OPW Flood Studies Update Project

Work-Package 4.1

FINAL REPORT

for

SCOPING STUDY OF URBAN FLOODING ISSUES

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Abstract

Since 1975, flood estimation in Ireland has generally followed methods as outlined in the Flood Studies Report (FSR). Many methods in the FSR were developed using data that was available up to and including 1969. An additional 37 years of data that should more accurately reflect current climate and catchment conditions is now available and this, coupled with more advanced analytical techniques could significantly improve the quality of flood estimation in Ireland. This was recognised by the Flood Policy Review Group and following from this, the Office of Public Works (OPW) in conjunction with interested state, semi-state and other relevant organisations initiated a review and update of the 1975 FSR.

The Flood Studies Update (FSU) commenced in 2005 and comprised a number of work-packages arranged around work-groups. Work-group 4 comprises research in Urban Catchment Flood Analysis and the first work-package within this work-group, undertaken by the Centre for Water Resources Research (CWRR) in UCD Civil Engineering, was a Scoping Study of Urban Flooding Issues.

This report summarises the findings of this scoping study which comprised a number of dependent phases of research, the main focus of which surrounds quantitative and qualitative research (self-completion questionnaires and Focus Groups) to review the methods of flood estimation in urbanised catchments currently in use in Ireland, assess any deficiencies associated with urban-runoff control in Ireland and identify achievable and realistic objectives for further work-packages under the Urban Catchment Flood Analysis Work-Group of the FSU.

A questionnaire, accompanied by an OPW letter of support, was developed around a number of key themes pertaining to urban flooding issues and circulated to 291 stakeholders in target sectors that ranged from Engineering Consultancies to Academic Institutions. A total of 100 questionnaires were returned equating to a 34.4% response rate. Responses were analysed using the SPSS statistics software package. Results from this analysis are contained in this report.

The qualitative element of the research involved a number of Focus Groups. The project brief recognised the requirement for the scoping study to review flood issues across Ireland and in keeping with this brief, Focus Groups were held in the major conurbations of Dublin, Cork, and Galway.

Acknowledgements

The CWRR in UCD Civil Engineering wish to acknowledge the financial support made available by the OPW for undertaking this research.

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1 Introduction

1.1 General Aspects

Flood estimation in Ireland currently follows methods outlined in the 1975 Flood Studies Report (NERC, 1975) and the numerous Flood Studies Supplementary Reports that followed. The Flood Studies Report (FSR) evolved from a joint research initiative involving the relevant UK agencies with responsibility for flood related issues and the Irish Office of Public Works (OPW). The FSR was superseded in the United Kingdom in 1999 by the Flood Estimation Handbook (Institute of Hydrology, 1999). The OPW however, was not involved in the development of the Flood Estimation Handbook (FEH) and consequently, FEH applications are more strictly limited to UK catchments.

In the context of increased urbanisation in Irish catchments and the impact of global climate change on the natural hydrology of catchments, over-reliance on the FSR is not recommended. Recognising the deficit in accurate methodologies for flood estimation in Irish catchments that is likely to increase moving forward, and the urgent need for improved prediction techniques, the OPW in conjunction with a Management Committee comprising interested state, semi-state and other relevant organisations have initiated a review and update of the 1975 FSR. A primary objective of the Flood Studies Update (FSU) is to avail of the additional years of hydrometric data that has been recorded in the intervening period since 1969 and to utilise advances in computer and digital technologies to provide the engineering community with improved methods of rainfall and flood estimation.

1.2 Scope of the FSU Programme

The work for the Flood Studies Update Programme comprises Research and Development in six specific Work-Groups (WG). These Work-Groups are summarised in Table 1.

Work-Group (WG)	Description
WG1	Meteorological analysis (data preparation and frequency analysis)
WG2	Hydrological analysis (statistical analysis of floods)
WG3	Flood hydrograph analysis
WG4	Urban catchment flood analysis
WG5	Development of information systems
WG6	Publication of Flood Studies Update products

Table 1 Work-Groups in Flood Studies Update programme

Work-Groups are further divided into a number of related and complementary Work-Packages. The Centre for Water Resources Research (CWRR) in UCD Civil Engineering has been appointed to undertake the first Work-Package in Work-Group 4 that deals with Urban Catchment Flood Analysis. This Work-Package (WP 4.1) involves a scoping study of urban flooding issues in Ireland and requires an assessment of methods used and problems experienced by practitioners in the area.

The study is keen to identify methods of flood estimation in urbanised catchments currently in use in Ireland and assess deficiencies generally encountered with urban runoff control.

Work-Package 4.1 was a six-month programme that was completed at the end of June 2006. This report outlines the work undertaken, discusses the findings and makes recommendations where further work in the area of Urban Catchment Flood Analysis should be undertaken.

1.3 Outline of Report

This report is divided into six main chapters. Chapter 2 presents, in summary, methods of assessing and managing urban floods in other regions of the world. The regions include Europe, Australia, the US, Asia and South Africa. Where possible, an attempt is made to assess these regions in an Irish context and to explain the commonly used methods of peak flow estimation and stormwater management. A complete review is beyond the scope of this work-package and as a result of the range of countries that are involved, coupled with significant variations in climatic conditions, the review provided is inevitably uneven. However, its objective is to provide some insight as to the manner in which urban flooding issues are dealt with in these areas.

Chapter 3 of the report sets out the rationale of the work-package and includes the aims and objectives of the work. Following this, Chapter 4 outlines the approach that was adopted to satisfy these objectives. This approach comprised both quantitative (questionnaire survey) and qualitative research (Focus Groups) elements and the manner in which these were undertaken is presented.

Chapter 5 comprises the results of the study. Results derived from quantitative research are generally presented in graphical or tabular formats and where appropriate, are supported by results from the qualitative research element.

The report finishes with the overall conclusions (Chapter 6) and in accordance with one of its objectives, makes recommendations for further Research and Development. The recommendations for improving methodologies for Urban Catchment Flood Analysis are based on this study and are therefore linked to specific problems encountered by practitioners on a day-to-day basis.

2 Urban Catchment Flood Analysis – Worldwide

2.1 Introduction

The realisation of climate change predicted for Ireland in terms of increased intensity and duration of winter rainfalls can be expected to impact on urban flood issues in the future. Currently, the majority of rainstorms that pass over Ireland are frontal, but with time, these are expected to reflect the characteristics of storms that are convective in nature. Storms of this type will have the capacity to further stress drainage networks and this, combined with the "locking" of outfalls that could potentially occur, will in some cases surcharge sewer systems. Other countries such as Australia, those in north America, Asia, South Africa and indeed some in Europe will be influenced by naturally occurring meteorological conditions that will deliver high intensity rainfall events of a type, albeit to a less severe extent, that may be expected in Irish catchments in the future.

As part of this study, an attempt is made to review, in summary, methodologies for urban catchment peak flow estimation and best management practices (BMP's) for stormwater management used in these countries. A complete review is beyond the scope of this work-package and as a result of the range of countries that are involved, coupled with significant variations in climatic conditions, the review provided is inevitably uneven. This mirrors the uneven development of methodologies that are used for estimating and managing stormwater runoffs in urbanised or urbanising catchments elsewhere in the world. However, it should serve to provide some insight as to the manner in which urban flooding issues are dealt with in these areas.

2.2 Europe

2.2.1 Context

Europe's Eastern boundary with Asia is the Ural Mountains in Russia. This boundary continues with the Caspian Sea, the Caucasus Mountains, on to the Black Sea; the Bosporus, the Sea of Marmara and concludes with the Dardanelles. To the South, the Mediterranean Sea separates it from Africa. With the exception of Iceland, the Atlantic Ocean generally represents its western boundary. Europe consists of 50 states and many have their own hydrometric networks, legislation and policies in relation to floods and urban drainage. Climatic conditions can be influenced by topography (shown in Figure 1) but typically range from northern arctic, where snow-melt is the principal river flood producing mechanism to Mediterranean conditions, in which intense convective cells are the principal cause of flash flooding, particularly in urban areas.

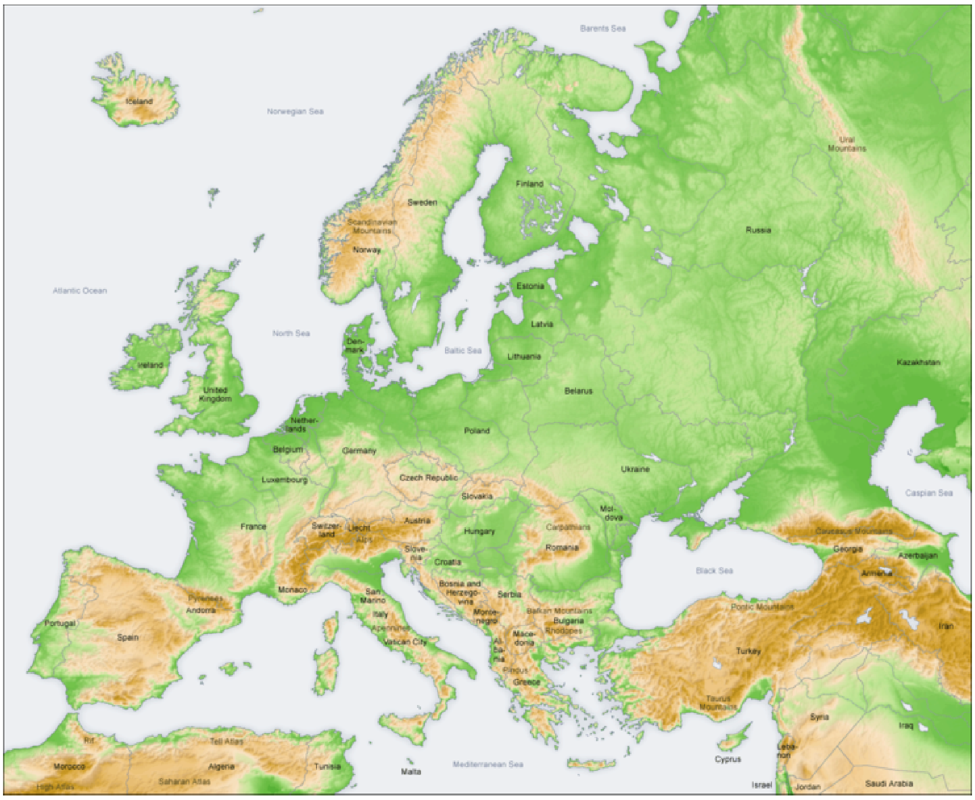

Figure 1 Topography of Europe

2.2.2 Peak flood Estimation

In most European countries, peak design floods are estimated from rainfall intensity duration relationships established by the national (or regional) meteorological services. For urban areas, either Rational Methods of the type originally developed by Mulvany (1851) or numerical hydraulic models of the drainage network are used to transform the rainfall amounts into peak discharge or discharge hydrographs. Much of the basic methodology was established over two decades ago, (e.g. Harremoës (ed.) 1983) and has been augmented by new technologies, the use of radar being an example (Koegst and Krebs, 2004).

In the UK, current practice is defined by the Flood Estimation Handbook (Institute of Hydrology, 1999) which superseded the Flood Studies Report (NERC, 1975), which is still used in Ireland.

In other countries, while there are agencies responsible for hydrometry and for hydrological guidance, there does not seem to be the same accepted uniformity in approach as in the UK. For instance, risk based approaches to design floods have been adopted in a number of countries, e.g. DIN 19700 for dam safety in Germany (Rissler, 2001, Plate, 1982). In France, the relevance of flood duration as well as flood peak was recognised (Sauquet *et al*, 2004) and flood duration frequency (QdF) curves were constructed. From these, mono-frequency hydrographs were derived. This approach, together with the GRADEX method of extending rainfall frequency information, has been used in regionalisation studies at Cemagraf in France, (Mic *et al*, 2002). Similar ideas are described by Le Clerc *et al* (2003) who use two parameters, one describing the spread near the flood peak and the other a flood duration, as well as the more usual scale and asymmetry parameters. The QdF method has also been applied in other countries, e.g. to the Elbe in Germany (Marco and Vašková, 2000).

In Sweden, and as a result of the large number of hydropower installations in this country, design flood estimation has focused on dam spillway design and dam safety (Harlin, 1989, Lindstrom and Harlin, 1992, and Harlin and Kung, 1992).

In the more arid southern countries, special care has to be taken in using hydrometric data from ephemeral channels in the determination of design floods (e.g. Daniil and Lazaridis, 2005).

2.3 Australia

2.3.1 Context

Due to its size, Australia experiences significant variations in meteorological conditions from region to region and also from season to season and year to year. The country is bisected by the tropic of Capricorn and experiences two distinct climates. The land mass north of this tropic includes the northern fringes of Western Australia, the Northern Territory and Queensland and enjoys a tropical climate, and areas south of the tropic, a temperate one. The tropical states have highly predictable weather characterised by hot, wet summers and dry winters. A greater variability occurs elsewhere in the country. Rainfall data in Australia is monitored by nearly 400 well distributed rainfall stations across the country (Lavery *et al*, 1997). Responsibility for maintaining these gauges lies with the Australian Bureau of Meteorology. About 80% of the country has an average annual rainfall of less that 600mm, about 50% has an average of less that 300mm and approximately 30% has an annual average of less than 200mm (Figure 2).

However, these figures mask the variations that exist across the country. The highest rainfall occurs in the tropical rainforest region of north-east Queensland where annual rainfall exceeds 4,000mm with peaks in excess of 10,000mm being not uncommon at some stations (Hobbs *et al*, 1998). Although annual rainfall totals in many areas of Australia are lower than those in Ireland, intensities tend be higher with values that can typically vary from 10mm/hour in the north of South Australia to 70mm/hour in the tropics. However, and more importantly from an urban flooding perspective, rainfall intensities vary from 15mm/hour to 40mm/hour in the heavily populated and well developed coastline that extends northwards and includes Melbourne, Sydney and Brisbane as shown in Figure 3 (Australian Bureau of Meteorology, 2006).

This contrasts with Ireland where hourly rainfall amounts are generally quite low. Hourly totals of 15 to 20mm tend to be associated with return periods of approximately 5 years and hourly totals exceeding 25mm are rare (Met Eireann, 2006).

