technical complexity that inhibits progress in resolving and progressing surface water management approaches. The stormwater management problem is often perceived as being ill-structured in terms of clear lines of legal and management responsibilities and consists of a set of interlocking legal, technical, administrative and social issues and constraints. Solutions and approaches are not necessarily right or wrong, but simply "better", "not good enough" or "worse". An important characteristic of wicked problems is that stakeholders often consider themselves to be separated by a cognitive "lock-in" perspective rather than being united in a situation for which often information and knowledge is scattered and technical in nature. In addition, it is difficult to learn more about the problem without trying out or having evidence of working solutions. However, every solution is expensive and will have lasting unintended consequences which are quite likely to spawn new "wicked" problems e.g. the emergence of an ecologically sensitive site on an original flood storage pond.

Wicked problems require approaches and tools which create a shared understanding and commitment and in a social/institutional context, what has been termed as "dialogue mapping" has been developed as an issue-based information approach to deal with the fragmentation associated with wicked problems (Conklin, 2005). Understanding and accepting solutions to a wicked problem are essentially about collectively making sense of the situation and coming to a shared understanding about who wants what and why. The issue of institutional capacity and the decision-making process to facilitate interventions in urban drainage infrastructure has already been highlighted and discussed in a previous SWITCH deliverable (Ellis *et al*., 2010). An early SWITCH briefing Note on the Learning Alliances also commented on the nature of stakeholder communication as constituting a "wicked" problem (Morris, 2006).

Dialogue mapping, the process of interactively crafting issue-based information maps and work flow charts, provides a structured approach to group communication which de-emphases personal dynamics in favour of a coherent shared group understanding. Such group dialogue will be subject to considerable changes in direction as individual disciplinary and/or personal contributions impact on the problem and evolving solutions, as indicated by the jagged green line in Figure 11. These variations reflect the knowledge and/or opportunity driven process between problem and solution spaces as the cognitive group understanding of the problem and emerging solutions becomes mutually shared. Figure 12 illustrates how the first data-gathering loop of the process framework (see dashed line in Figure 11), of a wicked stormwater problem might be impacted by different stakeholder contributions. Some contributions such as that delineated by path 2 might turn out to be a "blind alley" and taken out of further consideration by the steering group. In other instances, the socio-cultural group might develop objectives for water quality and sustainable urban development goals (labelled paths 3 and 4), that link into technical approaches and solutions acceptable to responsible water resource managers and regulatory authorities (path 1). In this way, a coherent and integrated solution can be formulated (labelled path 5).

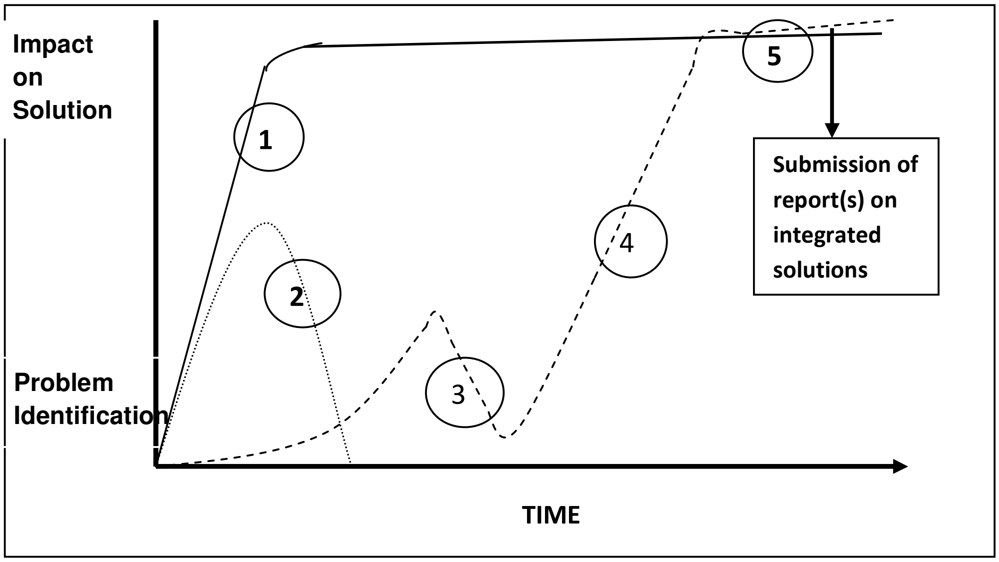


Figure 12. Impact of stakeholder contributions on the first loop solution to a wicked problem.

The UWC study needs to recognise that urban stormwater management represents a "wicked" problem which requires the adoption of the principles of shared stakeholder communication in order to be addressed satisfactorily. To date the large majority of the 39 local authority UWC studies conducted in England have been commissioned out to consultant groups and have only partially recognised the nature of the "wickedness" of the stormwater management problem. The scoping brief of an UWC study should therefore acknowledge the issue of inherent diverse and conflicting stakeholder interests and utilise a supporting dialogue mapping process to develop coherent, integrated solutions and management approaches.

3. UNDERTAKING AN URBAN WATER CYCLE (UWC) STUDY

3.1 Carrying out an Urban Water Cycle (UWC) study

An UWC study normally covers the two survey stages of outline and detailed studies followed by an implementation (and review) stage (Figure 13). The lower Level 1 study risk

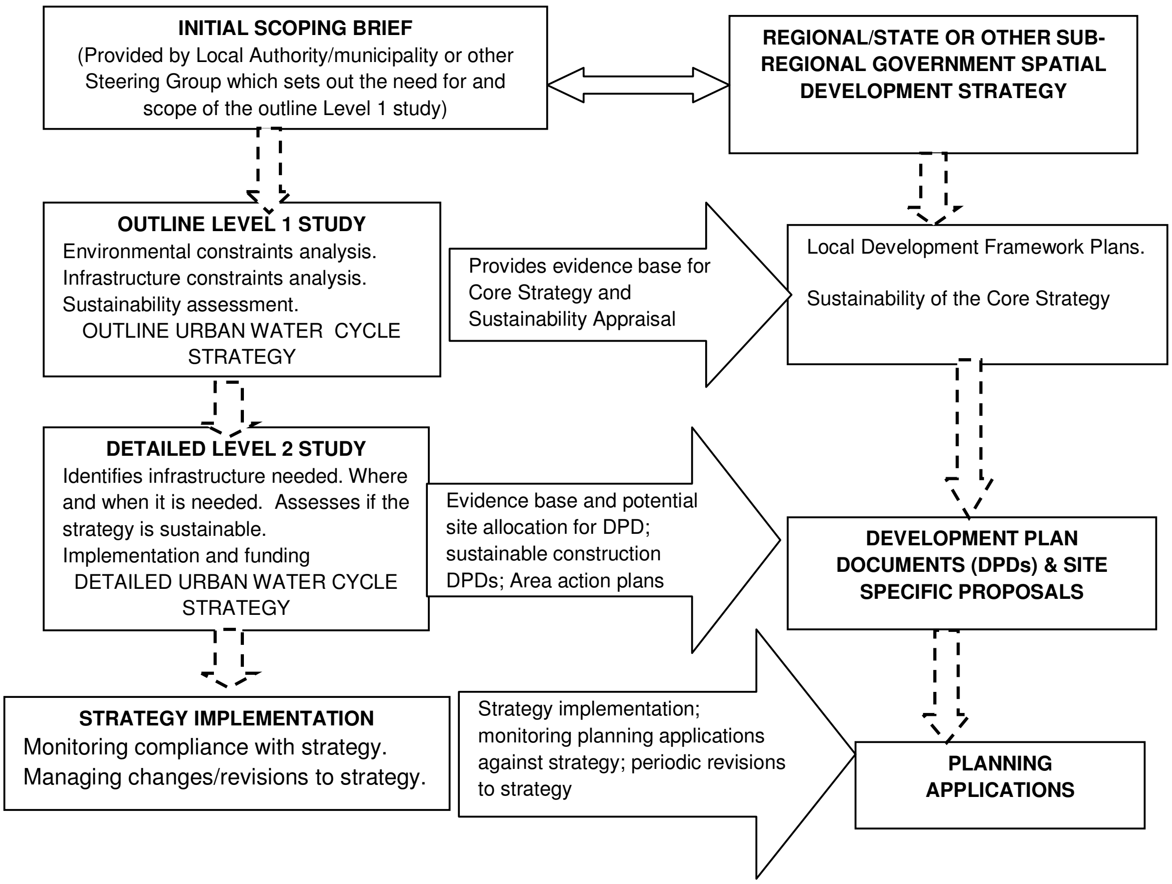


Figure 13. Stages in an Urban Water Cycle (UWC) study.

assessment should provide a strategic scoping of the nature and extent of flood and pollution potential (particularly for zones of high risk likelihood), and their implications for the Local Development Framework (LDF) plan. The main purpose and thrust of the upper Level 2 risk assessment would be to address the identification, quantification and mitigation of uncertainties associated with the flood and pollution risks in zones/areas carrying average to minimum risks as judged by the lower Level 1 analysis. However, it may not be necessary to undertake all three stages as sufficient preliminary risk assessment and other supporting planning evidence, provided perhaps from a SWMP, may already be available to proceed directly to a detailed Level 2 UWC study, and the timing of the various stages may need to be altered to fit in with local circumstances. The UWC approach is context rather than system-oriented and is an adaptive rather than optimisation approach, with the emphasis being on process, uncertainties and identification of a range of potential mitigating solutions. A major part of both outline and detailed Level 1/2 studies are concerned with the identification, collation and sharing of relevant data and information, which may be a source of stakeholder

tension where sensitive commercial data is involved (Fletcher and Deletic; 2007; Ellis and Revitt, 2010). It is also important that stakeholders recognise the various constraints that may apply to the identification of technically feasible solutions.

The rational choice of risk mitigating options frequently requires acceptance of trade-offs between competing or conflicting objectives as indicated in Figure 14. The light grey region in the figure represents the performance outcomes of a feasible solution that can provide water cycle services to meet required standards at acceptable lifetime costs. The Pareto

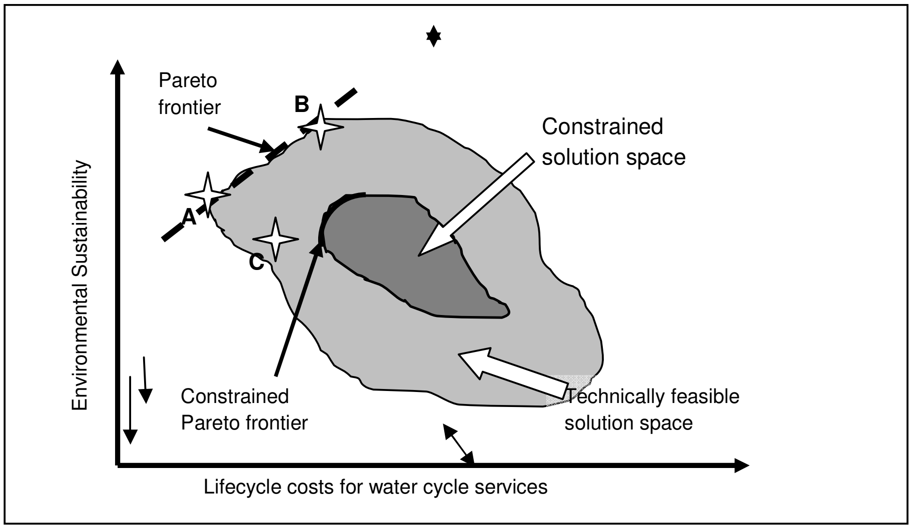


Figure 14. Conceptualisation of risk mitigating option constraints.

frontier describes the solutions that stakeholders need to examine to arrive at preferable sustainable decisions; solutions lying outside the Pareto frontier are unambiguously inferior e.g. solution B is inferior to A and A is also preferable to C. Stakeholders must examine the trade-offs between the different solutions (e.g. A, B and C) and in so doing implicitly value sustainability, in this case in terms of monetary value. The dark grey region of Figure 14 represents a sub-set of constrained solutions which might arise from institutional issues and constraints that limit or even prohibit implementation of certain feasible solutions. The price paid for artificially constraining the solution space can be considered with solution C, for example, as this produces much lower lifecycle costs and a more sustainable outcome than any solution that lies within the constrained space. Removing "artificial" constraints such as institutional barriers will therefore provide more beneficial and sustainable community outputs.