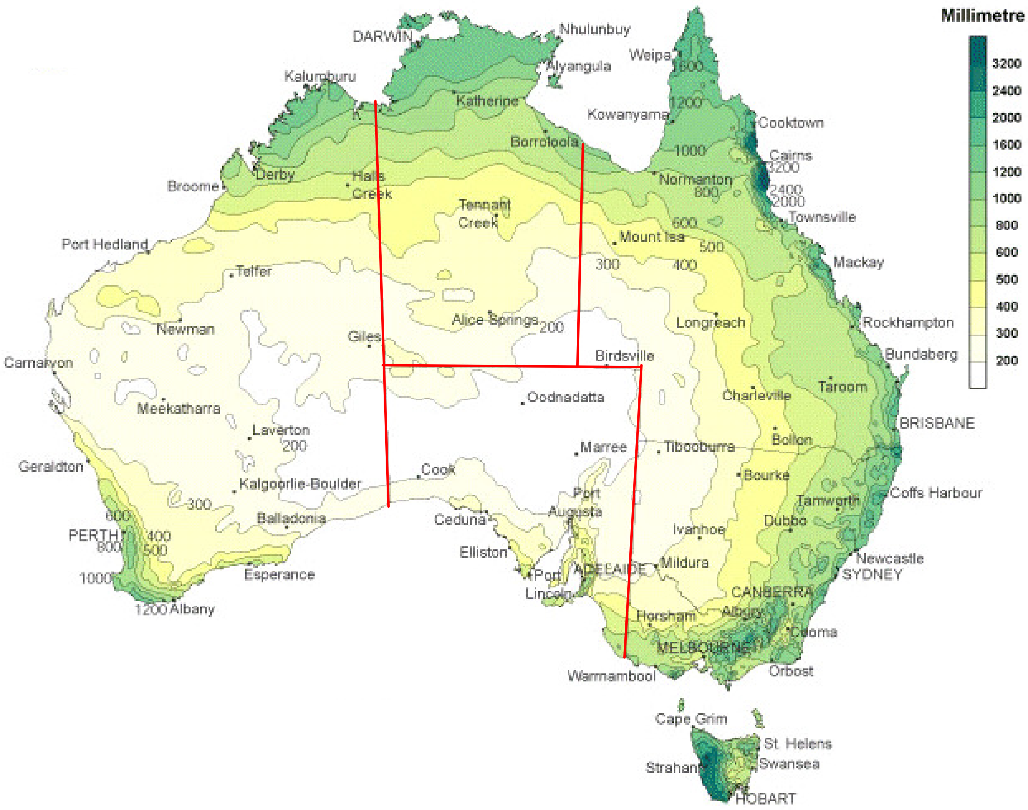

Figure 2 Average annual rainfalls across Australia (Australian Bureau of Meteorology, 2006)

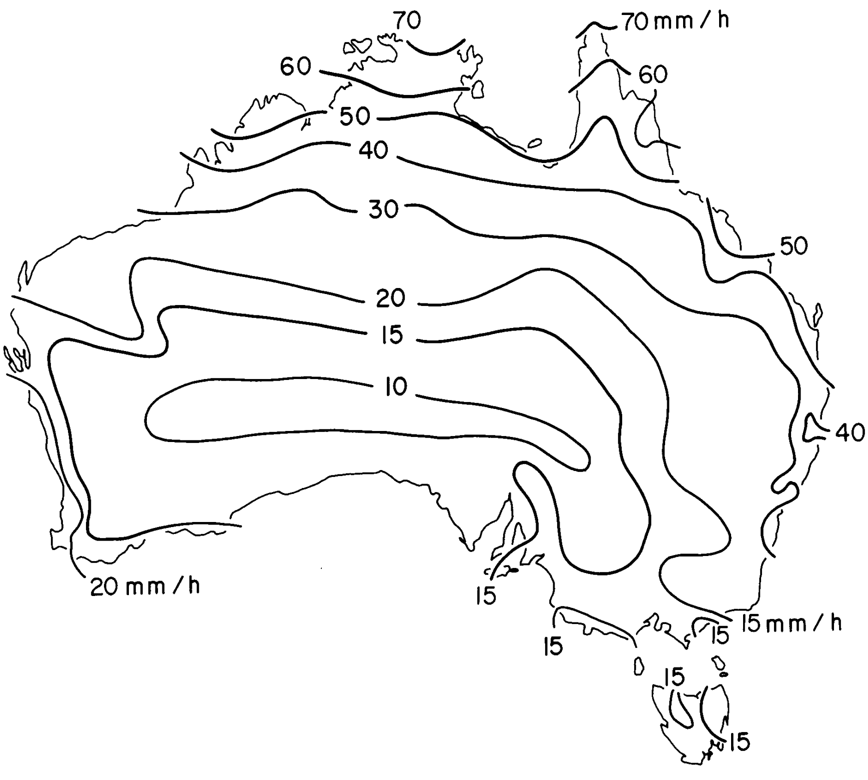

Figure 3 Indicative rainfall intensities across Australia (Australian Bureau of Meteorology, 2006)

2.3.2 Peak flood Estimation

2.3.2.1 Available Guidance

Up-to-date information for design flood estimation in Australian catchments is provided in the Australian Rainfall and Runoff (ARR) guidelines (Institution of Engineers, Australia, 1987 and 1997). The ARR is a national document that provides guidance, rather than prescription, for practicing engineers. ARR was first published in 1958 with updated editions that accounted for increased data and better knowledge following in both 1977 and 1987. The current edition, ARR97, is a revision of the ARR87 document that will facilitate progressive amendments of ARR in the future.

2.3.2.2 Methodologies

In terms of urban flooding and stormwater management procedures, peak flow estimates for specified average recurrence intervals (ARI's) from urbanised and small rural catchments are of most concern.

- **Small to Medium Rural Catchments**

The estimation of peak flows on small to medium rural catchments is probably the most common design problem in Australian flood estimation. These estimates are required for the design of culverts and small bridges, drainage works and soil conservation works etc. In almost all cases, no observed or gauged data are available in the proximity of the design site.

In the past, one procedure (namely the Rational Method as set out in ARR77) and set of design data have commonly been used for very large areas or the whole of Australia. The evidence now available has led to the recognition that there is not sufficient data from urban catchments to develop general runoff-estimation procedures that would be applicable to all Australia catchments. Different flood-producing characteristics and design values occur in different regions. Recent times in Australia have seen significant advances in the understanding of how these regional variations impact on peak flow values. These advances are included in the probabilistic interpretation of Rational Method procedures that are outlined in ARR87 and ARR97.

The regional variations have generally been developed to represent catchment characteristics with effects that can be identified in the observed data and take account of broad-scale differences in catchment characteristics through the region, such as general geological, soil and topographical features, and variations in the type of runoff processes. Data for these parameters is given in ARR97.

State authorities are responsible for collection and analysis of this regional data and as a consequence, the regional methods on which the data is based conform to state boundaries. This is a common criticism of ARR and it is hoped that more logical and realistic boundaries will be able to be used for future methods.

The Rational Method can generally be adopted for peak flow estimation for small to medium rural catchments, typically defined by upper limit catchment areas of $25km^2$ and $250km^2$, respectively. The general form of this equation is:

$$Q_Y = 0.278 C_Y I_{tc,y} A \qquad \textbf{Eqn. 1}$$

where Q_Y is the peak flow rate *(m^3/s)* of average recurrence interval (ARI) of *Y* years, C_Y is the runoff coefficient (dimensionless) for ARI of *Y* years, *A* is the catchment area (km^2) and $I_{tc,y}$ is the average rainfall intensity (mm/h) for design duration of t_c hours and ARI of *Y* years.

The peak flow rate is obviously dependent on two main input parameters. The first of these is the runoff coefficient (C_Y) and from Eqn. 2, the value of the runoff coefficient can be determined from:

$$C_Y = \frac{Q_Y}{0.278 A I_{tc,y}} \qquad \textbf{Eqn. 2}$$

Values of $I_{tc,y}$ for all of Australia are available in Book II of ARR. However, for several regions with adequate streamflow data, flood frequency analyses have been carried out for many small to medium sized catchments. From Q_Y values obtained by these analyses, values of C_Y have been determined and these, where appropriate are recommended for use. Derived values of C_Y have been found to vary in a reasonably consistent manner over the range of ARI values on a given catchment, and for different catchments over a particular region and therefore, provide a suitable basis for design.

Where insufficient streamflow data exists for the derivation of C_y values, it is necessary to recommend rather arbitrary values based on judgement, with some checking against observed data where possible.

The second parameter of concern in an application of the Rational Method is the time to concentration (t_c). For these Rational Method procedures recommended throughout Australia, formulae are specified in ARR for estimating t_c. The specified formula must be used with the particular procedure. In other cases where a complete procedure based on observed data is not available, the following version of the Bransby Williams formula has been adopted as an arbitrary but reasonable approach (Institution of Engineers, Australia, 1997). This is:

$$t_C = \frac{58L}{A^{0.1} S_e^{0.2}} \qquad \textbf{Eqn. 3}$$

where t_c is the time of concentration (min), *L* is the mainstream length measured to the catchment divide (km), *A* is the catchment area (km^2), and S_e is the equal area slope of the main stream projected to the catchment divide (m/km). This is the slope of a line drawn on a profile of a stream such that the line passes through the outlet and has the same area under it as the stream profile. In general, the values of t_c calculated by the relevant formulae give the total rainfall duration for rural catchments.

While Rational Method procedures are the most commonly applied methods for peak flood estimation in Australian catchments, other methods still have merit. Design Hydrograph Methods that involve unit hydrograph or runoff routing principles with design rainfall and loss data for a particular region, can be applied through ARR with relative ease.

Regional flood frequency methods are also recommended. In the development of these methods, flood frequency analyses (Book IV) are carried out on data from all catchments over a range of sizes in the region with sufficient records. Relationships between flood frequency data and catchment characteristics are then developed. Rainfall characteristics can also be incorporated. These relations allow estimation of floods of the required frequency at any location in the region.

• Urban Catchments

In Australia, urban area hydrological models are the same in principle to those applied to rural catchments. The Rational Method, unit hydrograph procedures and runoff routing models can all be applied subject to the availability of suitable data. However, at present, insufficient data exists to calibrate and validate hydrological models on a wide scale and rainfall-runoff models employing statistical design rainfall data are used for most applications. The Rational Method (Eqn. 1) is the best known of these and is the model most commonly used in urban drainage design.

2.3.3 Stormwater Management

Rapid urban growth in areas of Australia over the last three decades has resulted in an ever expanding footprint of urbanising areas around metropolitan areas. This has resulted in an increasing pressure on the existing drainage infrastructure in many areas and recognition that a fundamental change in the way urban water resources are managed is required.

Rainfall intensities in many areas of Australia are high and as such, attenuation of stormwater runoff is not realistic. Consequently, the use of sustainable urban drainage systems (SUDS) is not advocated. The need however, for protecting receiving waters and existing waters is recognised and is embraced in the concept of Water Sensitive Urban design (WSUD). WSUD is a catch-all term for environmentally sustainable water resource management in urban areas but more accurately, is a term used to describe an approach to urban planning that offers sustainable solutions for integrating land development and the natural water cycle (Lloyd, 2001). The use of integrated stormwater management systems is one component of WSUD that aims to minimise the impact of urban development on receiving waters. A major part of this is a source control approach to development that facilitates greywater reuse, through for example rainwater harvesting systems. This, in some developments where it has been implemented has been shown to have a positive impact on stormwater management.

WSUD has not however been universally adopted in Australia. The main impediments to its national adoption are similar to the perceived deterrents for the large scale adoption of some SUDS in Ireland and include the absence of an effective regulatory and operating environment at national, state or local government level, insufficient information on the operation and maintenance of Best Management Practices in WSUD and the perceived additional project costs from WSUD implementations.

2.4 United States of America

2.4.1 Context

Catchments in the US vary enormously and range from small-scale catchments, to much larger catchments such as the Mississippi which drains 41% of the U.S., parts of two Canadian provinces, and is the fourth largest catchment in the world.

The Federal Government provides a vast array of data collection, storage and dissemination in support of integrated flood management. Amongst these, the *US Geological Survey* provides baseline information and operates gauging stations on most US rivers. The largest allocation of federal resources to support integrated flood management is made annually to the *U.S. Army Corps of Engineers*, the majority of which is directed towards the lower reaches of rivers. The *National Oceanic and Atmospheric Administration* makes weather and flood forecasts as well as historic data available.

The annual average precipitation in the contiguous United States is shown in Figure 4. Two patterns stand out: the gradual transitions east of the eastern flanks of the Rockies, versus the heterogeneity in the West. In the West, the rainfall patterns are strongly controlled by topography and proximity to the Pacific Ocean. Places east of a N-S oriented mountain range, such as the Cascades of Washington and Oregon, are dry, drier than places at the same elevation on the west side of the same mountain range. A second pattern dividing east from west is that in the East, it tends to be wetter to the south, where warmer air holds more water vapour, which largely originates over the Gulf of Mexico. In the West, it is wetter to the north, as most frontal systems stay north, especially in summer.

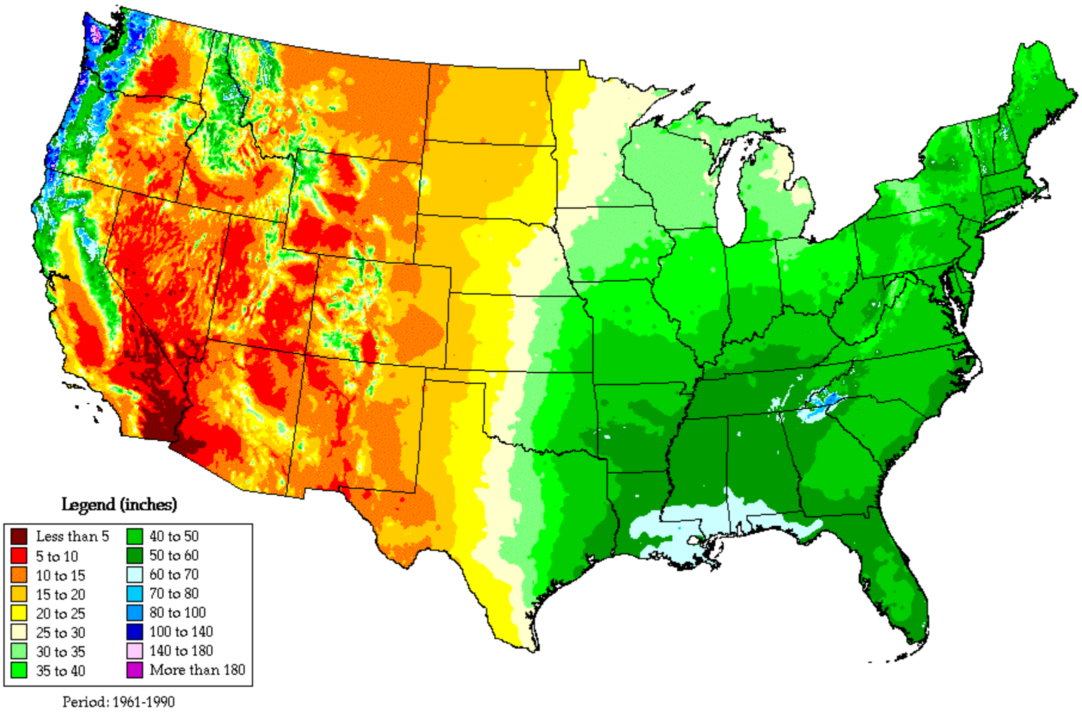

Figure 4 Annual average rainfall in the United States of America

2.4.2 Peak Flow Estimation

It would appear that, because of significant variations in climate and geography across the country, each State, in effect, regulates its own affairs in respect of stormwater management. For the purpose of this discussion, the methodology adopted by the State of New Jersey, as published in the New Jersey Stormwater Management Practices Manual (2004) will be taken as an example of current best practice in the US.

The State of New Jersey recommends the use of three runoff computation methods. The first two of these are the Rational and Modified Rational methods and the other is the Natural Resources Conservation Service (NRCS) method. Use of the Rational and Modified Rational Methods should be limited to drainage areas less than about 10 hectares with generally uniform surface cover and topography.

The NRCS method is perhaps the most widely used method for computing stormwater runoff rates, volumes and hydrographs. It uses the following empirical non-linear equation to compute runoff volumes:

$$\text{Runoff Volume (mm)} = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad \textbf{Eqn. 4}$$

where P is an accumulated rainfall value in *mm* and S is determined from the following relationship:

$$S = \frac{25400}{CN} - 254 \qquad \textbf{Eqn. 5}$$

where CN is a curve number representing the runoff potential of a surface. Curve number values typically vary from 2 to 100.

The methodology is particularly useful for comparing pre- and post-development peak rates, volumes and hydrographs. The key component of the method is the use of a curve number (CN), which is based on soil permeability, surface cover, hydrologic condition and antecedent condition. Suffice to say that high curve numbers (up to 100) indicate complete runoff with little retention, and low numbers indicate high retention and reduced runoff. The CN is the rough equivalent of the C-value used in the Rational Method.

A dimensionless unit hydrograph converts volumes into runoff rates as shown in Figure 5. Time of concentration is the key component of the dimensionless unit hydrograph.

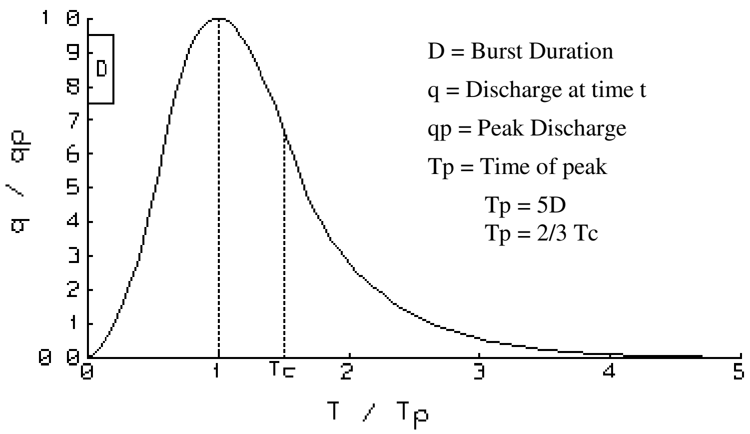

Figure 5 NRCS dimensionless unit hydrograph

The NRCS method is primarily applicable to small to medium catchments where flow originates as direct runoff from precipitation in the form of rain, characteristically distributed over the catchment (Archer *et al*, 2000). The method may not be reliable in catchments where floods typically include snowmelt or where runoff is attenuated by surface storages such as lakes and swamps or subsurface storage in karstic limestones or chalk.

Adherence to the New Jersey Stormwater Management policy requires that the impact of development is assessed in terms of:

- Groundwater recharge
- Stormwater quality
- Stormwater quantity

Consequently the issues of stormwater quantity and quality are treated together. In terms of groundwater recharge, new developments must comply with one of the following requirements:

Requirement 1: That 100% of the site's average annual pre-developed groundwater recharge volume be maintained after development;

or

Requirement 2: That 100% of the difference between the site's pre- and post-development 2-year runoff volumes be infiltrated.

For stormwater quality issues, it is required that structural and non-structural measures are designed to a standardised design storm. This storm has a rainfall depth of 1.25 inches and a total duration of two hours as illustrated in Figure 6.

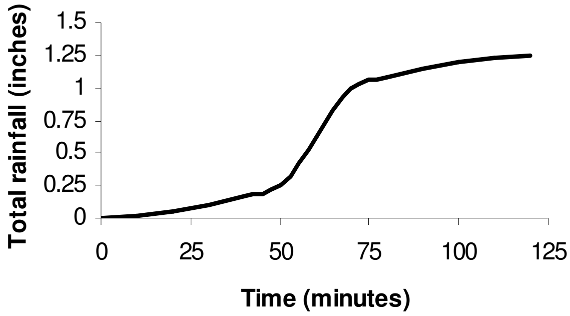

Figure 6 New Jersey Stormwater Management Policy 1.25/2-hour stormwater quality design storm

Finally, for stormwater quantities, the impact of development with respect to three frequencies must be assessed. These frequencies, which are of primary concern for stormwater quantity control due to their potential to cause downstream erosion and/or flooding, are the 2, 10 and 100-year events.

2.4.3 Stormwater Management

For over two centuries, structural measures, such as the construction of levees and flood walls, the control of tributaries to major floodplains by constructing upstream flood storage reservoirs, dominated the response to flooding. The 1936 flood along the Mississippi basin prompted the Federal Government to assume responsibility for flood control throughout the nation, again with a clear structural focus. It was not until about the mid 1950's that initial proposals were made for the use of non-structural measures to reduce flood damage. Such non-structural measures include:

(a) the use of flood warning systems;
(b) the purchase from willing sellers of large tracts of frequently flooded agricultural land to serve as flood storage areas;
(c) subsidised flood insurance with the requirement for participating communities to regulate land use in the floodplain.

Sustainable approaches to urban development have been promoted in the past 30 years, but only recently have they gained broader acceptance as low impact development (LID) in the

USA, sustainable urban drainage systems (SUDS) in the U.K. and water sensitive urban design (WSUD) in Australia. LID is an innovative approach to stormwater management that is being implemented by federal agencies, state, and local governments for aquatic resource protection and regulatory compliance. LID is a site level stormwater management design approach with the objective of maintaining the hydrologic cycle or meeting targeted watershed objectives. LID seeks to reduce and/or prevent adverse runoff impacts through sound site planning and by using both non-structural and structural techniques that preserve or closely mimic the site's natural or pre-developed hydrologic response to precipitation. As such, LID promotes the concept of designing with nature.

The New Jersey Stormwater Management Rules require that the design of any development that disturbs more than an acre of land or increases impervious the surface by at least 0.25 acres must incorporate the following non-structural stormwater management strategies 'to the maximum extent possible':

1) Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss;
2) Minimise impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces;
3) Maximise the protection of natural drainage features and vegetation;
4) Minimise the decrease in pre-construction 'time of concentration';
5) Minimise land disturbances including clearing and grading;
6) Minimise soil compaction;
7) Provide low maintenance landscaping that encourages retention and planting of native vegetation and minimises the use of lawns, fertilisers and pesticides;
8) Provide vegetated open-channel conveyance systems that discharge into and through vegetated areas;
9) Provide preventative source controls.

2.5 Asia

2.5.1 Context

The climate in Asia varies from region to region, from tropical in the south to sub-arctic in the north but is generally humid and dominated by monsoon, equatorial, tropical and marine oceanic influences and consequently some Asian areas are the wettest in the world. The average annual rainfall in Japan is about 1718mm/year (Murase *et al*, 2004). The rainfall in China is more variable with northern parts typically having rainfalls of 250mm/year, the northwest having rainfalls of about 400mm/year and the southwest and southeast having average rainfalls that can exceed 2000mm/year (Zhang and Wen, 2001). In Malaysia where an equatorial climate is experienced, average rainfalls are of the order of 2500 mm/year (Department of Irrigation and Drainage, Malaysia, 2000). Bangladesh, the worst flood hit country experiences an average rainfall of 2160mm/year of which 1728mm/year is during the monsoon season (Chowdhury, 2003). In India where the average annual rainfall is 1190mm/year, western areas can experience rainfalls that exceed 5000mm over the course of a year (National Institute of Hydrology, India, 2006). Consequently, with the exception of some regions in China, Asia endures rainfall that is higher, in some cases significantly higher, than is experienced in Ireland. Average annual rainfall rainfalls across Asia are summarised in Figure 7.

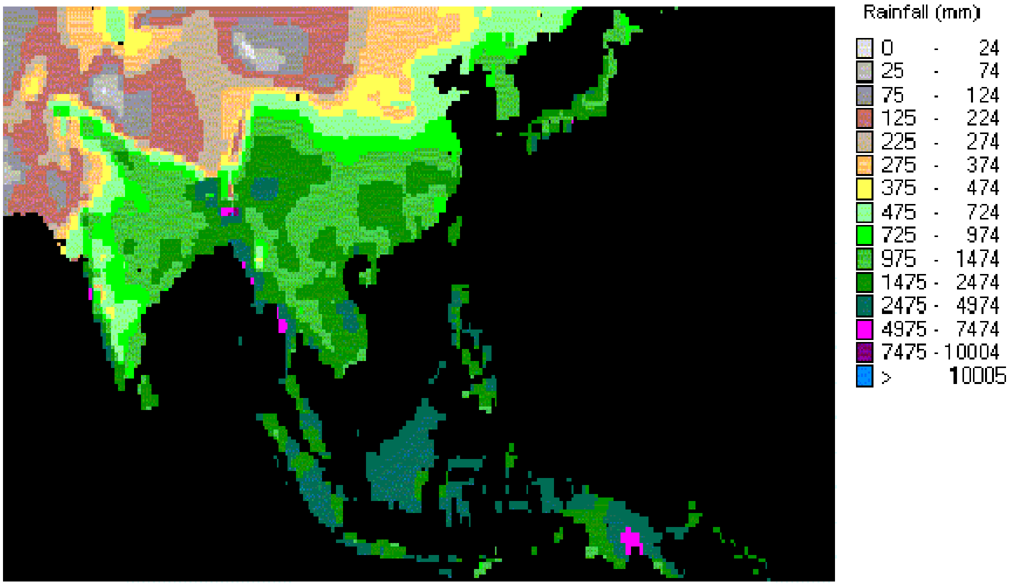

Figure 7 Average annual rainfalls across regions in Asia

2.5.2 Peak Flow Estimation in Asian Catchments

Commonality exists in the methodologies for peak-flow estimation from urban catchments in countries across Asia with Rational type formulae being common. However, differences in the form of the equation that is applied are apparent. In Japan, for instance, the Rational Method as represented (Eqn. 1) is generally applied but in China and Malaysia, the methods adopted are detailed in Table 2. Malaysian catchments tend to differ from urban catchments elsewhere in Asia and are characterised by very irregular topographies. It was recognised that Rational type formulae that form the basis for urban flood design do not take into account areal and temporal variation in storm rainfall and the detention and storage that occurs in surface depressions, gutters, and channels, and the Malaysian Urban Drainage Unit of the Drainage and Irrigation Department modified the method to improve its representation of these catchments.

Table 2 Rational type formulae used in China and Malaysia

China	Malaysia
$Q = \varphi F q$ where Q is the design rainwater discharge (l/s), φ is a runoff coefficient, F is the rainfall collecting area (ha) and q is the design rainstorm intensity. Values of q are specific to regions in China	$Q = C_s CIA$ where Q is the design flow rate, C is a dimensionless runoff coefficient, I is a rainfall intensity. $C_s = \dfrac{2t_c}{2t_c + t_d}$ where $t_C = t_o + t_d$, and t_o is the time to peak for overland flow and t_d is the time to peak for flows in storm drains

2.5.3 Stormwater Management

There are no universally adopted methods for managing excess stormwater across Asian countries. As might be expected, the wealthier countries of Japan and Malaysia tend to more sophisticated engineering approaches to stormwater management. In Japan, for example, large underground storage tanks combined with permeable type pavements and infiltration pipes are commonly implemented. Such an arrangement is shown in Figure 8.

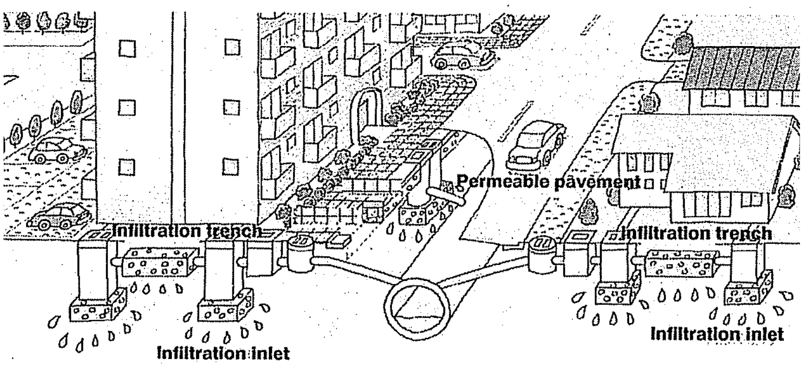

Figure 8 Urban stormwater management in Japanese cities (Fujita, 2005)

In addition to regional stormwater control of the type in Figure 8, it is generally required in Japan, that private properties install soakaways, infiltration trenches, and detention basins (Fujita, 2005). In many cases, this is achieved by converting residential septic tanks that have become redundant, to stormwater storage facilities.

In Malaysia and in compliance with the Stormwater Management Manual for Malaysia (Zakaria *et al,* 2004), all new developments must adhere to best management practices which result in stormwater impacts in terms of quality and quantity being neutral. The manual promotes a more environmental 'control at source approach' which emphasises the need for stormwater management and does not permit the previously acceptable approaches where excess stormwater was drained as expediently as possible, regardless of the environmental consequences. The source control approach endorses SUDS type implementations that can achieve detention/retention, infiltration, conveyance, purification processes as well as delayed flow. Also, on site detention (OSD) which includes Bio-Ecological Drainage Systems (BIOCODS) such as swales, sub-surface modules, dry ponds, wet ponds, detention ponds, constructed wetlands and wading streams are recommended (Zakaria *et al,* 2004).

2.6 South Africa

2.6.1 Context

South Africa has a temperate climate that is influenced by the warm Agulhas current from Mozambique as well as the Indian Ocean to the east and the cold Benguela current from the Atlantic Ocean on the west coast. Most rainfall occurs as a result of moist warm Indian Ocean air currents and this contributes to a rainfall distribution that decreases from east to west across the country. According to the South African Department of Water Affairs and Forestry (DWAF), the national average annual rainfall of about 497mm is well below the world average of 860mm. While a comparatively narrow region along the eastern and southern coastlines is moderately well watered, the greater part of the interior and the western portion of the country are arid or semi-arid. Sixty-five percent of the country receives less than 500mm of rain annually. Twenty-one percent of the country receives less than 200mm (DWAF, 2006). Furthermore, the average annual evaporation that ranges from 1100mm to 3000mm across the country is higher than the annual rainfall (Dallas, 2000). According to the South African Weather Service (SAWS, 2006), average annual rainfall in Cape Town is 510mm and average temperatures range from 9^{o}C to 17^{o}C in July to 16^{o}C to 27^{o}C in February. Overall the climate in South Africa is drier than that in Ireland.