3.2 A working brief for an Urban Water Cycle strategy

A water cycle strategy (WCS) study is a partnership project to integrate urban development and associated regeneration within the context of identified water resource and related environmental constraints and future water services infrastructure planning as a basis for achieving a more sustainable urban development outcome. An urban water cycle study therefore should produce a coordinated approach to strategic spatial plan-making by

holistically addressing the issues of water supply, water quality, wastewater collection and disposal and flood risks in both the built-up area and receiving waterbodies, and at the same time ensuring that infrastructure is provided in a timely manner. In particular, a key consideration should be whether there are sufficient water resources to serve the proposed development under any Regional Spatial Strategy. However, the WCS study should plan to site new and retrofit drainage controls so as to maximise the potential of the existing infrastructure and minimise the need for new/improved infrastructure. Such urban development and growth should be contained within the predicted environmental capacity and anticipated regulatory limits and take account of future climate change. It is within this general WCS framework that a template for the provision and operation of surface water drainage infrastructure should be considered. It is therefore difficult to isolate and independently consider surface water management from other water components of the urban water cycle when developing a water cycle strategy (WCS).

A strategic approach to urban development is now a requirement of UK government Regional Spatial Strategies and Sub-Regional Strategies. Policy is directing local authorities to provide a firm evidence base and the WCS study should therefore provide an important input into the local development planning process such as the Local Development Frameworks (LDFs) that all UK local authorities/municipalities are currently required to undertake. In addition, it should inform the wider regional strategic planning process through the provision of evidence that the environmental capacity will not be breached and that the necessary infrastructure can be delivered in time. The effect of development on the water environment is a key element in sustainability appraisal and, as a consequence, also of the Strategic Environmental Assessment (SEA) contained in the LDF core strategic process.

The brief for a water cycle strategy (WCS) study should contain the following elements:

- the background and context to the reasons why a water cycle strategy is required together with the prevailing legal and planning framework.
- the scope of the WCS and the key outputs and deliverables required from the water cycle strategy study.
- suggested information and data sources as well as the skills required to undertake the WCS study should be stated. Lead and key partners to the WCS study should also be identified together with any project steering review group.
- any particular issues that the WCS needs to address in more detail in terms of further study, analysis and consultation. This will comprise the core of the Outline Level I Initial Scoping Study as identified in Figure 10.
- a summary and recommendations of the inputs necessary to progress the water cycle strategy to the detailed Level II study.

It must be appreciated that surface water drainage comprises only one element of the overall WCS study, albeit an essential and significant component. However, it is important that in any WCS study, reference should be made to the need to ensure that surface water drainage is considered as a potential resource within the strategic scoping study and consideration should be given as to how this resource might contribute to other parts of the urban water cycle.

4 STORMWATER WITHIN AN URBAN WATER CYCLE STRATEGY FOR BIRMINGHAM EASTSIDE

4.1 Background and context of Birmingham Eastside

The Eastside development area represents a major urban regeneration initiative within the centre of Birmingham and covers an area of 170 hectares (www.sustainable-eastside.net). It is located in the heart of the city centre lying immediately to the east of the central business district. Figure 15 shows the boundaries of the proposed Eastside development with the River Rea running in a north easterly direction across the development area to join the River Tame near Junction 6 of the M6 motorway. The river has a number of culverted and bridged sections and also passes beneath the Warwick & Birmingham Canal. It lies in a flood plain having fairly steep side slopes to the north west and south east. The side slopes and flood plain have been extensively developed and the prevailing historical land use is shown in Figure 16. The buildings marked in white represent a mix of industrial/commercial premises, offices, warehouses, loading yards as well as service, access roads and car parks. A draft outline planning perspective, primarily focussing on transport and movement (*Eastside: Design and Movement Framework*) was published in September 2003 as a Supplementary Planning Guidance document (SPG 55).

The south-eastern section of the Eastside development area is characterised by the intense nature of the built-up area although much of the development has become derelict over time with some land parcels having already been cleared under compulsory purchase order in preparation for future development. However, the intensity of the built-up area means that there is a high impermeable surface area which generates large volumes of surface water runoff having very short times of concentration. The outcome of this is that the receiving River Rae channel as well as the local highway network, has been subject to severe overland flow flooding incidents in the historic past. Figure 17 illustrates the surface water drainage which discharges either directly to the Rae or enters the combined sewer system. As described in a previous deliverable (Ellis *et al*., 2008b), flows within the River Rea are restricted by a highly over-designed (>1:80 RI) channel which minimises overbank fluvial discharges from upstream. However, the high impervious cover, steep slopes and low hydraulic capacities of the small diameter surface water sewers (usually less than 160 mm), mean that large volumes of overland flow are generated during wet weather conditions leading to intense, localised pluvial flooding over the urban surface. Surcharging of the separate sewers in the development area is known to occur with storms exceeding the 1:5 RI event (Groundwork Birmingham & Solihull, 2007). Current work within SWITCH Theme 2 is focussing on the development and application of a coupled 1D/2D modelling approach to identify and quantify extreme event surface water flood depths and pathways for the 4.5 ha sub-catchment of the development area indicated by the dashed lines on Figure 17 (Viavattene *et al*., 2009). This modelling approach will support a risk-based assessment of flood potential as required under the SWMP guidelines as well as quantify the stormwater storage/attenuation volumes that need to be managed (and re-distributed) within an urban water cycle strategy.

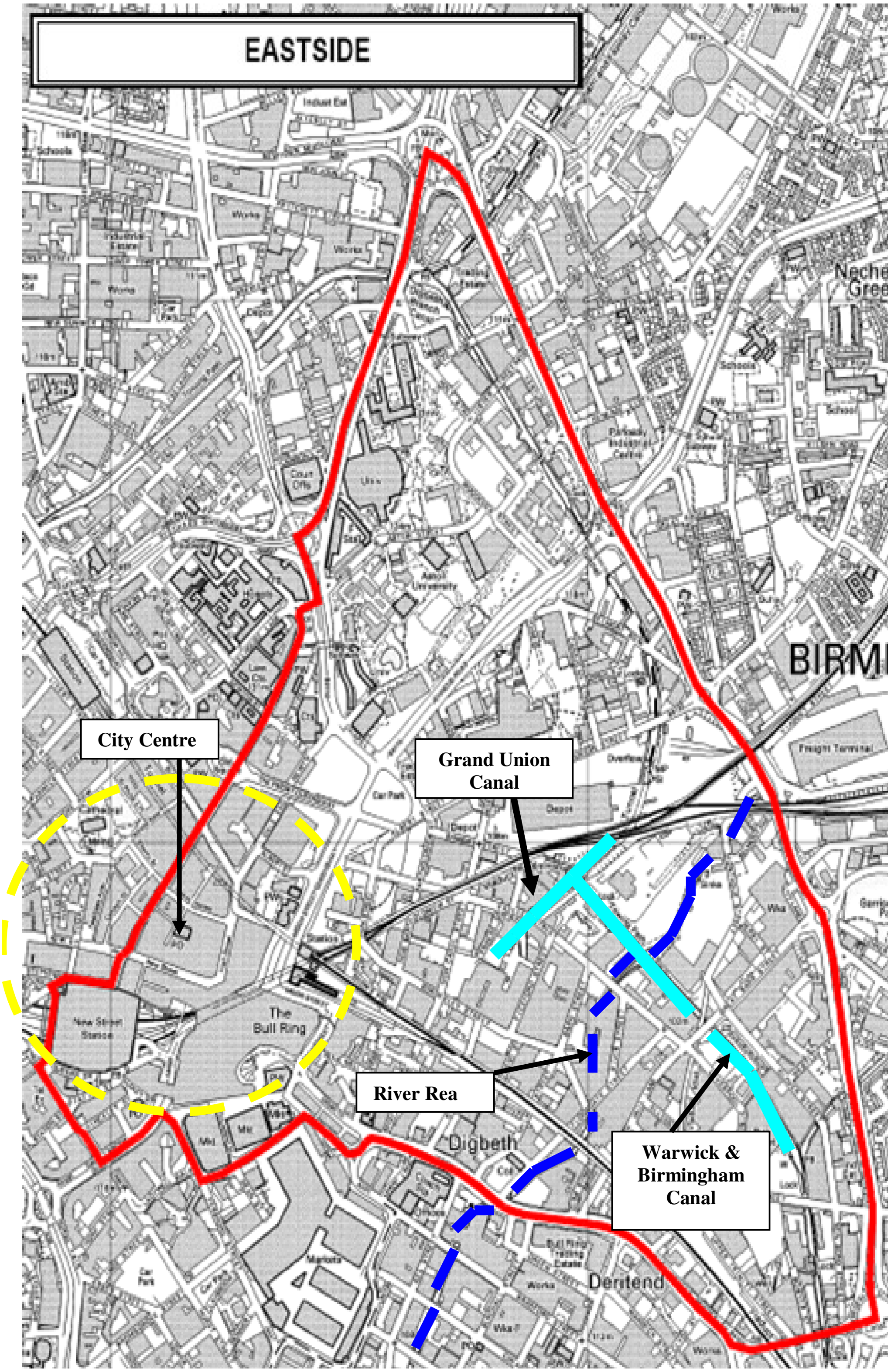


Figure 15. Birmingham Eastside development area.

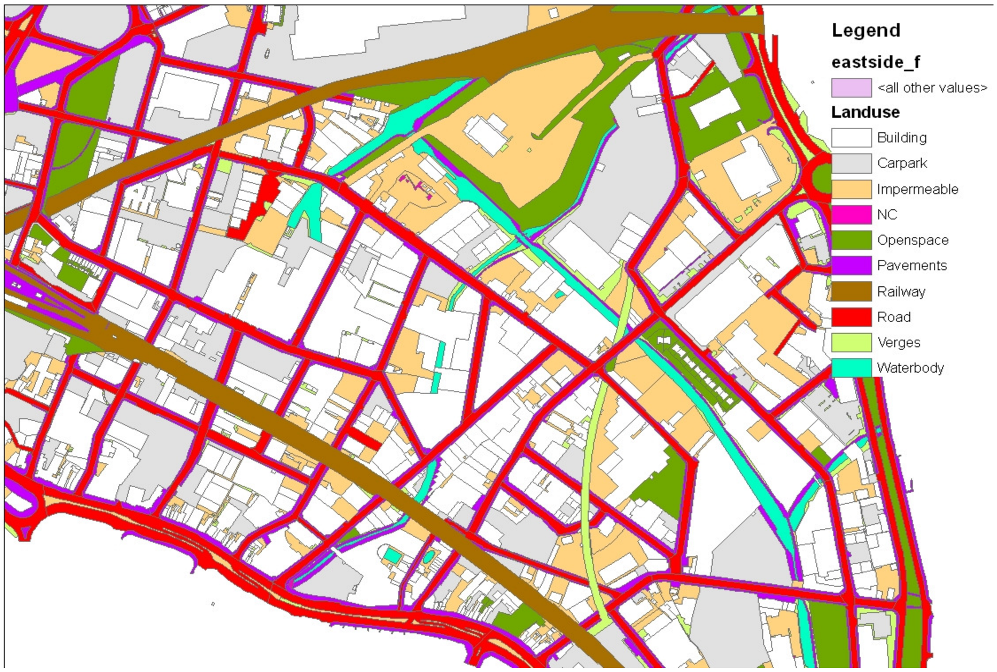


Figure 16. Historic land uses in Birmingham Eastside.

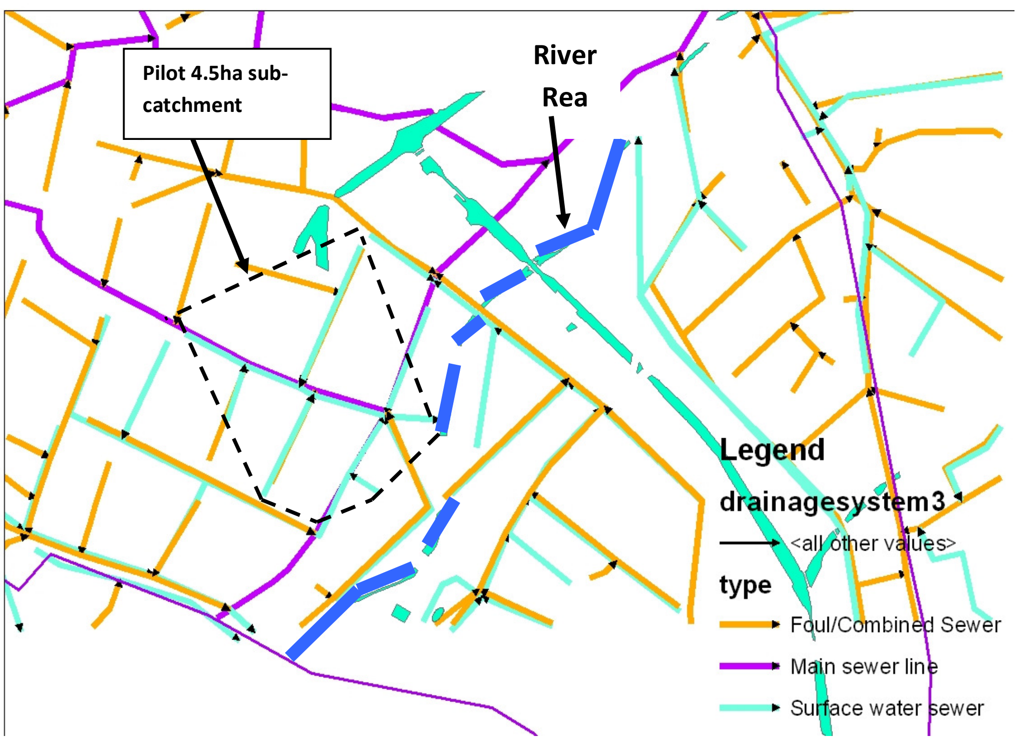


Figure 17. Surface water and foul drainage in Eastside.

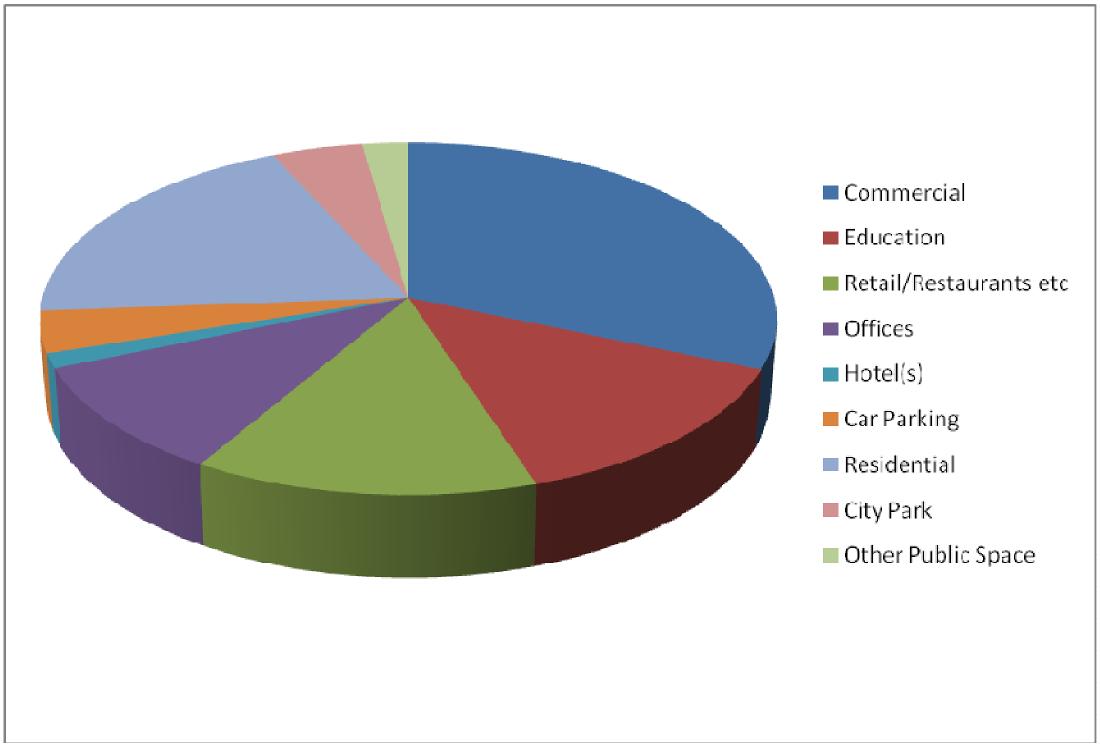


Figure 18. Proposed land use activities for Birmingham Eastside

The Eastside initiative intends to promote a new city quarter based on the themes of learning, technology and industrial heritage creating up to 12,000 new jobs during the lifetime of the initiative (www.birmingham.gov.uk/eastside). In addition, it will accommodate 3500 new dwellings as well as a range of business premises, a 3.2 ha city park and other public open spaces; detail of the proposed allocation of urban activities within the development area is given in Figure 18. This figure illustrates that highly impermeable landuse types such as commercial, office, education and retail activities dominate the development profile. Whilst such building types can present a highly impermeable coverage, they also offer considerable potential for green roofs, roof disconnection and associated infiltration systems as well as stormwater recycling schemes.

Figure 19 shows an overall perspective of the proposed 16 separate landuse development parcels planned within the Eastside area, with the major City Park shown in dark green lying to the north of the Curzon Park/Gateway developments above the east-west railway line into Birmingham New Street station. The discrete nature of these separate development parcels and their staged delivery mitigates against an integrated, holistic drainage infrastructure planning approach and there is no overall Eastside Planning Committee within the local administrative structure to provide oversight and guidance of the individual design schemes. The regeneration scheme is essentially being coordinated by the City Centre Development Team who comprise a sub-group of Birmingham City Council's Development Directorate Planning Service. A previous SWITCH deliverable has highlighted the difficulties and deficiencies associated with the decision-making processes and administrative structures for stormwater management in the UK (Ellis *et al.*, 2010). Governance mechanisms in the

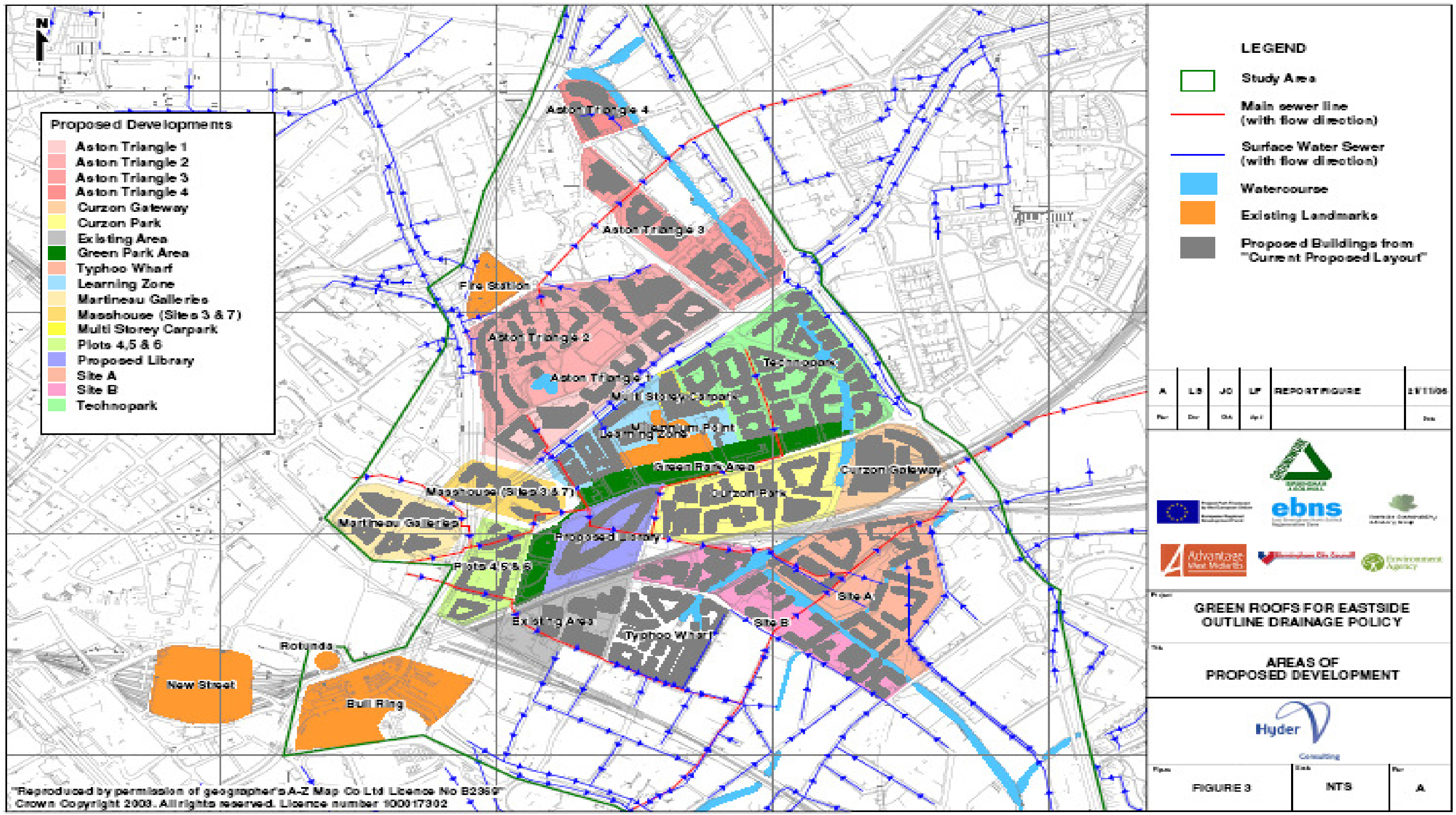


Figure 19. Proposed Developments Within the Eastside Regeneration Area.

planning process comprise a major barrier at the local municipal level to the achievement of strategic integrated implementation of drainage infrastructure (Ellis and Revitt, 2010).