2.6.2 Peak Flow Estimation in South African Catchments

When no recorded data are available at the site of interest, or if the records are inadequate, the common event-based rainfall/runoff methods for design flood estimation in South Africa include the Unit Hydrograph, Rational and SCS (formerly US Soil Conservation Service) Methods (Smithers and Schulze, 2002). South Africans have also developed their own Software package, UPFLOOD, in which the Standard Design Flood (SDF) forms the basis of the model. The SDF is a numerically calibrated version of the Rational Method (Eqn.1) to suit South African catchments (Alexander, 2002).

In applications of the conventional Rational Method formula, the runoff coefficient, C, is determined by giving numerical values to the catchment characteristics. This differs from applications of the SDF Method where the runoff coefficient is a calibrated value, based on a statistical analysis of recorded data within the region. Furthermore, runoff coefficients in the SDF Method are regional values and not site-specific values.

2.6.3 Stormwater Management

No standardised guidance document currently exists in South Africa for estimating peak flows from either urban and greenfield sites. However, a new Integrated Water Resource Management Plan (IWRMP) offers guidance on stormwater management for local authorities across South Africa. This government supported plan offers an integrated and holistic approach to stormwater control and deals with issues relating to both water quantity and quality.

3 Rationale of Work-Package 4.1

3.1 Background to Work-Package 4.1

Recent times in Ireland have seen an upsurge in the development of residential, commercial and industrial properties. Improvements in transportation that have accompanied this development have facilitated the dispersal of significant populations to the outskirts, and beyond, of urban areas. This has resulted in continued expansion of urban belts around the country where the outer fringes of towns and cities have increasingly become transition zones with adjacent centres of population growing together. Furthermore, the National Spatial Strategy for Ireland from 2002 to 2020 (National Spatial Strategy, 2002) is promoting a balanced approach to social, economic and physical development between regions. The strategy recognises that development in Ireland over the last decade has been uneven and has led to rapid development and congestion in some regions, but underdevelopment in others. The strategy has identified towns and cities that have the potential to be renewed and developed. These urbanising areas are shown as an overlay on the country's river network in Figure 9. Figure 9 indicates that a significant number of these 'renewable' areas that have been identified for further development are located along the corridors of the country's rivers.

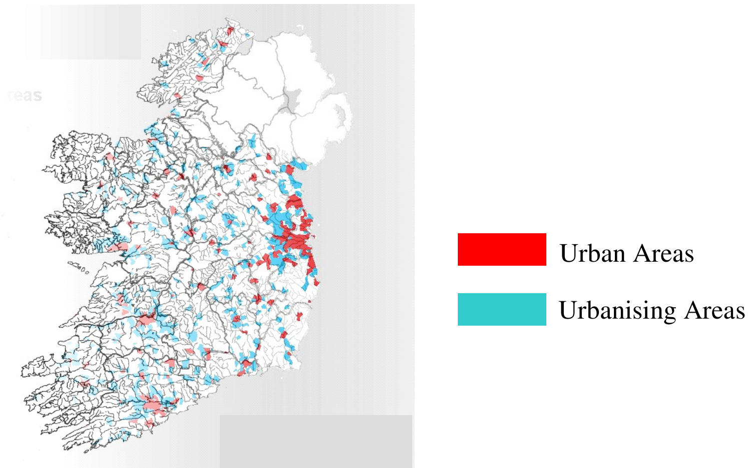

Figure 9 Interaction of urban and urbanising areas defined in the National Spatial Strategy (2002) with the river network (source National Spatial Strategy team)

3.2 Impacts of Urbanisation

Urbanisation within river catchments is typically characterised by the replacement of soft permeable surfaces (greenfield areas) with hard standing areas such as roofs, roads and pavements. The changes to the flow regime of receiving streams brought about by increases in both population and building density are well reported. Larger impervious areas result in a greater proportion of incident rainfall appearing as direct runoff than would be the case if the catchment was in its rural state. Furthermore, the addition of storm sewers and gulleys, combined with the culverting and realignment of natural streams which occur during urbanisation, results in stormwater being conveyed through the drainage network more rapidly. Higher velocities affect the shape of the runoff hydrographs (hydrographs are faster to peak and faster to recede) from urban areas and since larger runoff volumes are discharged in shorter time intervals, peak rates of flow inevitably increase. Complete urbanisation in a catchment can reduce hydrograph rise time by 75% and can, depending on the responsiveness of the catchment before urbanisation, increase mean annual flood magnitudes by between 200% and 600% (Natural Environment Research Council, 1979). However the actual increase is, among other factors, heavily dependent on the relationship of the urban response to the original rural response.

Increases in flood magnitudes can have implications for downstream sewers and rivers. This is of particular concern in Ireland, where many built up areas are located at the downstream end of rivers and drainage systems and where there is increased pressure to allow upstream developments. Increased levels of runoff can also overload existing drainage systems, resulting in surcharging of component pipes in these systems. This problem will be exacerbated in coastal or tidal areas and in inter-tidal river zones where climate change impacts will result in increased tide levels going forward (Greater Dublin Strategic Drainage study (GDSDS), 2005). Consequently, urban flood analysis requires the application of hydrological and hydraulic principles.

3.3 Peak Flow Estimation

Historically, urban flood peaks were estimated using deterministic or fixed percentage runoff formulae. These Rational type methods are generally based on each surface type having a fixed percentage runoff and in their simplest form do not properly account for variations in rainfall intensity, flow velocity or temporal storage in a sewer system. The rate of increase in the contributing catchment area to peak flow generation means that it is only truly applicable to small urban catchments.

The current approach to stormwater management in Ireland promotes sustainable development by restricting the outflow from new developments to the greenfield values that would have occurred prior to development (Doyle *et al*, 2003). In practice, this involves determining runoff rates for specified design storms from urban portions of development areas using Rational type methods and controlling or attenuating the difference between these and the greenfield runoff before allowing entry to drainage networks or water courses. Dublin City Council (1998) suggest using the 3-Variable equation presented in the Institute of Hydrology (IoH) Report No. 124 for developments of up to 24ha and using the 3-paramater equation contained in Flood Studies Supplementary Report (FSSR) No. 6 (NERC, 1978) for developments in excess of 24ha. The 3-Variable equation in the FSSR No. 6 evolved following testing of the FSR methodologies in which it was shown that floods on small catchments were less well predicted than on larger ones. These equations yield mean annual flood flow values ($\overline{Q}$). Peak flows from these equations for specified return periods are determined by multiplying $\overline{Q}$ values by dimensionless regional growth curve constants derived in the FSR. These constants are based on average responses to rainfall for 1700 record years from 112 gauged sites across Ireland. The concept of a unique growth factor for a specified design storm that is applicable to all areas of the country is open to question and Bruen (2005) has illustrated that these factors for catchments on the east coast of Ireland are low and result in underestimates in peak flow values.

The IoH No. 124 and the FSSR No. 6 3-Variable equations are expressed in terms of catchment descriptors as follows:

$$\textit{IoH No. 124 Eqn.:}\ \overline{Q} = 0.00108 AREA^{0.89} SAAR^{1.17} SOIL^{2.17} \qquad \textbf{Eqn. 6}$$

$$\textit{FSSR No. 6 3-Variable Eqn.:}\ \overline{Q} = 0.00066 AREA^{0.92} SAAR^{1.22} SOIL^{2.0} \qquad \textbf{Eqn. 7}$$

where $\overline{Q}$ is the mean annual flood, *AREA* is the catchment area, *SAAR* is the standard annual average rainfall and *SOIL* is a number depending on soil type.

The FSSR No. 6 3-Variable equation is based on a regression analysis of 53 small catchments (less than 20km^2) of the FSR data set. However, these catchments were not evenly distributed across the full range of soil types with 41 of the catchments having soil types 4 and 5. Consequently, the equation performed well for high runoff soils (SOIL indices greater that 0.45 and representing soil types 4 and 5) but less well for soil types 1, 2 and 3. Furthermore, a problem using this equation lies in accurately determining numerical values for the relevant catchment descriptors, and in particular the SOIL parameter. SOIL parameters tend to be determined from poor resolution FSR mapping where perhaps, a site specific value would yield more accurate mean annual flows. The problem of determining SOIL parameters from FSR maps is exacerbated for cases where catchments are small. The standard factorial error for the 3-Variable FSSR No. 6 equation is 1.58 (Cawley and Cunnane, 2003).

The IoH No. 124 equation is widely used in the UK and, as a result of it being recommended by Dublin City Council, is now commonly used throughout Ireland for estimating greenfield runoff for stormwater management of development sites. The equation is based on regression studies of 87 catchments, 71 of which were completely rural (rural fraction of less that 0.025). Catchment areas varied up to maximum values of 25km^2 and as with annual average rainfall (SAAR), were evenly distributed over the catchment sample. However, analysis of the SOIL parameter indicated that only 16 of the 71 rural catchments were represented by soil types 1, 2 and 3 but 39 of the catchments were characterised by very high runoff, soil type 5 (Cawley and Cunnane, 2003). It was further shown that for the 17 catchments of the sample having areas of less than 5km^2, soil types 1 and 2 are not represented at all, soil types 3 and 4 are represented in 4 catchments and soil type 5 has 9 catchments. Consequently, as with the case of the FSSR No. 6 3-Variable equation, a significant bias exists towards high runoff soils. The standard factorial error for the IoH No. 124 equation is 1.65.

It is important that inconsistencies in the sweeping approach to the application of these statistical formulations are not overlooked. While these equations are based on ‘small’ catchments, the limiting areas for the FSSR No. 6 and IoH No. 124 equations are 20km^2 and 25km^2 respectively with only one catchment in the IoH study having an area of less than 1km^2. The scale of catchments for SUDS applications is often less than 1km^2 and this calls into question the ‘one size fits all’ approach often applied to urban drainage issues in Ireland. This, combined with the fact that significant areas of Ireland are represented by soil types 1, 2 and 3 (low to medium runoff) which are not well represented in either the FSSR No. 6 or IoH equations, further questions the confidence in predicted flows. This is potentially compounded when it is considered that predicted flows are very sensitive to the SOIL parameter included in the calibration and which for Ireland, is generally based on poor resolution FSR mapping. This sensitivity to the SOIL parameter was demonstrated by Cawley and Cunnane (2003) who, by including three catchments with urban fractions of 0.03, 0.05 and 0.06 that were originally excluded in the IoH catchment sample, showed that the regression equation (Eqn. 6) would become:

$$\overline{Q} = 0.001 AREA^{0.89} SAAR^{1.15} SOIL^{1.88} \qquad \textbf{Eqn. 8}$$

The standard factorial error of this equation was shown to be 1.71.

It is anticipated that in the future, issues relating to determining catchment descriptors from poor resolution mapping will be resolved by using Geographic Information Systems (GIS). This would be in accordance with the approach in the UK Flood Estimation Handbook where the process of determining channel descriptors that would typically have been associated with large operational difficulties such as stream frequency, channel length and slope is no longer required. These have been replaced by parameters that lend themselves more readily to unique determination from digital mapping databases. It should be noted that GIS are currently being used on some Irish catchments in work being done to meet the requirements of the Water Framework Directive.

Climate change predictions of increased winter rainfalls in terms of intensity and frequency can also be expected to impact on urban flood issues into the future. Currently, the majority of rainstorms that pass over Ireland are frontal, but it is expected that more convective rainfall will occur in the future. Higher intensity storms will further stress drainage networks and this combined with the "locking" of outfalls that could potentially occur, will in some cases surcharge sewer systems.

Future climate change and changes in catchment land use have the potential to exacerbate current urban flooding problems and highlight the need for a more radical and holistic approach to urban runoff control in Ireland. This is accepted in the Report of the Flood Policy Review Group (2004) where the need to appreciate, accept and manage future flood risk in vulnerable areas without the additional pressures to develop in these areas is recognised.

3.4 Aims of Work-Package 4.1

In light of the uncertainties that result from the issues raised in Sections 3.2 and 3.3, the main aim of this work-package was to undertake a scoping study to review urban flood issues in Ireland. The scoping study is not intended to develop new or improved methodologies for peak flow estimation or stormwater management, but rather to gauge the opinions of practitioners dealing with these issues on a day-to-day basis. From this, it is envisaged that recommendations for future Research and Development for improving methodologies for Urban Catchment Flood Analysis that will evolve from the review will be linked to specific problems encountered on the ground.

With regard to this main aim of the work-package, the following will be undertaken:

- A review of the methods of flood estimation in urbanised catchments currently in use in Ireland;
- An assessment of deficiencies associated with urban-runoff control in Ireland;
- A development of achievable objectives for further work-packages under the urban catchment flood analysis Work-Group of the Flood Studies Update.

Full details of how these specific tasks were undertaken are detailed in Chapter 4 of the report that follows.

4 Approach to Work-Package

4.1 Introduction

The methodology of the scoping study adopted by the CWRR was structured to satisfy the technical requirements of WP 4.1. These requirements are summarised as:

(i) Reviewing the methods of urban catchment flood analysis currently in general use in Ireland;
(ii) Reviewing the status of these and other methods with regard to software provision and the scientific and legal supportability of the methods;
(iii) Recommending items of Research and Development with the capability of delivering improved and generally applicable methods of urban catchment flood analysis.

The various phases of the methodology, shown in Figure 10, were undertaken over a six month period that commenced with a project initiation meeting with the Technical Steering Group of the FSU in December 2005.

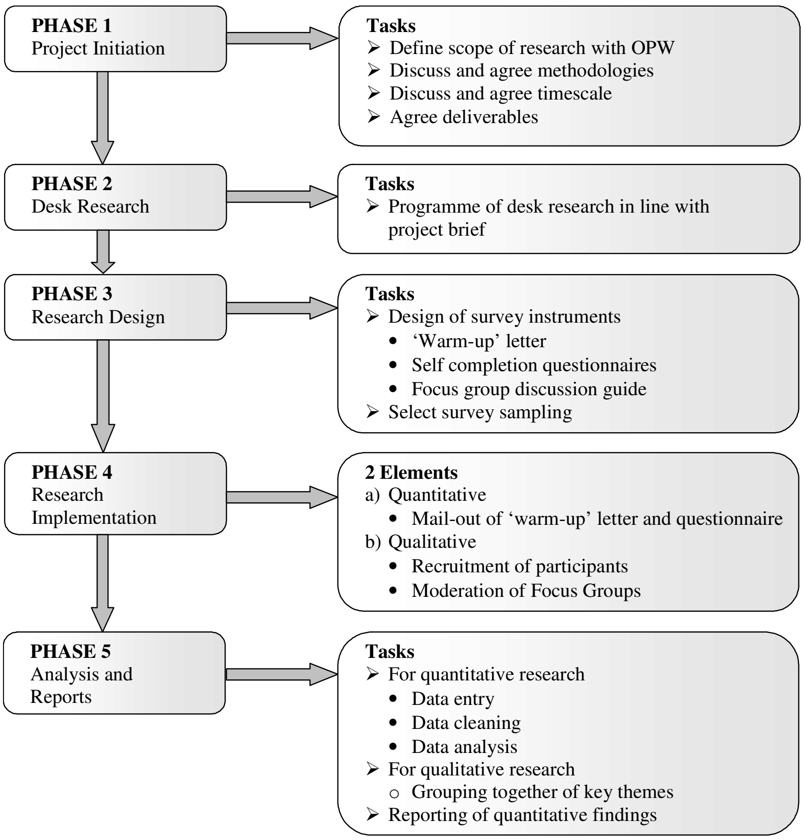

Figure 10 Overview of work-package 4.1

While the scoping review of urban flooding issues involved an ongoing desk study, the main body of data to satisfy (i) and (ii) of the technical requirements had its source in *Phase 3* and *Phase 4* of the Work-Package and involved engaging with practitioners in the area of urban flooding.

Two elements comprised *Phase 3* and *Phase 4*:

Element 1 – Quantitative Research
The quantitative research in the programme involved the preparation of a postal questionnaire for circulation to stakeholders in target sectors with the objective of generating both baseline and detailed information on currently applied approaches to estimating and managing stormwater runoff in urban areas. Information provided in the questionnaire also facilitated the recruitment process for Element 2 of the research.

Element 2 - Qualitative Research
The qualitative element of the research involved Focus Groups that were recruited from the questionnaires in Element 1. Focus Groups concentrated on specific issues identified in Element 1 that were of particular concern to practitioners of urban hydrology in Ireland.

4.2 Quantitative Research

The *Quantitative Research* in this Work-Package 4.1 involved two main elements. These are summarised as:

- Identification of target sectors
- Preparation of survey instruments

4.2.1 Identify Target Sectors

Target sectors were selected to cover a range of organisations, agencies and institutions who would be involved with planning and design issues pertaining to urban drainage and urban flooding or who would have responsibility for ensuring that stormwater is controlled according to best practice. The target sectors that were identified for this work-package are summarised as:

- Engineering consultants
- Engineering contractors
- Architects / landscape architects
- Local Authorities
- County Councils
- City and Town Councils
- Dublin Cork and Galway Corporations
- Academics

Organisations in each of the Target Sectors were identified from a number of sources including the directories of the Association of Consulting Engineers of Ireland and the Irish Construction Federation, the Engineers Ireland water correspondence files and internet sites.

Contact names for individuals in these organisations / agencies that were likely to be involved in urban flooding issues were obtained primarily from a cold-calling exercise to the administrative section of the organisation. A *Microsoft Access* database was established in the CWRR to contain the details of names and addresses for each contact.

4.2.2 Produce Survey Instruments

Two survey instruments for the *Quantitative Research* in this project were prepared. The first of these was a self-completion postal questionnaire and the second of these, which was to accompany the questionnaire, was a letter of support from the OPW.

(i) Self-Completion Questionnaire

The aim of the questionnaire was to produce quantitative information on issues of urban flooding in Ireland with particular regard to the flood estimation methods for urbanised catchments that are most commonly used. To achieve this, a self-completion postal questionnaire was developed for circulation to all contact names in the selected organisations.

The questionnaire adhered to the key principles of questionnaire design and, as such, the majority of questions were short and simple and of a pre-coded and prompted nature. Precise and unambiguous questions were formulated to minimise misunderstanding. Both open-ended and closed questions were included in the questionnaire. Closed questions were designed with a meaningful scale that was selected to provide a good spread of answers. Where appropriate, scales comprised equal intervals between equivalent end points (e.g. disagree strongly, disagree slightly, neither agree nor disagree, agree slightly, agree strongly).

The questionnaire was structured around eight themes as follows:

- Introduction
- General information
- Implications of urbanisation
- Peak flow estimation in greenfield catchments
- Peak flow estimation in urban catchments
- Guidelines for peak flow estimation in either greenfield or urban catchments
- Design and modelling of stormwater drainage systems
- Stormwater management

The format of the questionnaire evolved through consultation with members of the OPW Technical Steering Group and the final version, as circulated to all contact names is contained in Appendix A.

(ii) OPW Letter of Support

A letter of support was prepared by the OPW to accompany the postal questionnaire. This is contained in Appendix B.

The self-completion questionnaire, accompanied by the OPW letter of support, was posted on 20th and 21st January 2006 to 190 contact names in organisations representing the full range of Target Sectors that were identified. A return date of February 3rd 2006 was stipulated, allowing respondents approximately two weeks to participate in the survey. A stamped addressed envelope was included with all questionnaires.

Postal questionnaires were augmented on the 23rd January 2006 by an electronic circulation of the questionnaire to 85 contacts on the Engineers Ireland Water and Environmental Engineering Society and to a further 9 academics.

Two rounds of *reminding* telephone calls were made to participating individuals to improve response rates. The first of these took place on the week beginning the 6th February 2006 and the second commenced on the week beginning the 13th February 2006.

4.3 Qualitative Research

The Qualitative Research in Work-Package 4.1 involved four lunchtime Focus Group meetings in three locations across Ireland. In keeping with the project brief where the requirement for the scoping study to review flood issues across Ireland is recognised, Focus Groups were held in the major conurbations of Dublin (2 groups), Cork and Galway.

A Topic Guide (contained in Appendix C) for these Focus Groups was developed through consultation with the OPW and Technical Steering Group of the FSU and in the interest of independent and unbiased reporting, *Social and Clinical Research Consultants* were appointed to moderate the Focus Groups.

Focus Groups were recruited from the target sectors already identified in Section 4.2.1. The final question in the self-completion questionnaire discussed in Section 4.2.2 asked if respondents would be willing to participate in Focus Groups. Approximately, 65% of survey participants agreed to this request.

The optimum number of participants at each Focus Group was identified from best practice as being 7 – 8 which would have given an overall attendance of between 28 and 32. However, late cancellations for the Focus Groups organised for this scoping study reduced this to 24 participants. The details of the Focus Groups are summarised in Table 3

Focus Group Meeting	Focus Group Date	Venue	No. of Participants
Dublin No. 1	10th April 2006	Mont Clare Hotel, Dublin	12
Dublin No. 2	31st May 2006	Earl of Kildare Hotel, Dublin	5
Galway	1st June 2006	Forester Court Hotel, Galway	3
Cork	2nd June 2006	Victoria Hotel, Cork	4

Table 3 Summary of completed Focus Groups

In addition to the Focus Groups, an in-depth telephone interview was held at the request of a participant who was unable to attend a specific Focus Group. A Focus Group meeting undertaken as part of this research is shown in Figure 11.

Figure 11 Focus Group meeting undertaken in research

A summary of all four Focus Group meetings that comprised the qualitative element of this research is contained in Appendix D.

5 Results and Analysis

5.1 Introduction

A total of 291 questionnaires were circulated, both electronically and by post. A total of 100 questionnaires were returned equating to a 34% response rate. Processing and analysis of the questionnaire responses were carried out using the SPSS software package.

A total of 83 of the 100 respondents completed the questionnaire in full, the remaining 17 stating that their organisations were not involved in urban catchment flood analysis or drainage system design. Questionnaires were circulated to practitioners in all 26 counties of the Irish Republic and returns were received from all but four of these counties. A summary of the questionnaires returned by organisations within the target sectors is shown in Figure 12 with a full breakdown of complete and incomplete survey responses for these target sectors being represented in Table 4.

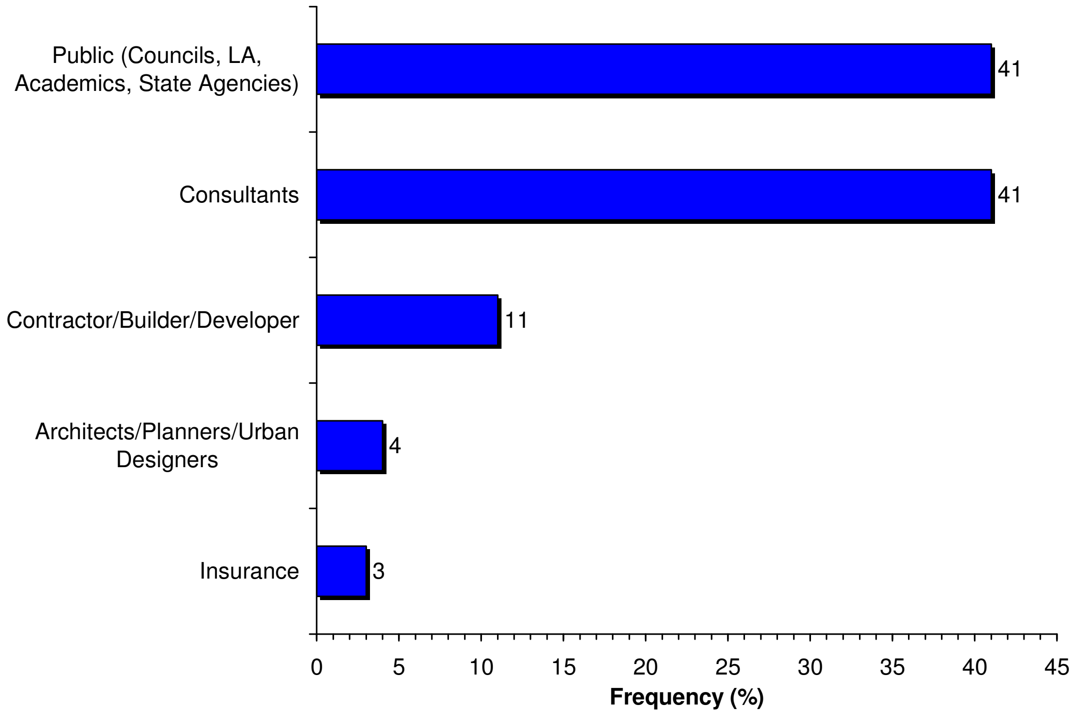

Figure 12 Questionnaires returned from target sectors identified in research

Respondent by organisation type	Questionnaires circulated	Questionnaires returned	Incomplete returns	Total responses	Response rate (%)
Contractor / Builder / Developers	31	7	4	11	35.5
Consultant	104	36	5	41	39.4
Public (Councils, LA, Academic, State...)	135	36	5	41	30.4
Insurance	14	1	2	3	21.4
Architects /Planners/Urban designers	7	3	1	4	57.1
Total	**291**	**83**	**17**	**100**	**34.4**

Table 4 Full breakdown of responses to questionnaires

The majority of questionnaires (82 in total) were returned from engineering consultancies and public bodies (Local Authorities, County Councils, City Corporations etc.) indicating that these organisations lead in the design, planning and implementation of all aspects that relate to urban flooding. Results suggest that only minor inputs to urban flooding issues are made by engineering contractors, architects and planners.

Respondents to the questionnaire were requested to express their position within their various organisations and to classify their primary role in the area of urban catchment flood analysis. Responses to these questions are summarised in Figure 13 and Figure 14, respectively.

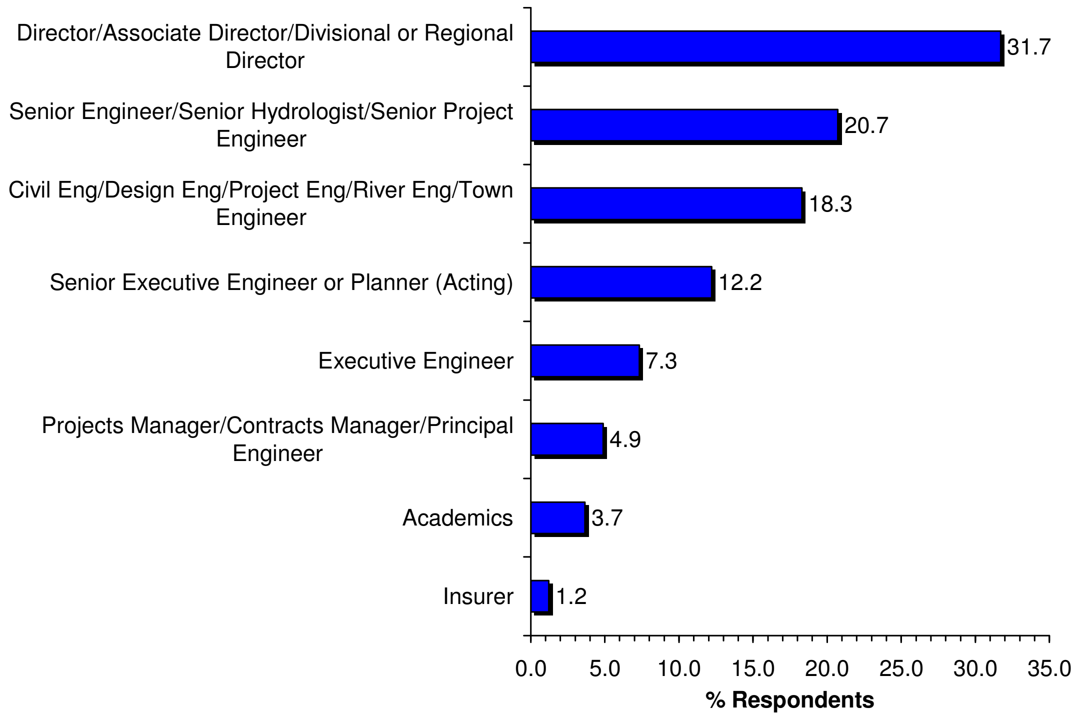

Figure 13 Respondents positions within organisations

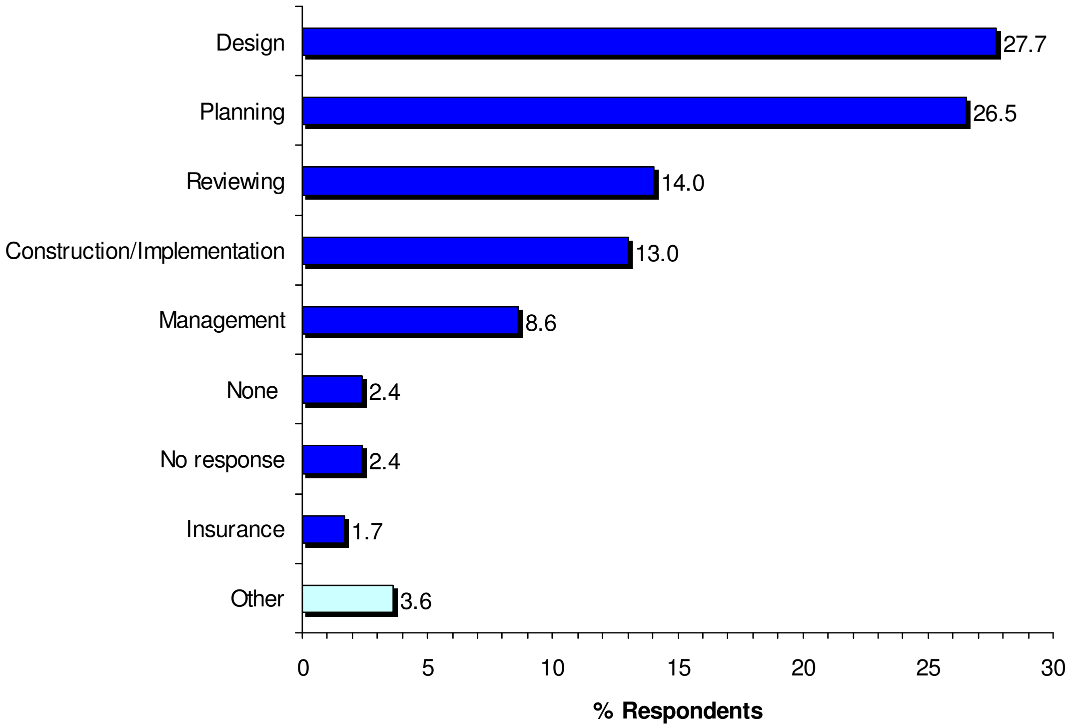

Figure 14 Primary role of respondents in the area of urban catchment flood analysis

5.2 Implications of Urbanisation

Respondents were asked whether issues relating to urban flooding were of particular concern in their work. In excess of 85% of respondents (70 of the 83 completed questionnaires that were returned) indicated that it was of concern as shown in Figure 15.