Figure 19 also shows both the main surface water (blue) and foul water (red) sewer systems within the development area. In this south-eastern section of the Eastside development area lying below the railway line, the separate surface water sewers are principally directed to outfalls into the River Rea as confirmed in Figure 17. The only controls on this surface drainage system are flap valves located on the outfalls into the river channel, which being located near to the base of the channel wall, shut at the initiation of "rise" conditions in the river flow. This induces rapid filling of the small diameter surface water pipes by overland flow during storm events and consequent surcharging of the system onto and over the urban surface. The infrequency (or even lack) of gully chamber cleaning further exacerbates overland flows as the roadside gullies are often blocked with grit and debris.

4.2 Main stormwater concerns of an Eastside UWC study

Outline planning permission has been granted for the various mixed land use development parcels of Birmingham Eastside shown in Figure 19 and some initial site clearance phases of the development have already taken place. The £2.7 billion investment in this urban regeneration programme is being driven by Birmingham City Council who have prime responsibility for local highway and surface water drainage. Severn Trent Water holds prime responsibility for wastewater collection and conveyance, with additional core responsibilities for aspects of surface water drainage. The Environment Agency (EA) currently have responsibility for the regulation of surface water drainage in respect of pluvial overland flooding, although it is intended to pass this responsibility and associated duties to the local authority on passage of the forthcoming Floods and Water Management Bill by the UK government. The EA also hold full responsibilities for receiving water quality in respect of both surface and groundwaters.

The primary concerns for surface water drainage infrastructure provision across Eastside include:

- water demand and usage rates and the capacity to meet requirements
- the need for on-site attenuation, storage and/or infiltration facilities especially in respect of overland flows associated with extreme storm events
- the need to maintain and/or extend the drainage infrastructure, including retrofitting, where appropriate
- the timetable for staged and integrated planning and delivery of drainage infrastructure controls
- the operational reliability and sustainability of the drainage network resources being delivered.

Stage 1 of the UWC study should essentially be a desktop study exercise drawing on existing technical work and strategic planning documentation provided by the local authorities and their statutory partners, identifying the constraints to and opportunities for future development growth. In addition, this desktop study should take cognisance of strategic regional and national guidelines for drainage infrastructure controls and management. The Stage 1 outline scoping study might consider alternative strategic options within the context of the identified constraints as illustrated in the colour-coded Table 1 matrix. This matrix

approach enables the identification of relative degrees of difficulty and constraints in providing adequate water related services and infrastructure to the development area. The initial Stage 1 scoping study will include the collation and analysis of available data, consideration of baseline conditions, identification of stakeholder partners and potential strategic options as well as guidance on areas/aspects for further consideration in Phase 2 in order to inform decisions on particular development parcels.

Table 1. Development constraint matrix

Water Resources		Wastewater		Surface Water Drainage and Pluvial Flood Risk	Fluvial Flood Risk		
Water Resource Availability	Water Supply Network	Sewer Network	Sewage Treatment Works (STW)		FZ1	FZ2	FZ3
Water resource available to meet planned developments	Existing network available with spare capacity	Existing sewer network can accommodate the proposed developments	Existing STW flow headroom can accommodate the proposed developments and there are no compliance issues	Low risk of flooding within sites or downstream	Flood Zone 1; Low probability of annual exceedance (<0.1%; <1:100)		
Water resource available but may need new source(s) to meet developments	Existing network available with no spare capacity	Existing sewer network may need to be upgraded	Existing STW flow headroom can accommodate the proposed developments but there are compliance issues	Medium risk of flooding within sites or downstream	Flood Zone 2; Medium probability of annual exceedance (1% - 0.1%; 1:100 – 1:1000)		
Exisrting resources not adequate to meet developments	No existing sewer network available to serve the specific development parcel(s)	Existing sewer network cannot accommodate the proposed developments	Existing STW flow headroom cannot accommodate the proposed developments	High risk of flooding on development site(s) or downstream	Flood Zone 3; High probability of annual esceedance (>1%; >1:1000)		

Building on the outcomes and findings of the Stage 1 study, a more detailed Stage 2 strategic analysis should involve further technical studies of specific issues and uncertainties in conjunction with the Local Development Framework (LDF) planning process to ensure integrated and timely delivery and management of water services and associated infrastructure to provide more efficient and sustainable future approaches.

4.3 Water demand and usage in Birmingham Eastside

No forward planning for water management at a local area/district level has been undertaken for Birmingham Eastside and Severn Trent Water consider current practice to be sufficient to ensure water supply and wastewater disposal for at least the next 10 – 15 years. Thus no work is available which explores whether on-site water supply and water re-use can be applied to offset any increases in future demand.

However, a first-order inventory and benchmarking of stormwater and wastewater generation within the Eastside development area has been undertaken by Coyne *et al*. (2008) which can be used as a baseline study. This analysis was based on a 1:2 year return interval (RI) storm event, for which an effective runoff rate (with instantaneous peak discharge) of 26.4 mm/hour was derived by reference to local rainfall records. However, it should be noted that a 5mm rainfall event in April 2000 produced a peak intensity of 113 mm/hour, although the storm only occurred over a relatively short period of time. Thus a five-fold reduction in the intensity has been applied in the modelling analysis by Coyne *et al* (2008). The modelling assumes that this storm design threshold meets the Environment Agency regulatory requirements that no surface flooding equivalent to the 1:30 RI storm event results from the predicted outflows. The analysis also assumed a 0.9 runoff coefficient for all the development parcels, with the exception of the Green Park development parcel for which a value of 0.4 was assigned. Maximum flows in the combined sewer system (with peak sewer flow rates limited to 2 m/s) were assumed to arrive simultaneously at sewer node points and a climate change addition of 20% - 30%, as well as an 80% limitation to runoff from each development parcel, were applied in the analysis. These requirements serve to add to the amount of local attenuation (and/or storage) that would be necessary for outflows generated at each site.

Table 2 shows the peak water usage rates for each of the development parcels shown in Figure 19 together with their predicted peak wastewater flows for the modelled 1:2 year RI storm event. Table 3 shows the predicted peak flows at various nodal points in the surface water sewer network and the likelihood of surcharging for the same storm event. Note that contributing areas 16 and 17 (Aston University and Aston Science Park) have been excluded from the analysis as their surface water discharges are conveyed to the north away from the remainder of the Eastside developments. The calculations are based on benchmarked service consumption rates of 125 l/hd/day for residential use and between 1.6 – 2.4 l/m^2/day as best practise for commercial, retail, and office premises. Per capita wastewater is estimated at between 90% (123 l/hd/day) to 95% (148 l/hd/day) of water supply. The table suggests therefore that the average water demand for the new developments will be some 20% less than the national average of 150 l/day (Defra, 2008a), reflecting an assumed implementation of water saving devices to WC and washbasin appliances.

The data in Table 3 do not make any allowances for in-pipe turbulent loss effects due to steep gradients and the impact of highway/road runoff on the surface water sewer system is also not included; flows from this latter source would substantially increase in-pipe discharges and initiate surcharging at much lower levels than indicated in the tables. Even ignoring the potential effects of highway discharges, the analysis demonstrates that at least six nodes on the surface water system would probably surcharge as a result of inadequate hydraulic capacity, and for what can be regarded as a relatively high frequency storm event.

A separate modelling analysis for the pilot 4.5 ha sub-catchment of the Eastside development area shown in Figure 17 has been undertaken for the low frequency, high magnitude (<1:80 RI) storm event which occurred on 13/14 June 2007. This event generated a total of 35 mm rainfall over a 10 hour period with a maximum intensity of 36 mm/hour and produced a peak outflow of 568 m^3/hour for the surface water system (Viavattene *et al*., 2010). The small diameter sewer network in this sub-catchment has a maximum hydraulic capacity of 0.2 m^3/s which is considerably less than indicated for the sewer network shown in Table 3. This tabled data is based on information supplied by the developers who may well be overestimating some of the pipe capacities for individual sites. Irrespective of these

Table 2. Summary of peak flow data for Eastside water services.

Development Parcel	Contributing Area (m^2)	Peak (Average) Water Demand (l/s)	Peak Wastewater Discharge (l/s)
1 City Park	42900	22.0	50
2 Curzon Park	40470	32.5 (5.8)	314
3 Curzon Gateway	16200	6.0 (2.1)	120
4 VTP200			
5 BCU	14164		105
6 Ventureast	52609	58.0 (4.5)	401
7 Masshouse	62483	(3.8)	462
8 Martineau Galleries	54997	(2.5)	407
9 City Park Gate	18939	(6.2)	140
10 Millenium Point	48562	1.4	360
11 Multi-storey Carpark	8462	Negligble	63
12 Warwick Bar	18600	10.0 (1.0)	104
13 Devonshire House			
14 Typhoo Wharf	37400	(1.1)	277
15 UB40	3965	(0.5)	29
16 Aston Science Park	89030	(3.0)	659
17 Aston University	254450	(3.5)	
TOTAL	**77 (ha)**	**~106**	**3491**

[After: Coyne *et al*., 2008]

Table 3. Peak flows in the Eastside surface water sewer system

Sewer Node	Contributing Parcel(s)	Pipe Capacity		Total Peak Flow in Pipe (m^3/s)	Surcharge Potential
		Minimum (m^3/s)	Maximum (m^3/s)		
A	1,4,6,11	0.9	1.8	0.5	Unlikely
B	1,2,4,5,7,8,9,10,11	0.9	1.7	2.3	Probable
C	1 - 12, 14, 15	5.1	5.1	2.8	Unlikely
D	4,11	0.1	0.1	0.06	Unlikely
E	1,4 - 11	0.9	1.7	1.9	Probable
F	6	0.6	0.6	0.4	Unlikely
G	7	0.1	0.1	0.5	Probable
H	8	0.6	0.6	0.4	Unlikely
I	8,9	0.4	0.4	0.5	Probable
J	1,4,6,10,11	0.9	1.8	0.8	Unlikely
K	11	0.1	0.1	0.1	Unlikely
L	1,2,4 – 12,14,15	8.3	8.3	2.7	Unlikely
M	13	0.08	0.07	0.04	-
N	14	0.1	0.1	0.3	Probable
O	1,2, 4 - 11, 15	0.9	1.7	2.3	Probable
P		0.9	1.8	0.7	Unlikely

[After: Coyne *et al*, 2008]

reservations and the working assumptions of both modelling approaches, it is evident that pluvial surface flooding can be expected for storm events exceeding the 1:30 RI. Indeed, it is highly probable that some surface flooding of the separate system at critical nodal junctions can be expected for storm events falling within the 1:5 to 1:30 RI spectrum.