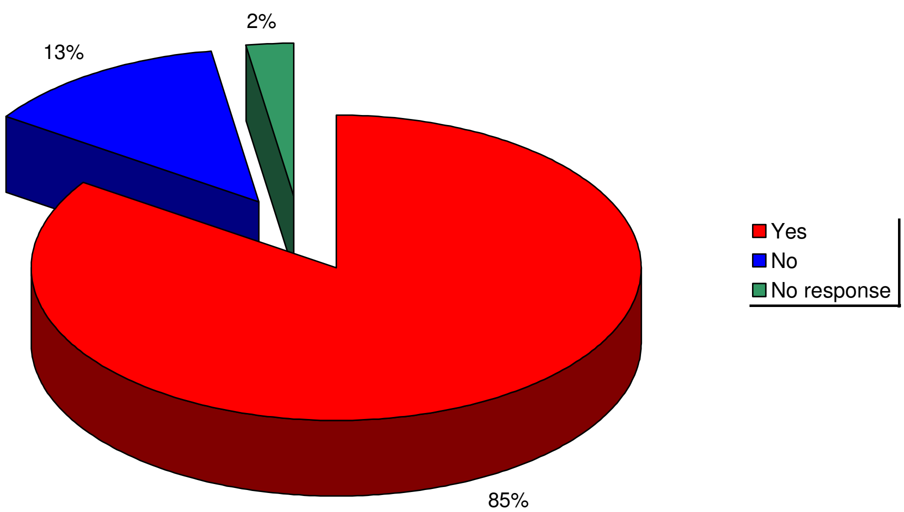

Figure 15 Importance of urban flooding issues in the work of respondents

In conjunction with Figure 14 above, almost 28% of respondents, mainly engineering consultants and members of County Councils or Local Authorities, were involved with urban flooding in a design, SUDS implementations or river improvement context. A further 26.5%

of respondents, again comprised mainly from the target sectors of engineering consultants, Local Authorities and County Councils were involved with reviewing planning applications influenced by urban flooding issues and a further 13% of respondents from the same target sectors were engaged in flood defence design and its operation and maintenance. Finally, 10% of respondents classified their primary role in urban flooding as that relating to drainage policy, action area plan development or insurance. Many incomplete responses were received from engineering contractors and consequently it is concluded that this target sector currently has little or no input in urban flooding issues in Ireland.

5.2.1 Effects of Urbanisation

Respondents were asked to rank, in terms of disagreeing strongly or agreeing strongly, with a number of statements relating to the effects of urbanisation on the natural hydrology of a catchment. These statements are summarised as:

1) Urbanisation results in a greater proportion of incident rainfall appearing as direct runoff;
2) Urbanisation results in stormwater being conveyed through the drainage network more rapidly;
3) Urbanisation can affect the shape of runoff hydrographs;
4) Urbanisation can result in hydrographs that are faster to peak and faster to recede;
5) Urbanisation can result in hydrographs with increased peak rates of flow;
6) Urbanisation may reduce baseflows in receiving watercourses; and
7) Urbanisation can have an adverse affect on water quality in the receiving watercourse.

The full range of respondents opinions are summarised in Table 5

Statement		**Reaction from Respondents (No. of citations with % of respondents in brackets)**					
No.	**Implications of Urbanisation**	**Disagree strongly**	**Disagree slightly**	**Neither agree nor disagree**	**Agree slightly**	**Agree strongly**	**No opinion**
1	Urbanisation results in a greater proportion of incident rainfall appearing as direct runoff	0	1 (1.5%)	0	8 (11.9)	57 (85.1%)	0
2	Urbanisation results in stormwater being conveyed through the drainage network more rapidly	0	0	5 (7.5%)	9 (13.4)	52 (77.6%)	0
3	Urbanisation can affect the shape of runoff hydrographs	0	0	2 (3.1%)	12 (18.5%)	46 (70.8%)	4 (6.2%)
4	Urbanisation can result in hydrographs that are faster to peak and faster to recede	0	1 (1.5%)	3 (4.5%)	16 (24.2%)	40 (60.6%)	5 (7.6%)
5	Urbanisation can result in hydrographs with increased peak rates of flow	0	1 (1.5%)	4 (6.0%)	15 (23.1%)	41 (63.1%)	3 (4.5%)
6	Urbanisation may reduce baseflows in receiving watercourses	3 (4.5%)	3 (4.5%)	8 (11.9%)	19 (28.8%)	26 (39.4%)	6 (9.1%)
7	Urbanisation can have an adverse affect on water quality in the receiving watercourse	0	5 (7.5%)	5 (7.5%)	17 (25.4%)	39 (58.2%)	0

Table 5 Perceived effects of increasing urbanisation in catchments

If the resolution of the responses in Table 5 is coarsened into three options of agreeing, disagreeing, or, neither agreeing nor disagreeing, the opinions can be represented graphically as shown in Figure 16. This indicates that a very significant majority of respondents understand the impacts of increasing urbanisation on the natural hydrology of a catchment.

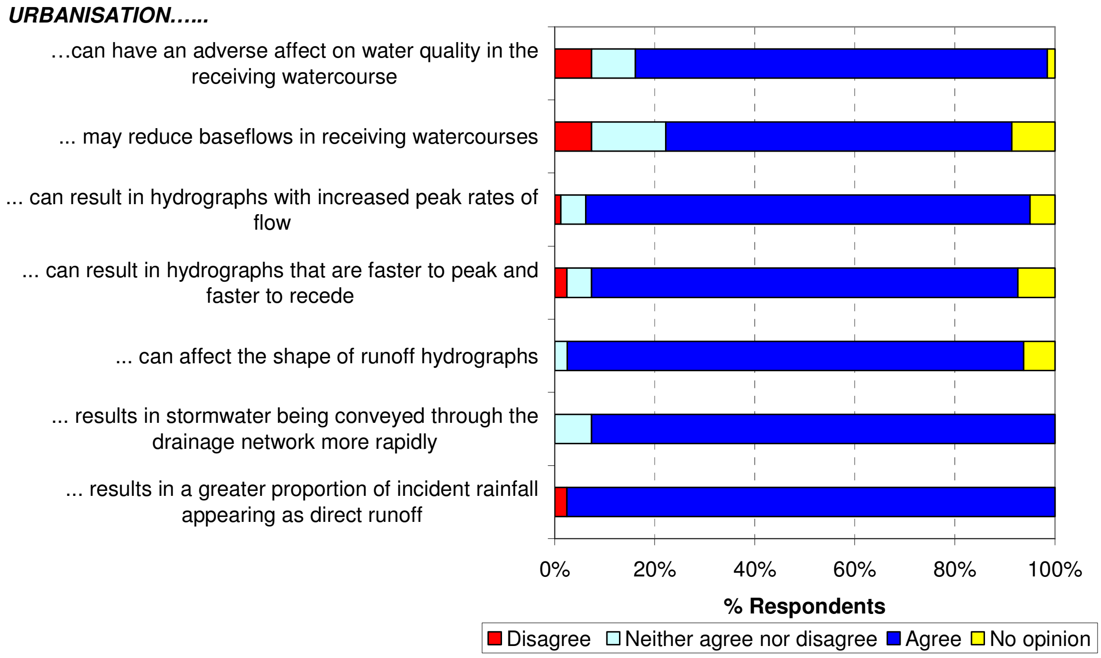

Figure 16 Respondents' opinion of impacts of urbanisation within a catchment

5.3 Peak Flow Estimation in Greenfield and Urban Catchments

In this section, respondents were asked whether they had calculated, or had experience of using, peak flow runoffs from either greenfield or urban catchments. All but one of the 83 respondents replied to this question with approximately 61% and 53% having direct experience with peak flow estimation in greenfield and urban catchments respectively. These findings are displayed graphically in Figure 17.

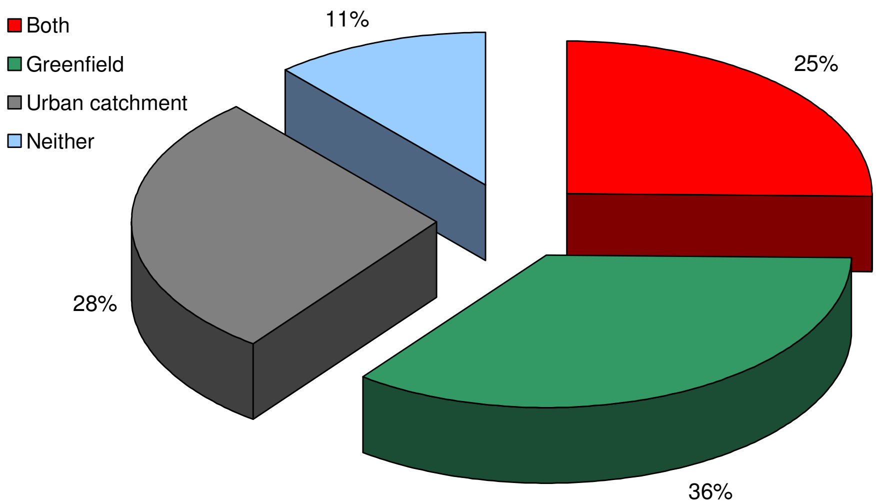

Figure 17 Respondents experience with greenfield and urban peak flow estimation

5.3.1 Equations / Methods Used in Determining Peak Flows from Greenfield Sites

Respondents were asked to state the methods for calculating peak flows from greenfield sites with which they were most familiar. A list of commonly used methods was provided in the questionnaire. The responses for this question are shown in Figure 18.

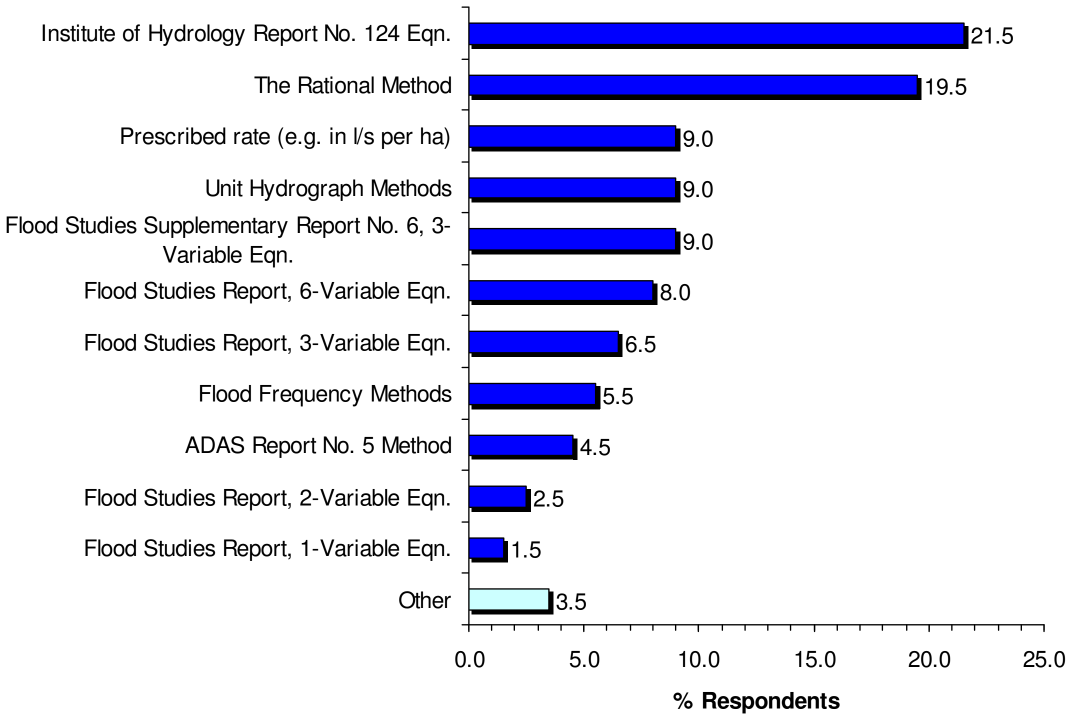

Figure 18 Percentage of respondents familiar with Equations/Methods used for estimating peak flows from greenfield catchments

Responses contained two hundred citations of equations / methods that were listed in the question. Figure 18 indicates that the Institute of Hydrology (IoH) Report No. 124 Equation and the Rational Method are the methods most commonly adopted with 21.5% and 19.5% of respondents having experience of these approaches. This perhaps reflects the respondent's familiarity with the Dublin City Council - Stormwater Management Policy for Developers (1998), which recommends the use of the IoH method for catchments of up to 24 hectares in area. The concept of limiting greenfield runoff to prescribed rates is familiar to 9% of respondents. The Unit Hydrograph approach, the Flood Studies Report (FSR) 6-Variable and 3-Variable equations and the Flood Studies Supplementary Report (FSSR) No. 6 3-Variable equation are also well represented.

In addition to the results in Figure 18, some respondents also mention using the Flood Estimation Handbook (FEH) and the Transport and Road Research Laboratory (TRRL) Report No. 565 and Report No. 585 as methods for estimating peak flows from natural catchments. A catchment area ratio method, SMARG (NUI Galway software) and the *TopKApi* physically based and fully distributed hydrological modelling system were also included in responses.