The two modelling approaches imply that anything between 7560 – 58680 m^3 of instantaneous temporary attenuation storage would be required assuming that all impermeable surface runoff (but excluding highway drainage) contributes to the separate sewers. Based on the national guidance contained in the UK government strategy document for future water usage (Defra, 2008a), it could be expected that at least a 20% reduction on these estimated discharges might be achieved through water efficient fittings to WCs, washbasins and dishwashers, which would reduce water demand to about 80 l/hd/day. Further reductions in storage requirements of the order of 10% - 20%, could be achieved through the introduction of green roofs and limited source infiltration controls. The introduction of recycled "greywater" facilities would undoubtedly lead to substantial reductions in the combined sewer discharges to treatment as reported in Table 3, which would be of the order of 35% - 40% according to the household consumption data reported by Defra (2008a). One estimation for the Typhoo Wharf development parcel for 1.1 ha of residential/apartment roofing suggests that water savings of 8,700 m^3/year could be achieved through rainwater harvesting with a payback time of 3 years (Faber Maunsell, 2004). The study also claimed a 18.6 m^3/year "greywater" recycling capacity for a 350 bed hotel planned for the Masshouse development parcel with a 10.5 year payback time. Table 4 indicates the potential for the implementation of rainwater harvesting and greywater recycling schemes within Birmingham Eastside together with estimated payback times (excluding lifecycle costs).

Table 4. Stormwater and greywater re-use in Birmingham Eastside.

LANDUSE SECTOR	**RAINWATER HARVESTING**		**GREYWATER RECYCLING**	
	Potential	**Payback Time** (Years)	**Potential**	**Payback Time** (Years)
Single residential	✓	16	✓	44
Shared residential	✓✓	3.1	XX	-
Public community buildings	✓	6.9	XX	-
Hotels	✓	38.4	✓	10.5
Commercial office buildings	✓	?	XX	-
Retail buildings	See Mixed use development			
Industrial buildings	✓	?	?	?
Leisure buildings	✓	6.1	✓	7.8
Public open space	✓✓	?	XX	-
Mixed use developments	✓✓	?	✓✓	4.1

KEY: ✓ Potential; ✓✓ High potential; XX Negligible potential

[After: Faber Maunsell, 2004]

However, such recycling schemes would appear prohibitive given the high "upfront" and maintenance costs as well as the possible requirement for the implementation of a third "labelled" supply system. These considerations mean that it is highly unlikely that greywater recycling will be introduced into the Eastside developments even for non-potable uses. Nevertheless, it is acknowledged by Defra (2008a) that the introduction of rainwater harvesting schemes to impermeable roof surfaces could meet a significant proportion of on-site garden/lawn watering requirements which might reduce total water demand by 5% - 10%.

Although the above brief demand/usage analysis incorporates substantial uncertainties and data limitations, it is clear that there are opportunities for future re-distribution of water resources in the Eastside developments. Within such re-allocations, it is also evident that stormwater contributions could be significant in facilitating a more sustainable water cycle

strategy. Management of surface water flows during extreme events within the development area will undoubtedly require the introduction of further attenuation/storage controls which could be used as a (re)source to meet demands elsewhere in the urban water cycle, including on-site amenity lakes/fountains, lawn/garden irrigation, groundwater recharge etc.

4.4 BMP/SUDS application and runoff reduction

A GIS-based BMP modelling tool to predict storm runoff and source mitigating measures has been applied within the context of the SWITCH project to the 4.5 ha surface water sub-catchment within the Birmingham Eastside development area delineated by the dashed lines in Figure 17. Detail of the separate surface water sewer network for this sub-catchment is given in Figure 20. A very rapid response in the pipe flows to the rainfall distribution is

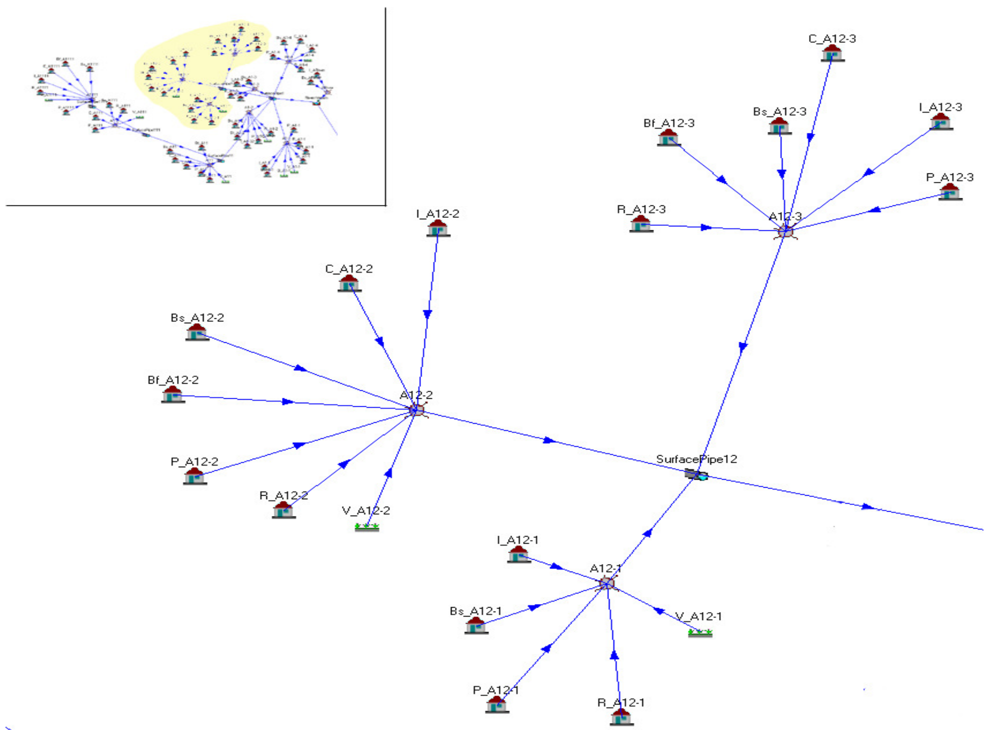


Figure 20. The STORM modelled sewered sub-catchment in Eastside

predicted by the STORM model with very short lagtimes, frequently less than 3 minutes. The hydraulic capacity of this separately sewered pipe system is exceeded by flows greater than 0.2 m^3/s and thus surcharged overflows from the PIPE12 manhole occurred frequently during the 1:80 RI extreme event of 13/14 June 2007 as shown in the inset diagram to Figure 21, which illustrates the values of the exceedance flows at one minute intervals between 03.30 and 03.45 hours. This analysis confirms the inadequate hydraulic capacity of the small diameter separate surface water system within Eastside and the ease with which surface flooding occurs with the onset of storm conditions.

The developed SWITCH BMP Tool allows the user to identify and add a particular type of BMP/SUDS to a GIS-based urban land use distribution. The tool interacts through the mouse cursor symbol to select an appropriate BMP location. As the cursor moves across the screen,

the cursor image changes automatically according to whether the site area is suitable or not for the particular BMP/SUDS being considered (Viavattene, 2009). Figure 22 shows locations within the Eastside experimental sub-catchment where the BMP Tool considers that both green roofs and porous paving are possible drainage solutions, covering 40% (1.8 ha) and 30% (1.35 ha) of the total 4.5 ha surface area respectively. The STORM model was then re-run with these BMPs in place with the simulation outcome shown in Figure 23. The sewer overflow times remain much the same as previously predicted, but the severity and incidence of surcharging is reduced. It is also clear that a considerable 'damping down' of the flow variability in response to the rainfall fluctuations is predicted with the BMPs/SUDS installed which emphasises the potential benefits from installing such source controls for surface water drainage.

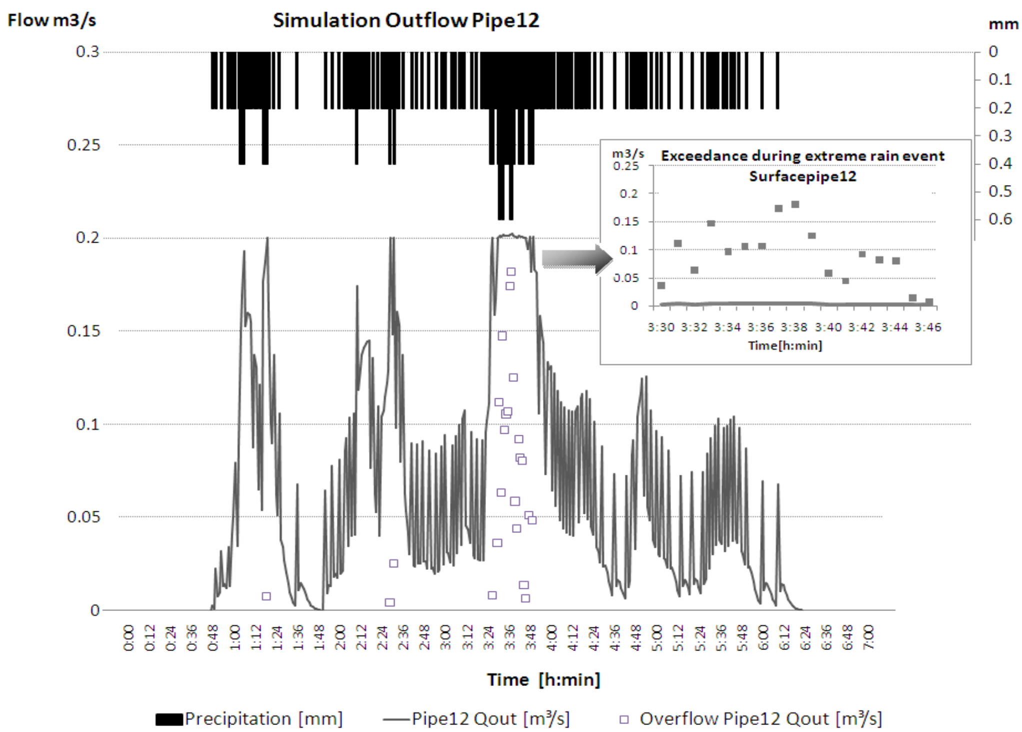


Figure 21. Predicted flow distribution and exceedance overflows for an extreme storm event

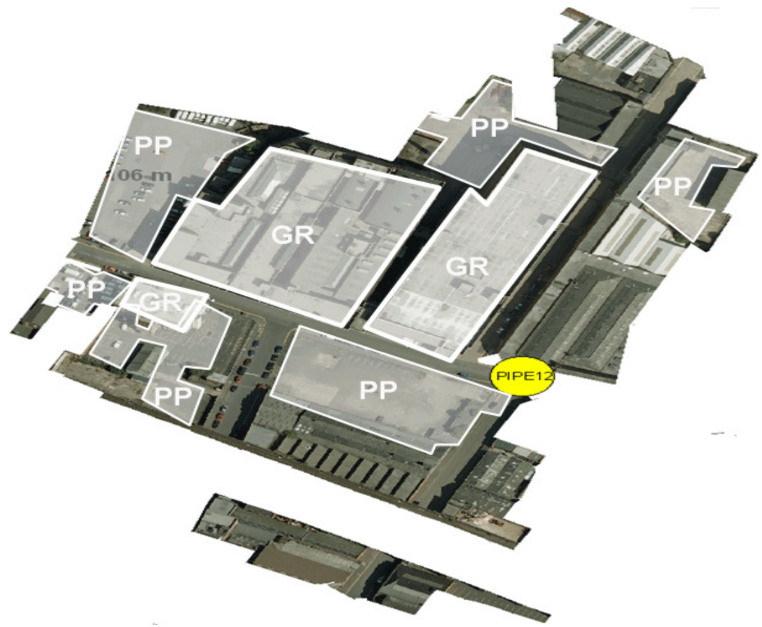


Figure 22. Identified Green Roof (GR) and Porous Paving (PP) placement in the studied catchment.

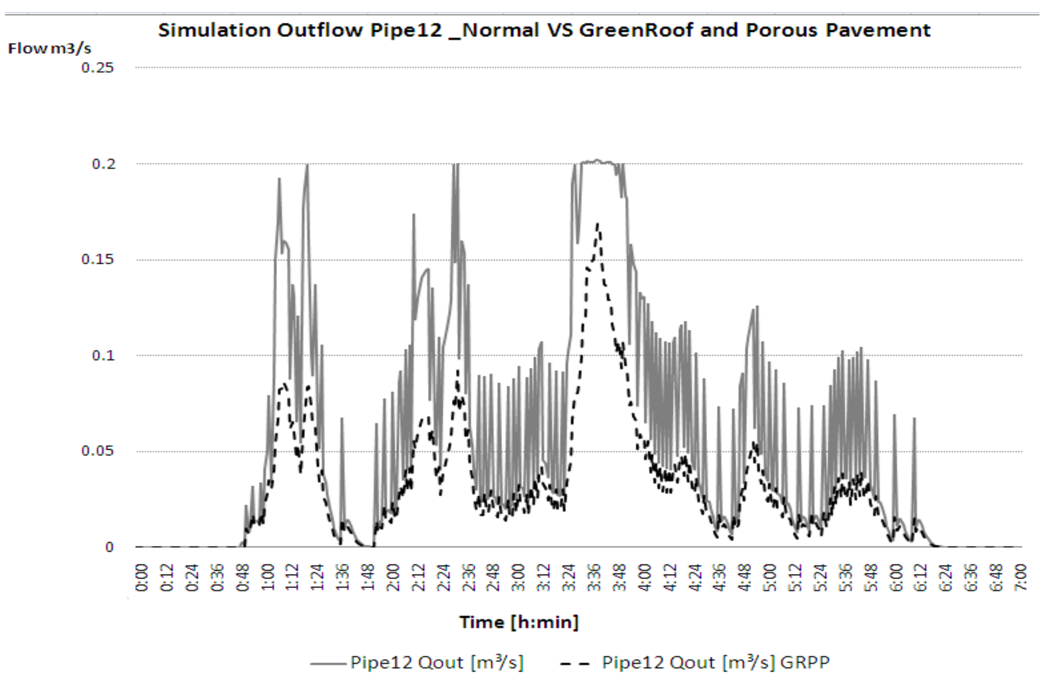


Figure 23. Comparison between predicted flow distributions with and without BMPs installed

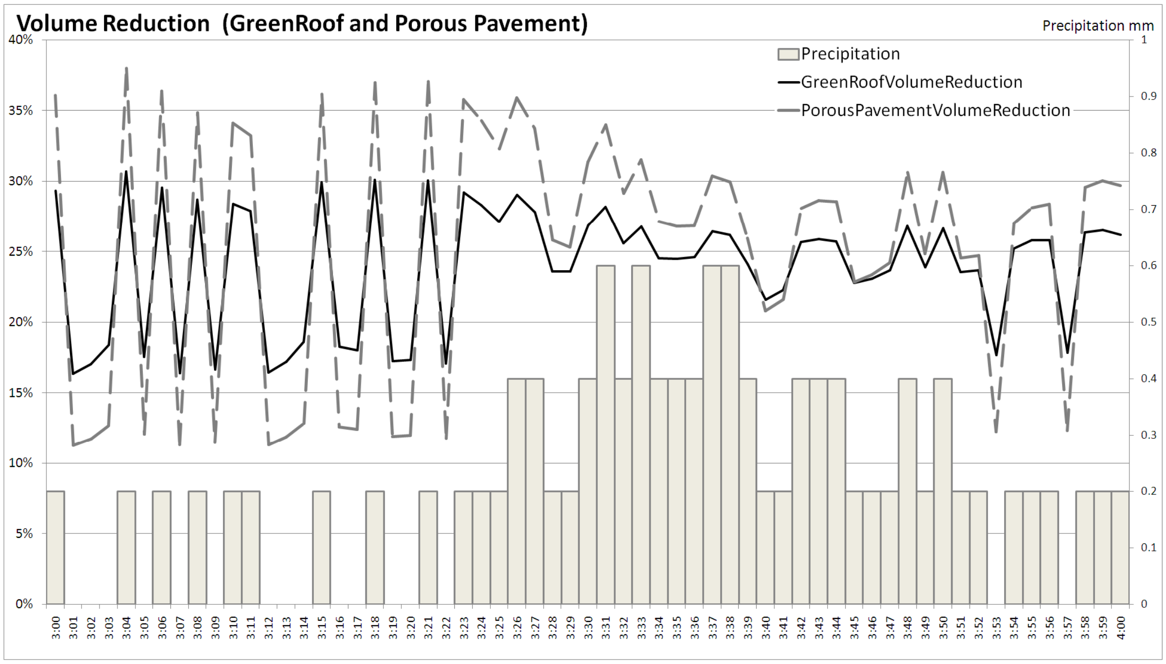


Figure 24. Temporal variations in runoff volume reduction in relation to the rainfall pattern.

The patterns of runoff volume reductions during the storm event for the two BMP forms are shown separately in Figure 24, which illustrates the performance effectiveness of both source control facilities. The runoff reduction performance of the simulated green roof and porous paving BMPs/SUDS incorporated into the Birmingham Eastside development area indicate that substantial reductions in total runoff volumes can be achieved. However, the average 22% - 28% reductions for the 4.5 ha site generated by the simulation modelling shown in Table 5 appear to be only some 50% or so of the minimum figures generally reported in the literature (Viavattene *et al*. 2010).

However, the data in Table 5 gives flow reductions for the green roof/porous paving 3.2 ha scenario set within the context of the whole 4.5 ha catchment. Therefore the reductions shown in Table 5 take into account the flow reduction of both the different types of BMP/SUDS and those of their representative surface areas. If surface area adjustments are factored in, the true BMP flow reductions range between 57% - 65% for the green roofs and 73% - 93% for the porous paving. However, it would not be wise to rely on the outcomes of any individual single event to characterise the general long term cumulative performance behaviour of these types of BMP/SUDS. There is a need to consider the full distribution and sequence of flows within the context of the overall flow regime and as rainfall depths/intensities increase, the design concern will shift from source infiltration and volume reductions to site flood reduction and wider-scale pluvial/fluvial catchment management. As indicated in Figure 24 the timing and patterns of volume reduction for both types of BMP/SUDS are very similar, with both BMPs showing a rapid response to the variability in rainfall inputs over time. The porous paving does exhibit a much greater variability than the green roof particularly during the earlier part of the storm event which reflects the "pump" action of the infiltrative mechanism associated with the porous surfacing and rapid temporary blocking of the underlying sub-base horizons.

Table 5. Birmingham Eastside BMP runoff volume reductions.

		FLOW (m^3)			FLOW REDUCTION (%)	
Time Period	Precipitation (mm)	Normal	Green Roof	Porous Pavement	Green Roof	Porous Pavement
1am-2am	5.6	230	169	174	26%	25%
2am-3am	7	304	227	220	25%	28%
3am-4am	13	568	425	410	25%	28%
4am-5am	5	228	171	166	25%	27%
6am-7am	3.2	143	107	104	25%	27%
7am-8am	0.2	13	10	10	23%	22%

The green roof by comparison is able to soak-up a larger proportion of the incident rainfall. Both BMPs become more stable to rainfall fluctuations after the peak rainfall intensity, probably as a result of saturation of the BMP storage sites.

The results of the modelling analysis clearly demonstrate that GIS-based platforms can assist in providing a better understanding of how rainfall-urban surface-sewer interactions can lead to surface flooding. In addition, such platforms can inform stakeholders of the benefits which can be achieved by the appropriate location of selected BMPs/SUDS, but the major lesson from this preliminary runoff investigation is that BMP/SUDS controls can provide a strategic solution to drainage infrastructure objectives of reducing pluvial flood risks, reducing sewer discharge volumes and mitigating impacts of combined sewer stormflows to STWs.

This brief analysis of surface water drainage for Birmingham Eastside would clearly suggest that alternative stormwater strategies could be deployed to deliver a more sustainable and balanced urban water cycle, enabling surface water runoff to make positive contributions to the local water resource budget.

4.5 Supporting documentary materials for a UWC study

4.5.1 Birmingham City Council documentation

Local Development Framework (LDF)

All local planning authorities in England and Wales were required in 2004 to produce Local Development Frameworks (LDFs) to replace the previous system of Local, Structure and Unitary Development Plans. Birmingham City Council is working up the "Birmingham Plan" as the statutory LDF based on further development and refinement of the *Birmingham Unitary Development Plan* (UDP) published in October 2005. The UDP is the main urban

land use planning document containing strategic city-wide planning policies and proposals that will guide development and land use within Birmingham up to 2011 when it will be superseded by the LDF. It contains general topic/theme chapters e.g environment, transport, housing etc., setting out broad objectives and policies to guide development and land use. Detailed policies related to specific types of development and area statements are also included.

The February 2007 *Core Strategy (Planning for the Future of Birmingham)* document will comprise one of the key parts of the LDF setting out the vision for the city and identifying key issues and options based on a variety of source evidence including a Level 1 *Strategic Flood Risk Assessment* (Birmingham City Council & Atkins, 2010). The *Core Strategy* will replace the strategy chapters of the UDP (Chapters 2 – 7). The *Local Development Scheme* (LDS) which covers the period 2009 – 2012, sets out the time scales for the preparation of the local development documents (LDDs) that will eventually form the council's LDF. The LDS incorporates policy objectives included in regional spatial strategy documents and is prepared in consultation with the regional government office of the West Midlands (GoWM). Regular *Annual Monitoring Reports* review progress in implementing delivery of the policies to be contained in the LDF and on preparation of the LDS documentation; the most recent is the 2009 Monitoring Report. The final element of the LDF is the *Statement of Community Involvement*, published in April 2008, which sets out how the city council intends to involve local communities in planning and the decision-making process.

A further Supplementary Planning Document (SPD) published in June 2007, "*Sustainable Management of Urban Rivers and Floodplains*", provides further guidance for development located within river corridors in Birmingham. It builds on policies contained in the UDP and provides additional proposals to encourage links between land use planning and water management. Policy 3 of the SPD states that the "***full potential for the use of SUDS will be needed in the initial stages of development and it must be demonstrated by the developer that the potential for the use of SUDS has been considered, and where appropriate, used in the surface water drainage strategy for the site***". In addition, Policy 4 of the SPD states that there "***should be a reduction (or no net gain) of surface water runoff where possible as a result of new development or re-development sites***". Birmingham City Council has also issued a separate drainage *Policy Statement of Flood and Coastal Defence* which recommends "***measures for ensuring sustainable urban drainage systems to control surface water runoff***".