Figure 18 indicates that a number of equations / methods are frequently used for peak flow estimation in greenfield sites and this non-uniformity of approach was perceived as a difficulty in the Focus Group meetings that were held. The difficulty is epitomised by the following comment that was forwarded at one such meeting:

> *"Our main problem with the methodologies is that there's so many of them. If there was a unified methodology for the whole country, it would be easier"*

The topic of peak flow estimation in greenfield catchments was extended by requesting respondents to identify the main difficulties / limitations that were experienced when using these methods. A total of 48 of the 83 respondents (58%) who returned questionnaires provided information for this section of the survey. The most common responses were grouped and are summarised in Figure 19. These responses tended to be general and rather sweeping in their nature. It is clear that respondents are aware that uncertainties exist in the application of the various peak flow estimation methods to urban catchments but evidence of a deeper understanding of where these uncertainties may originate is not so apparent. As an example, Figure 18 indicates that the IoH No. 124 equation is commonly used across Irish catchments and a perceived difficulty with the method lies in extracting catchment descriptors from poor resolution FSR mapping. While this is without doubt the case, a greater uncertainty when using this equation may well result from the regression study on which it is based and particularly the range of soil types in the catchment sample (refer to Section 3.3), a point not raised by any respondents.

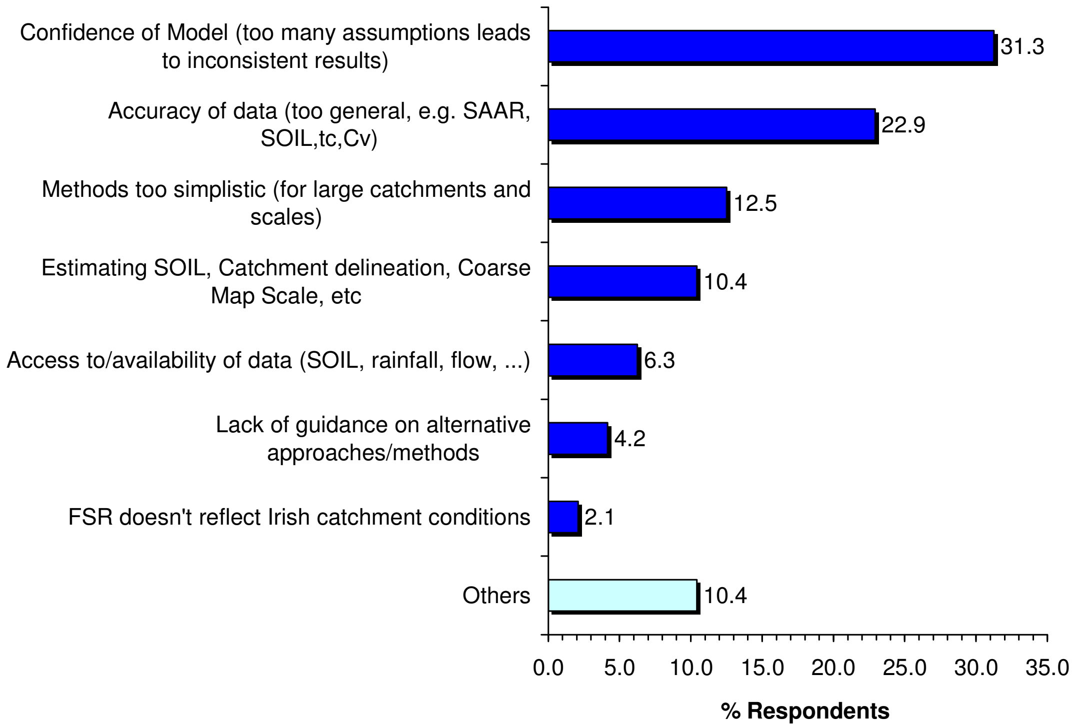

Figure 19 Main difficulties / limitations identified by respondents when calculating peak flows from greenfield catchments

The main difficulty or limitation in Figure 19 identified by over 31% of respondents was the inconsistency in the values of the peak flow determined from the various methods and how these varied over catchments of different sizes. It was noted that some of the commonly applied methods overestimate design flows, imposing extra costs on developers for attenuation structures. The manner in which the behaviour of ground conditions is oversimplified by assumptions inherent in many of the methodologies was also perceived as a problem. This lack of confidence in the various approaches is reflected in the following comment that was made at a Focus Group:

> *"The quality of the result is related to the relevance of the formulae used and the catchment size"*

Another major problem, identified by almost 23% of respondents was the accuracy, resolution and validity of the data on which the methodologies are based. Some of the required variables, (SOIL, SAAR, runoff coefficients, concentration times) are not site specific and can vary widely. Furthermore, interpolation, where required, of hydrological parameters is subjective and open to question. In addition, it was identified that SOIL parameters do not account for site topography or slope. Issues relating to data quality are reinforced by the following comments that were made in Focus Group meetings:

> *"Quality as opposed to quantity is important in information on water-related issues"*

> *"I think that soil should be classified, from hard rock down to sand, because it's another specific variable. If Ireland is small enough to classify the soils, then they could calculate infiltration rates. A new soil map should be developed"*

> *"There's also a problem with Met Eireann's calculation of one in five year storms. I know that since I started working, we've certainly had more frequent storms. The rainfall data certainly has to be addressed"*

> *"Soils can vary over a catchment, even if you have a map. The hydrologist should understand if he has impervious clay or a pre-draining material and be able to have some guidance on how to classify that himself"*

The issue of poor quality data, particularly relating to SOIL, was further addressed in the Focus Group meetings. The idea of imposing on developers the requirement for site specific infiltration/percolation tests where planning permissions are being sought was discussed. It was generally agreed that this would be a positive initiative that would facilitate a more accurate assessment of site specific hydrological characteristics and *"should be part of"* all developments. It was also considered that *"it would be very good to get site specific data"*. This was further endorsed by the following Focus Group comment:

> *"A survey* (to determine hydrological characteristics) *of smaller catchment areas, of the typical area for development, up to 10 hectares would establish a dataset for that range of catchment size, and then at least, we'll have a back up* (for situations where data resolution is problematic)*"*

Furthermore, if this initiative was promoted at a national level where all data was collated in a single database:

> *"It would probably be very useful information …. for the country"* but would *"involve a huge amount of data…."*

However, the distinction between percolation and infiltration was raised and it was noted that a percolation test:

> *"would not yield too much data, but it tells you how quickly water would drain away in the event of a flood. You are forced to dig and so can gain more information on the subsoil"*

Concerns were also raised about the perceived cost and the time implications of imposing obligatory soil tests on developers. One Focus Group participant mentioned that:

> *"The time factor there is a problem. …. you mention it to a developer,* (that) *the percolation test is quite easy to do but they say 'I haven't time for that"* but *"All you have to do is dig a hole and watch the water drain through"*

On a similar theme to that of poor quality data, it was also noted by 12.5% of respondents that methodologies were too simplistic in the context of relying on catchment descriptors determined from poor resolution maps. These maps are really only suitable for large catchments and are not appropriate for small catchments on which the majority of development planning applications are based. Issues of map scale are represented by the following comment that was made:

> *"There is a lack of particular information on streams that you would be looking at on the greenfield site. You can't use a six-term* (FSR 6-Variable) *equation if a stream does not appear on the 1 in 50,000 maps* (Ordnance Survey of Ireland, Discovery Series map). *Information on stream frequency is required for the six term equations. I would say though that the three-term* (3-Variable) *equation......provides a factor of safety"*

Similar issues relating specifically to soil index estimation, catchment delineation and poor map resolution were mentioned by an additional 10% of respondents and these are considered to be consistent with the data quality issue already discussed.

In addition to the above responses, about 6% of respondents have concerns over access to or availability of data including rainfall, flow and soil type. It was noted that at times in the past, rainfall and river monitoring equipment had fallen into disrepair and significant time periods had elapsed before these devices were operating:

> *"There is measurement stations placed along rivers alright, but these are not repaired immediately when they break down…"*

Another 4% have identified the lack of national guidance governing 'best approaches' to the problem of runoff estimation from greenfield sites. A guidance document, if made available, could assist in providing clarity to results and to improve confidence levels for practitioners. The following comments in relation to a national guidance document were made in the Focus Group meetings:

> *"I think it's important to have a national document."*

> *"The problems with methodologies are linked to the absence of a holistic approach to catchment analysis"*

> *"The OPW could do a manual that could be sent around to County Councils, a code of accepted practice"*

> *"There should be a recognised small catchment approach and a big catchment approach"*

> *"I know I'm only involved in road design, but I'd be looking for a procedure for greenfield sites. I'd need a set of steps. At the moment, it's grey* (a grey area) *on what you do or don't need to design for"*

> *"Guidelines are needed. It doesn't have to be the OPW who comes up with these. The Local Authority could do it as well."*

With regard to the type of information that a national guidance document should contain, the following was stated:

> *"It should be in handbook form without being overly prescriptive. It should give worked examples and solutions. It should also give examples of jobs and likely problems from start to finish, but the book should also allow engineers to have independence of judgment. The book would become de facto if respected".*

Another concern raised by about 2% of respondents was that the FSR does not fully reflect Irish catchment conditions, especially with regard to the FSR SOIL map.

The majority of the difficulties / limitations were raised by engineering consultants. However, County Council and Local Authority representatives also contributed.

5.3.2 Equation / Methods Used in Determining Peak Flows from Urban Catchments

Respondents were asked to state the methods for calculating peak flows from urban catchments with which they were most familiar. A total of 123 citations of various methods of urban catchment peak flow estimation were received. These are summarised in Figure 20.

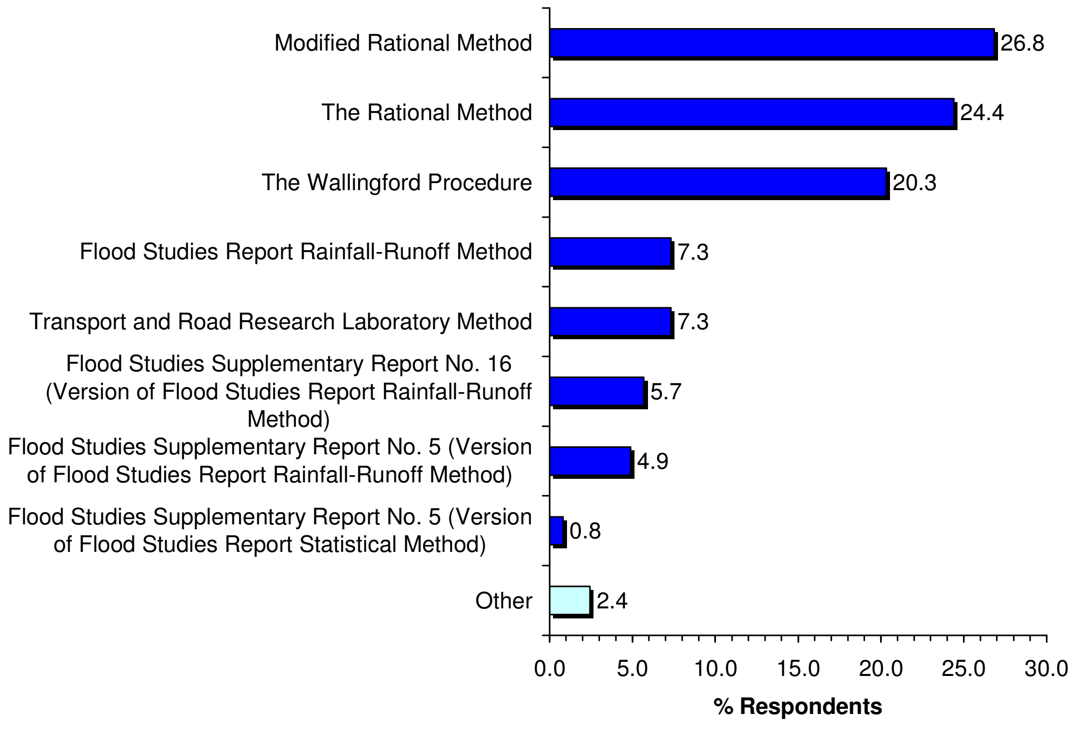

Figure 20 Percentage of respondents familiar with equations/methods used for estimating peak flows from urban catchments

As expected, Figure 20 shows that Rational type formulae represented by the Rational and Modified Rational Methods and the Wallingford Procedure are the most commonly used formulae for peak flow estimation in urban catchments. Respondents also have familiarity with the rainfall-runoff methods in the FSR and FSSR No. 5 and FSSR No. 16 where 7.3%, 4.9% and 5.7% of respondents respectively stated they had either direct experience with these methods or had experience using flows calculated from these methods. The Transport and Road Research Laboratory Method (TRRL) was familiar to 7% of respondents with the 'other' grouping comprising respondents who mentioned having experience with methods such as HEC-1, TR-20 and TR-55. HEC- 1 refers to flood hydrograph software package produced in the Hydrologic Engineering Centre of the United States Army Corp of Engineers. TR-20 and TR-55 refer to Technical Releases from the Natural Resources Conservation Service in the United States Department of Agriculture in which simplified procedures applicable to urbanising watersheds are presented to calculate runoff volumes, peak flows and hydrographs.

The perceived difficulties and limitations in applying these methods and equations to urban catchments are represented in Figure 21.