In accordance with national strategic planning policy guidance (see Section 4.5.3 below), Birmingham City Council in partnership with the consultant group Atkins, has produced a Level 1 "*Strategic Flood Risk Assessment*" (SFRA). The purpose of the SFRA is to assess and map all known sources of flood risk including, surface water, taking into account future climate change predictions, to enable the Council to use this as an evidence base in future development planning (Birmingham City Council & Atkins, 2010). The City Council had previously led a water group consortium developing a structure and strategy for the delivery of integrated urban drainage (IUD) management within the Upper River Rea catchment as part of a national pilot programme (Birmingham City Council, 2008). This IUD pilot study drew attention to the substantial issue of extreme event exceedance flooding associated with surface water runoff.

4.5.2 Regional government documentation

Regional planning policy provides the overarching framework for the preparation of the Birmingham City Council LDF and forms part of the national statutory planning procedure. The *Regional Spatial Strategy* (RSS) for the West Midlands (RPG11) was published in January 2008 setting out a development vision for the region by 2021 and promoting a more integrated approach to delivering policies for the management of flood risks and adaptation controls for future climate change (GoWM, 2008). Policy QE9 of the RSS identifies that development plans should "***reduce any adverse effects on the water environment by encouraging consideration of sustainable drainage systems where appropriate at an early stage in the design process***".

A regional flood risk appraisal (RFRA) was published in October 2007 (Faber Maunsell, 2007) as an aid to inform the regional planning policy making process, highlighting broad locations of flood risk at a regionally significant level. The RFRA recommends that "***SUDS solutions should be adopted for all significant developments……..whilst incorporating habitat and amenity improvements wherever possible***". The Environment Agency have issued a pre-publication draft of a catchment flood management plan (CFMP) for the River Trent catchment (EA, 2010), providing an overview of the main sources of flood risk and how these might be mitigated and managed in a sustainable manner over the next 50 to 100 years. The CFMP highlights issues relating to urban pluvial flooding and the need to reduce surface runoff within the built-up area of Birmingham, including Eastside. Some 5% of the metropolitan area is located within Flood Zone 3 (see Table 1), although the Eastside area is excluded from any risks of fluvial flooding due to the deep channelisation of the River Rea through the development area.

4.5.3 National government documentation

Central government national planning policy will always play a key role in shaping the direction, objectives and strategies of regional and local planning authorities as illustrated in Figure 10. The prime national land use policies for England & Wales are set out in a series of Planning Policy Statements (PPS) of which the most important for urban surface water drainage is PPS25, "*Development and Flood Risk*" (DCLG, 2001). PPS25 was accompanied by a consultative (or living draft) best practice guide seeking views on the implementation of the national planning policy statement (DCLG, 2008a). PPS1, "*Delivering Sustainable Development*", is also of relevance as it places a statutory requirement on regional and local planning authorities to ensure that new development should avoid areas of flood risk and that such development should meet the wider national objectives of adaptable, resilient and sustainable infrastructure provision.

These PPS policy documents compliment other national planning policies for flood/pollution risks and water management including "*Making Space for Water*" (MSfW; Defra, 2005), "*Future Water*" (Defra, 2008a), "*Learning Lessons from the 2007 Summer Floods*" (Pitt, 2008) and the draft "*Floods and Water Management Bill*" (Defra, 2009b). Aspects of the consultation process to the latter policy document include a number of supporting national reviews such as "*Impact Assessment of Local Flood Risk Management and the Increased Use of Sustainable Drainage Systems* (Defra, 2009c) and "*Improving Surface Water Drainage*" (Defra, 2008b) Both these latter consultation documents further developed proposals set out in the government's earlier "*Future Water*" strategy policy. Central government appraisals of

long term investment and policy strategies for flood risk management contained in the above national documents have also been accompanied by parallel consultations undertaken by parliamentary committee reviews. The most significant of these for urban surface drainage are those of the Environment, Food & Rural Affairs Committee (EFRA) of the House of Commons on "*Flooding*" (EFRA, 2008).

Under the proposed terms of the forthcoming "*Floods and Water Management Bill*", local authorities will be required to produce Surface Water Management Plans (SWMPs) as recommended in PPS25 and in the Pitt Review. These SWMPs will follow the national template produced by Defra (2009a). Such SWMPs were initially advocated in the government's "*Making Space for Water*" consultation document and were trialled to some extent in the 15 Integrated Urban Drainage (IUD) pilot studies commissioned by Defra during 2007 - 2008 (Gill, 2008). The Upper River Rea catchment in Birmingham comprised one of these national IUD pilots (Birmingham City Council, 2008). Birmingham City Council are currently preparing their SWMP which will follow the Defra (2009a) national technical guidance template.

4.5.4 Other national documentation

Two central nationally available documents providing detailed technical and administrative guidance on stormwater BMP design and adoption are the CIRIA "*SUDS Manual*" (Woods-Ballard *et al*., 2007) and the "*Interim Code of Practice for SUDS: ICoP*" (National SUDS Working Group, 2004). The former provides design and maintenance guidance on differing SUDS types together with consideration of flood risks and assessment techniques, whilst the latter provides guidance detail on SUDS adoption and management arrangements including model agreements on BMP adoption and maintenance (ICoP SUDS MA2 and MA3). Other relevant CIRIA documentation includes best practice advice on "*Designing for Exceedance in Urban Drainage*" which covers the operation and management of urban sewers and drainage systems to reduce the impacts of extreme flow conditions (Balmforth *et al*., 2006). CIRIA has also very recently published the outcomes of the major UK national R&D WaND project on improved water cycle management for new urban developments (Butler *et al*., 2010). This document reviews a range of water-saving devices, rainwater harvesting, greywater recycling and SUDS systems as basic approaches to urban surface water management. The CIRIA SUDS website (www.ciria.com/suds) provides detail of further supporting booklets and publications covering various design aspects of SUDS.

The UK regulatory Environment Agency (EA) has outlined its strategic approach for future sustainable water resource management which reviews principal drivers and pressures on water cycle budgets (EA, 2009a). This national strategic review is accompanied by a series of regional action plans including one for the Midlands Region (December 2009) which looks at the interlocking of catchment, regional and local planning approaches for water management. The EA has also produced general flood maps indicating areas liable to flooding and extreme event inundation. The EA flood probability map for the Birmingham Eastside area has been shown and discussed in the previous SWITCH Deliverable 2.1.1b (Ellis *et al*., 2008b). The draft River Basin Management Plan (RBMP) for the Severn River Basin District was published by the EA in December 2009 (EA, 2009b) and the equivalent Trent River District Plan has been pre-published in draft (EA, 2008a), with the final report due shortly (EA, 2010). Both RBMPs support the implementation of SUDS as best practice urban drainage and as essential components in water recycling schemes. The EA has also

recently made available to local councils outline plans showing areas specifically susceptible to surface water flooding as a basis for supporting the production of local SWMPs. The mapping methodology excludes all sewered drainage and is based on a single rainfall event for a 6.5 hour storm with a 0.5% average probability of being exceeded each year i.e. a 1:200 annual probability.

There are also elements of the Severn Trent Water planning process that may be pertinent to the Birmingham Eastside UWC study and specifically in terms of potential integration with spatial planning timelines of both the local and regional government. Severn Trent Water has received (spring 2010) a draft determination from the central government regulatory agency Ofwat on its 2010 – 2015 strategic business plan for capital asset investment (AMP5), under which it is likely to be allocated some £2.5 billion. This business plan (Severn Trent Water, 2009a) includes reference to Key Strategic Intentions (KSIs) for catchment management and sustainable drainage solutions (KSI4) and for which £0.6M per annum is earmarked for Opex expenditure. KSI2 pledges contributions to local authority SWMPs in order to work with them to develop integrated flood solutions including recommendations arising from the Pitt Review (Capex £19M expenditure and Opex £1.6M per annum), and KSI1 intends to promote water efficient devices.

Severn Trent Water (2009b) also recently published its Water Resources Management Plan (WRMP) which envisages the introduction and promotion of water efficiency options including rainwater harvesting, although admitting only a slow "take-up" is likely. Much of the water savings may accrue through the adoption of the "*Code for Sustainable Homes:CSH*" (DCLG, 2008b) which together with the UK Building Research Establishment environmental assessment procedure for buildings (BREEAM), will support the use of low water appliances and fittings. However, it can be argued that property based water efficiencies need to be provided in addition to, and not instead of, strategic SUDS drainage.

4.6 A UWC study partnership approach

The UWC study should be undertaken by cooperation between key stakeholders involved in the planning, provision and operation of drainage assets and water infrastructure in the Birmingham Eastside development area. Representatives of this stakeholder group would serve as a key point of reference for data collection as a basis for achieving a collective understanding of water cycle issues. The local stakeholders group might consist of an outreach extension of the existing SWITCH Learning Alliance (LA) consortium:

- Birmingham City Council (City Centre Development Directorate: Planning & Regeneration Service Planning & Environment: Drainage Services)
- Severn Trent Water
- Environment Agency (Midlands Region)
- British Waterways
- West Midlands Consumer Council for Water
- Advantage West Midlands; Regional Development Agency
- Groundworks West Midlands

It may also be appropriate to add representatives of two consultant groups (Hyder and Ove Arup) to the key stakeholder group given their input to previous reports commissioned by Birmingham City Council on urban drainage issues.

The UCW study should be led by Birmingham City Council with the stakeholder group agreeing allocation of responsibilities and an approved framework and work schedule to tie the key stakeholders together. The scope of the outline Phase 1 UWC study should be agreed and all key stakeholders consulted in respect of their vested interests, strategies, objectives and plans for surface water drainage infrastructure provision for Birmingham Eastside. The initial consultation phase should also identify data sources and availability as well as develop confidentiality agreements where appropriate.

4.7 UWC outputs and benefits

The outputs from the outline Phase 1 UWC study of the Birmingham Eastside development area should be reports that address the following questions:

- what and where are the risks from surface water flooding for the development parcels and will these developments be resilient to the effects of future climate change and the likely impacts to flood risk drainage and water supply?
- how will the effects of staged parcel development impact on the provision of an integrated, sustainable drainage infrastructure?
- how can rainfall-runoff and associated overland flows be managed within the development area for extreme storm events and what is the potential for SUDS implementation?
- are there locations that can be safely utilised for attenuation, infiltration and/or storage of exceedance flows?
- what water savings and demand management approaches can be implemented within the developments, especially in respect of potential rainwater contributions to other components of the urban water cycle?
- is there an increased risk of stormwater outfalls and overflows operating outside their agreed limits as a result of the proposed developments?
- will there be a water quality impact on the receiving watercourses and/or groundwater resources?
- how will other outstanding concerns and uncertainties in respect of urban surface water drainage infrastructure be addressed e.g. costs, adoption, maintenance etc.? The scoping study might identify options for first-cost estimates for water cycle infrastructure as well as possible alternative cost apportionment mechanisms.
- identify any information, data, funding or policy/planning gaps and technical uncertainties that require further exploration in a more detailed Phase 2 UCW study in conjunction with the local development framework (LDF) planning process.
- identify procedures and supporting structures to ensure a coordinated stakeholder approach to strategic water resource management.

It is anticipated that the understanding, approaches and evidence base developed in the UWC study will provide useful working information and platforms for future land use planning decisions on drainage infrastructure provision, maintenance and costing. Directions for strategic policy and tactical solutions to drainage infrastructure provision should be identified in outline together with guidance on measures that developers should provide in order to reduce impacts on the water cycle. The direct benefits to the urban environment will be to reduce flood risk and facilitate emergency flood preparation as well as inform water resource

management. The study should also generate a more coordinated and flexible stakeholder consultation procedure and help to lever private investment and dovetail this with public amenity and utility infrastructure.

The outline Phase 1 UWC study should therefore provide an evidence-based study which specifically addresses the impact of the Eastside development area on the water cycle, with particular emphasis on the consequences for the provision and maintenance of surface water drainage infrastructure and management. The output should provide an important component towards the preparation of the Birmingham City Council LDF and should build on the already completed strategic flood risk assessment (SFRA) and existing supplementary planning guidance on drainage. In addition, the UWC material should provide a significant evidential document to the Birmingham City Council SWMP as well as supporting the sequential testing procedure contained in the SFRA.

4.8 Deliverables contributing to the UWC strategy

- Interim technical report
- Final Phase 1 technical report
- Final Phase 1 summary report

Attendance at 2/3 Steering Group meetings
Public presentation of final results.

4.9 Skills required to complete the UWC strategy

- an understanding of sustainable development issues and initiatives together with awareness of sustainable urban drainage systems (SUDS) and urban drainage infrastructure design and application
- a knowledge of the planning system, requirements of the local development frameworks (LDFs) and the context of regional and national planning and strategic surface water management.
- a knowledge of flood risk assessment and discharge consenting, impacts of EU regulation e.g. WFD, Floods Directive etc..
- a knowledge of water resource planning and management, water efficiency and recycling.
- contributions from water and sewerage company planning and asset targets including strategic direction statements and business infrastructure planning
- familiarity with the implications of recent government consultation documents and reports on urban flood management, SUDS and climate change.

4.10 Resources required to complete the UWC strategy

Discussions conducted as part of the Flood & Water Management Bill have estimated that the preparation cost for a local SWMP could be of the order of £100,000 requiring around 3 FTE staff with a Phase 1 UCW study requiring 0.5 FTE to establish the administrative/management groundwork necessary to introduce and oversee the required

work (Defra, 2009c). The final Phase 2 UCW study and SWMP (overall cost; £100,000) would involve approximately £20,000 in desk research, £40,000 for further field investigations and asset mapping with a further £20,000 for uploading data onto an asset register. The remaining £20,000 would be required in the following years to update and maintain the register.

The Defra Integrated Urban Drainage (IUD) pilot studies indicated that localised changes to road cambers, kerbs, culverts and other street furniture etc could be made at relatively low cost (£5K - £20K), but which could lead to significant reductions in local surfacing flooding risks. The introduction of alternative SUDS systems was estimated to cost an additional £6 per property per year but result in a benefit to cost ratio of 4:1 over a 50 year period.

The outline Phase 1 UCW study should identify cost apportionment options so that developers can be made aware of what infrastructure is required. This cannot result in any legal agreement under the current UK regulatory regime as water companies have strict charging regulations imposed by Ofwat and there are further concerns regarding the right of local councils to enforce any charging mechanism. Therefore, currently such charges can only be based on generic protocols that may need to be applied on a voluntary basis, but perhaps through a formal "signing-up" arrangement.

The Phase 1 UCW could work up a developer checklist to summarise the basic requirements for urban drainage infrastructure within a "tick-box" format to be submitted with their planning applications and a possible outline for such a checklist is given in Annex 1. This would encourage the delivery of green infrastructure and best practice for both consumption demands and surface water management.

The provision by the developer of strategic surface water integration works not necessarily dependent on any one specific development but required for the achievement of an overall spatial catchment-scale strategy will have significant costs. Such costs will normally not have any earmarked or central budget and thus must be recovered from the developer. A simple cost apportionment mechanism would split costs equally between developers according to the dwellings/premises proposed for the site (based perhaps on total surface area or impermeable surface area). Any charges should be applied through the Section 106 mechanisms with the local authority setting up a ring-fenced fund to receive developer contributions and using the fund for appropriate flood defence works. This would result in a range of developer contributions depending largely upon their location within and impact on the (sub)catchment. Contributions to the fund not used should be returned to the developer but if they provided more than the minimum required for the overall strategic works, then their contribution might be reduced accordingly. Other possible funding mechanisms that could be explored in the Phase 1 study might include planning gain supplements to recoup any increases in land value following the granting of a planning application or alternatively an up-front tariff whereby each developer is charged a set amount per impermeable surface area.

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ANNEX 1

Developer checklist for Urban Surface Water Management

SURFACE WATER RUNOFF
1. Is the site over 1 ha? If so, a Flood Risk Assessment (FRA) is required to comply with PPS25 "*Development and Flood Risk: A Practice Guide Companion*" (DCLG, 2008a)
2. Will the site contain more than 20 dwellings and be less than 1 ha? If so, a FRA is required given the potentially significant impact in terms of demand on sewer capacity.
3. Confirm the previous use of the site and state the extent of impermeable surface cover both before and after development.
4. Provide evidence that the surface water runoff rate will be restricted to 2 l /s/ha (or demonstrate that the existing greenfield/brownfield runoff rate will be reduced or maintained).
5. Confirm that the peak runoff rate for the fully developed site will be no greater that it was for the pre-development site. This should comply with the CIRIA "*SUDS Manual*" (Woods-Ballard *et al*., 2007) recommendations for at least the 1:1 and 1:100 year return period events.
6. For additional peak runoff volumes above pre-development level will they be entirely reduced for storms up to and including a 1:100 RI, 6 hour duration event? Provide evidence to show how such additional peak runoff volumes will be reduced.
7. Confirm that no runoff discharge to a watercourse will occur for rainfall depths up to 5mm as specified in the CIRIA "*SUDS Manual*" (Woods-Ballard *et al*., 2007).
8. Confirm that sizing of any flood balancing facilities are in accordance with the Defra/EA (2005b) guidance contained in "*Preliminary Rainfall-Runoff Management for Developments*" (Revision C).
9. Confirm that any surface water storage devices are designed for varying rainfall events up to and including a 1:100 year RI storm including +10% climate change allowance.
10. Provide layout plans, cross-section details and long-section drawings of any attenuation devices.
11. The number of surface water outfalls should be minimised. New or replacement outfall designs should adhere to standard guidance form SD13 (See local EA offices for details and forms).
12. Confirm familiarity with local authority SWMPs and demonstrate that consideration has been given to implementing a strategic solution to surface water management for the site.
13. Has the site been previously subject to overland pluvial flooding during extreme rainfall events? If so, provide evidence that modelling of overland surface water flood routes and depths has been undertaken.
SUDS
14. Provide detail of any SUDS proposed for the site with supporting information e.g. calculations of sizing, ground investigation, soakage tests etc.
15. Quantify the percentage of surface water runoff to be attenuated or controlled through SUDS drainage and rainwater holding facilities during the peak flow of storm events e.g. 1:1, 1:30, 1:100 RI events. Does this satisfy the minimum standard requirements defined in Chapter 4 of the DCLG (2008b) "*Code for Sustainable Homes*" (CSH) Technical Guide? Does this percentage of attenuation also satisfy the requirements of other statutory bodies such as the EA?

16. Confirm whether any driveways, hard standings and other hard surfaces are to be constructed from permeable surface materials and provide evidence of their suitability for the site.
17. Confirm whether the proposed SUDS are to be adopted as part of public open space or by a wastewater undertaker and provide supporting evidence. Provide details of maintenance contributions to be provided over the lifetime of the development.
18. Provide details of any proposed measures to encourage and/or promote public awareness of SUDS facilities and increased community participation in the drainage infrastructure provision.
WATER CONSUMPTION
19. Confirm whether the development will include rainwater harvesting; with minimum rainwater tank sizing of 2.5 m^3 per dwelling as recommended by EA (2008b) guidance.
20. Has a practical alternative strategy been included to use stored/diverted rainfall-runoff water or other sources of water supply for fire-fighting purposes and/or for open space irrigation?
21. Confirm whether any roof disconnection is to be implemented together with details of infiltration/soakaway disposal and associated soakage and groundwater testing.
22. Confirm whether greywater recycling is to be utilised and where applicable provide location and details of the measures.
23. Is there a strategy provided (including details and calculations), of how reduction in water demand to 120 l/head/day will be achieved e.g. through water saving appliances, rainwater harvesting etc?
24. Provide details of any proposed measures to increase public awareness and community participation campaigns in reducing water demand
FLOOD RISK MANAGEMENT
25. Is a flood risk assessment (FRA) submitted with the application in accordance with PPS25 Annex E?
26. Is the proposed development within Flood Zones 2 or 3?
27. If yes, has the Sequential Test been applied? (See PPS25 Annex D, para D9)
28. Have the three elements of the Exception Test been passed? (See PPS25, Annex D, para D9)
29. Does the FRA assess all possible sources of flooding? Does the FRA include reference to extreme event exceedance overland flow flood paths and depths? Is the development located outside extreme event flood flow paths? (See PPS25, Annex C)
30. If the development is for an area with medium/high probability of flooding (fluvial, sewer, pluvial or groundwater), are the building ground levels, access roads and car parks above the flood level?
31. Does the FRA assess the implications of climate change and suggest ways the impact can be minimised? (See PPS25, Annex B).
32. Provide evidence confirming whether there will be a reduction in flood risk to downstream (and upstream) locations.
33. Is evidence provided for safe dry access/egress for residents and emergency services in the event of flooding? (See PPS25, Annex G).
34. Provide outline details of any proposed flood resilience and resistance measures to reduce damage impacts to the development (See PPS25, Annex G).
POLLUTION PREVENTION
35. Provide details of any diffuse pollution prevention measures to be provided over the lifetime of the development e.g. oil and/or silt interceptors, SUDS etc. (See PPG2, PPG5,

PPG6 and PPG21).
36. . Provide details of any SUDS infiltration and/or biofiltration devices for solids, nutrient, oil or other contaminant control.
37. Provide reasons why permeable surfacing has not been used for car parking, hard standing, driveway areas within the development.
COMMUNITY ENHANCEMENT
38. Confirm if any green infrastructure provision, such as may be used for the surface water drainage system, links to neighbouring green infrastructure to assist in the creation and maintenance of green corridors.
39. Confirm whether street rainwater gardens and/or street tree and shrub planting has been considered?
40. Identify whether opportunities for increasing damp grassland/wetland areas e.g using surface drainage facilities such as swales, grass buffers etc., has been explored to benefit ecology and habitat.
41. Confirm that at least 25% of flood attenuation ponds/wetlands will be designed for multi-functional uses e.g. footpaths, cycleways, recreation, amenity, habitat etc. and submit outline details.
42. Confirm whether the local biodiversity action plan (LBAP) has been consulted and whether any habitats or species detailed within the LBAP are present or near the development site.
43. Confirm whether an environmental assessment (proportional to the size and nature of the development) has been undertaken. This should identify any impacts on ecology and wildlife habitats together with appropriate mitigation measures.
44. State if any public or local community environmental awareness campaigns or other approaches to raise awareness of the advantages and benefits of BMP drainage are planned as part of the development design.