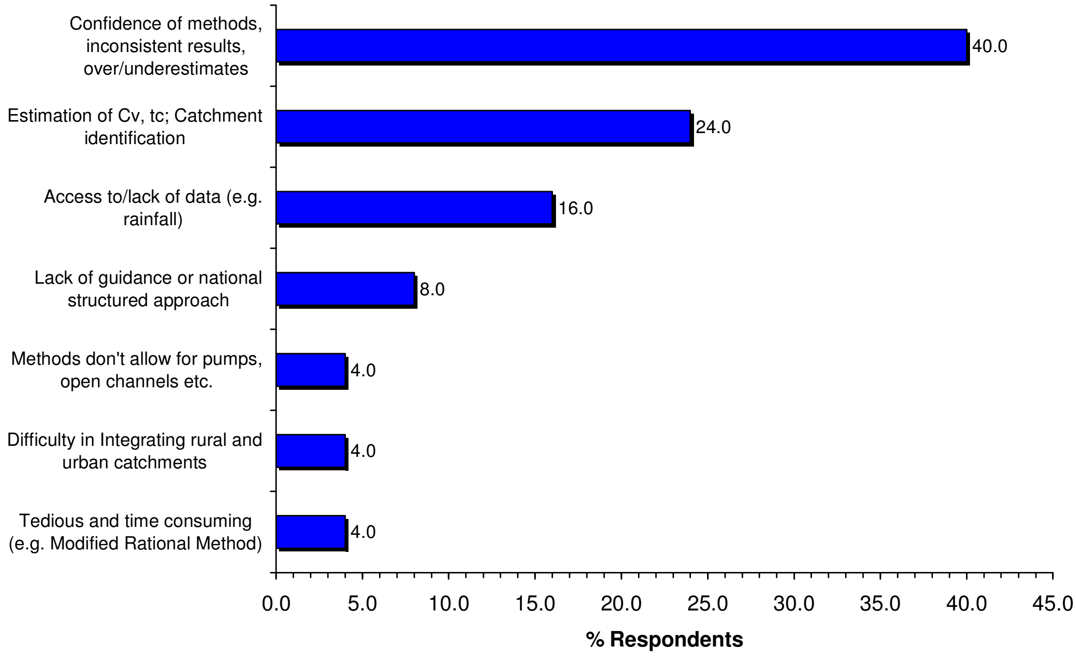

Figure 21 Main difficulties / limitations identified by respondents when calculating peak flows from urban catchments

As in the case of greenfield methodologies, Figure 21 indicates that confidence in the results obtained from the various methods is of most concern to respondents. The problem of poor confidence was identified by 40% of respondents as resulting from inconsistencies in calculated flows determined from the various methods, the ability of methods to over or under-estimate peak flow values, the dependency of the methods on poor quality and poor resolution information inputs that are uncertain and on various assumptions that are made. This inconsistency is reflected in the following Focus Group comment:

> *"…different engineers trying to calculate flow for the same catchment would arrive at different results."*

Difficulties in estimating routing coefficients, runoff coefficients, entry times and delineating catchment areas were identified by 24% of respondents as limitations of the urban catchment methodologies. This following comment represents difficulties of this type:

> *"The problem with using FSSR No. 5 in small catchments is that you don't have a stream frequency or an S1085 value that you can use. It's basically a small stream going through the site, it doesn't appear on the 1 in 50000 mapping* (Ordnance Survey of Ireland, Discovery Series map) *either. Your only choice is to choose one of the three* (3-Varible) *equations given in hydrology* (textbooks). *They're quite good, but the soil*

parameter is very general from mapping"

As in the case of greenfield catchments, issues relating to a lack of data for urban catchments were identified as being problematic. A total of 16% of respondents identified these limitations and this was endorsed by the following comment:

> *"Certainly I would see the SOIL* (soil index values) *issue as a problem. I mean, the resolution of the maps is so poor. In many cases, all you get is something the size of a postage stamp and the methodology is very sensitive to soil around the catchment"*

However, one participant was aware that new SOIL maps are soon to be published by Teagasc:

> *"I believe that new soil maps are soon to give us more extensive mapping. I think Teagasc are doing it. That will help improve the situation"*

It was suggested by a South African hydrologist at one Focus Group that the approach to urban catchment hydrology and management presided over by Local Authorities is *ad-hoc* in nature. The participant contrasted the Irish approach that he has experienced in his time in Ireland to that he experienced while working in South Africa:

> *"There has been a lot of study done on catchments in South Africa. Hydrology is critical to us there because of monsoon rainfall. Hydrology is a highly developed science. Rivers are fast flowing. Runoff is critical. An understanding of the history of the flooding of the area is critical. That's what I've been looking for here and I'm not able to find it. In South Africa, there is more of a study of the runoff, so that individual catchments can have rainfall measured over a lot of years"*

The same participant also highlighted the unwillingness of engineering consultancies to disseminate or share information with other consultancies and again contrasted this with South Africa where:

> *"….. we have annual 3-day symposiums on the subject where ideas are shared between consultants"*

The lack of guidance and the absence of a national policy document on urban catchment flood analysis were considered by 8% of respondents to represent a very real constraint in developing a uniformity of approach across the country. This was mentioned on numerous occasions in Focus Group meetings as reflected in the following comments:

> *"There's no standard approach, but I'm aware that the results I use are pretty primitive. There's no resource available in Ireland…."*

> *"I worked in a part of the US, where they had a drainage manual with clear criteria. It worked well for urban catchments."*

> *"There's no agency dealing with this at all…the OPW once had a very good hydrology department, but that closed down…"*

Guidance should, it was considered, recommend or identify appropriate estimation methodologies for catchments across Ireland. This does not necessarily require that new methodologies be developed but rather, scope exists for improving the basis of the Rational and Modified Rational Methods and the Wallingford Procedure for Irish catchments.

Other, less significant limitations in undertaking peak flow estimations in urban catchments identified by respondents are also shown in Figure 21.

The information contained in this section on peak flow estimation in urban catchments was based on a reasonably equal distribution of questionnaire responses from the two target sectors of engineering consultants and County Councils / Local Authorities.

5.3.3 Guidelines for Peak Flow Estimation in Greenfield and Urban Catchments

Respondents were asked to specify the sources of reference that are accessed for guidance on peak flow estimation. A list of what were perceived to be common sources was provided in the question. The main sources of reference are the Flood Studies Report (FSR), Local Authority Guidelines and standard hydrology textbooks as shown in Table 6.

References	References accessed by respondents (%)
The Flood Studies Report	19.2
Local Authority Guidelines	16.9
Standard hydrology textbooks	16.9
HR Wallingford reports	12.8
Hydrology conferences	9.6
Training courses	8.7
Journal articles	5.5
Related web sites	5.5
'Other'	5.0

Table 6 Sources of reference accessed by respondents for guidance on peak flow estimation from either greenfield or urban catchments

Respondents also made reference to the Greater Dublin Strategic Drainage Study (GDSDS, 2005), CIRIA guidelines, FEH, BRE Digest, ARUP Infrastructure Design Guidance Notes, An Foras Forbatha guidelines, Dublin Stormwater Policy Guidelines, and Haestad Methods. The Masters of Hydrology course in NUI Galway was also mentioned.

In addition to the list of references listed in the questionnaire, survey participants also mentioned specific texts books and other guidelines. These include:

- Books by: Elizabeth Shaw, EM Wilson, Lloyd Davis, Butler and Davies, RL Bras;
- Publications by: HR Wallingford, CIRIA;
- IoH Reports;
- Dublin City Council Stormwater Guidelines for Developers;
- Seminars and Hydrological workshops;
- Hydrology articles by AM Cawley and C. Cunnane and by G. Kiely *(most likely to be referring to Cawley and Cunnane, (2003) and Kiely, (1999))*;
- Dun Loaghaire Rathdown County Council guidelines;
- FSR Vol. 1 – 5;
- OPW and Met Eireann data:
- An Foras Forbatha guidelines;
- InfoWorks electronic help;
- Extreme rainfall return period (ERRR) tables;
- Department of the Environment and local Government (DOELG) guidelines for site development works.

- Various SUDS publications (for example CIRIA Report 609 that offers Hydraulic, Structural and Water Quality Advice)

The diversity of the reference sources in Table 6 serves to highlight the absence of a national policy document for urban catchment flood analysis that was identified by respondents in Figure 21 as being a major limitation in the area.

Respondents were asked to specify how they became aware of guidance that is available (see Table 7). In addition to the sources in Table 7, respondents also mentioned independent research, UCD basic hydrology lectures, training courses and OPW Section 50 documentation.

Sources	Respondents (%)
The accepted method used in organisation	23.1
Recommended by Local Authorities	20.6
Recommended by another person	19.4
Hydrology conferences	10.6
Related web sites	8.8
Journal articles	8.1
Training courses	6.9
'Other'	2.5

Table 7 Sources through which respondents become aware of the guidance available

Respondents were also asked for their opinion on the adequacy of current guidelines for peak flow estimation either for greenfield or urban catchments. Of those that expressed an opinion, only 36% of respondents felt that current guidance was adequate while 42% felt that it was inadequate. These responses are summarised in Figure 22.

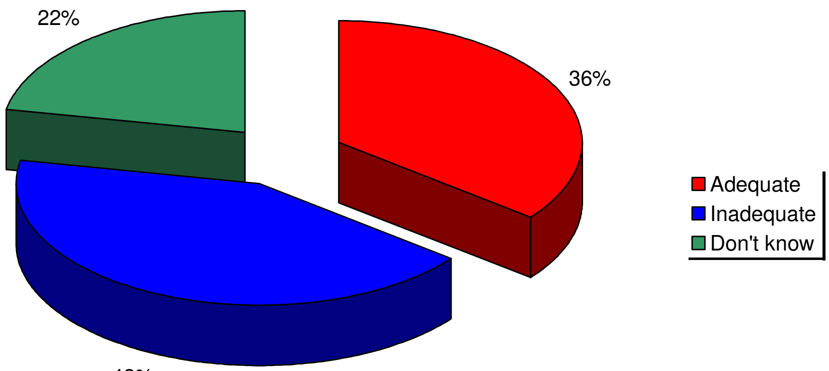

Figure 22 Respondents' opinion on the adequacy/inadequacy of current guidelines for peak flow estimation in either greenfield or urban catchments

Respondents were asked to identify specific limitations of certain guidelines. There was commonality in many issues raised and these are grouped in four categories in Figure 23.

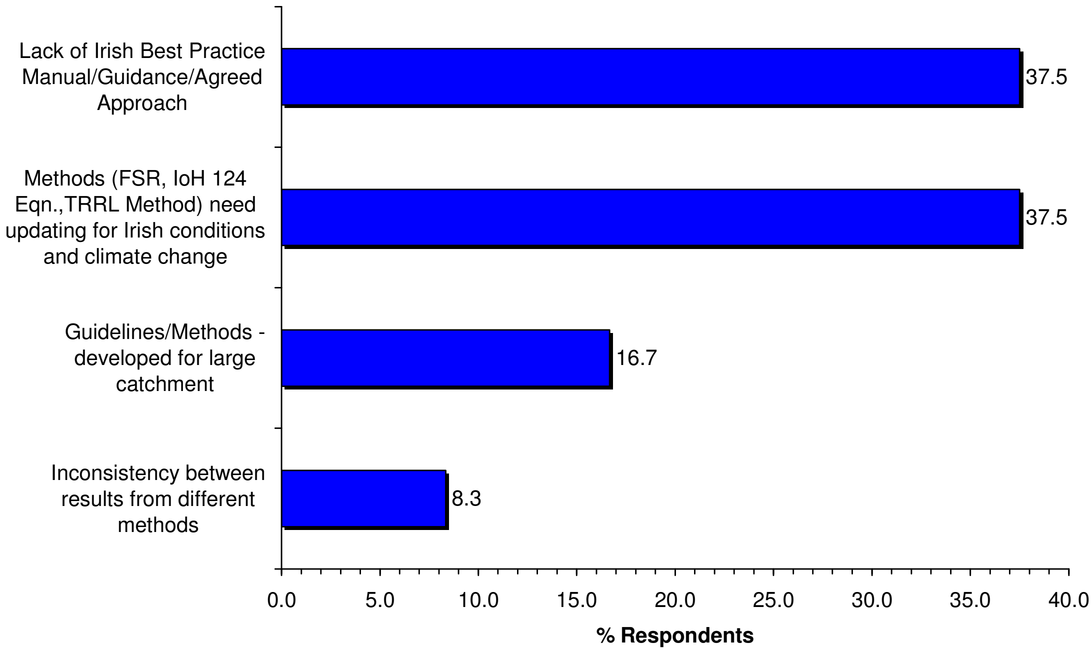

Figure 23 Common limitations with peak flow calculation guidelines identified by respondents

Figure 23 indicates the recurring theme of a national guidance policy (37.5% of respondents) and shows that issues relating to inconsistencies and lack of confidence in peak flow values determined from various methodologies (as presented in Figure 19 and Figure 21) also permeate through the identified deficiencies and limitations with the available guidance. The need to update some of the commonly used methodologies (FSR methodologies, IoH 124 equation and the TRRL methods) for improved suitability to Irish catchments was identified by over 37% of respondents.

In addition to the above grouped issues, the following specific points were made:

- The need for greater detail and description in quantifying errors and confidence intervals when using FSR methodologies;
- The variability of ground conditions induces errors in results determined from the IoH No. 124 equation;
- Volumes of runoff permitted in Local Authority Guidelines are not appropriate to city/town centre sites;
- The Dublin City Council Stormwater Management Policy for Developers should be made more comprehensive to include tables with values for variables such as SOIL, etc.;
- The GDSDS revised regional curves reduce storage requirements but hugely increase river flow estimates.

The following more general comments were also made:

- Guidelines are sometimes too general;
- Most methods are strictly applicable to large catchments;
- The linear relationship for scaling catchments inherent in some estimation methodologies is questionable;
- Uncertainties in defining the extent of urban areas within catchments can induce uncertainty in flood estimates;
- Data and information on which flood estimates are based is outdated;

- There is no agreed structure between practitioners for flood estimation and this results in a lack of consistency;
- Peak flows estimated from various methods are subjective and are often very conservative.

5.3.4 Availability of Data for Calculating Peak Flows

Respondents were asked whether they were satisfied that the data for calculating peak flows in either greenfield or urban catchments is readily available. Only 41% of respondents were satisfied with available data as summarised in Figure 24.

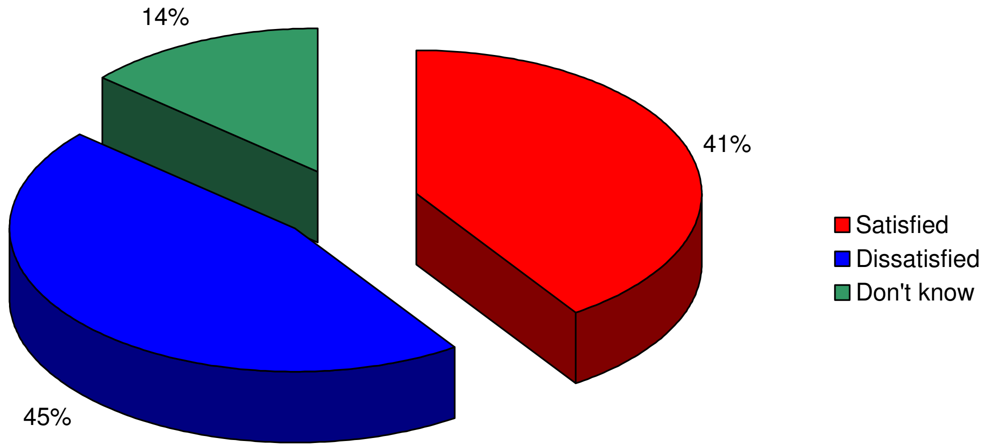

Figure 24 Respondents' satisfaction/dissatisfaction with the data currently available for peak flow estimation in either greenfield or urban catchments

Respondents were asked to expand on the reasons for their dissatisfaction with the currently available data. While many reasons were mentioned, the main factors are represented in the three groupings represented in Figure 25. This shows that an overall lack of, or access to, various data for accurate flow estimation is the most significant source of dissatisfaction, with over 40% of respondents identifying this as a problem. However, the accuracy and the resolution of the data that is available is also a significant problem and is reflected in the 37% of respondents who mentioned that existing data is more readily applied to large catchments. In this regard, it was specifically noted that the "data available is not specific to a particular region" and that "values read from FSR maps are too general and are not site specific". Characteristics specific to some Irish catchments were also raised by one Focus Group participant who recognised the "*problems with karst and the indeterminate nature of underground flow as well as runoff*". Regarding these conditions it was noted that *"they're characteristic of Irish catchments, but we often have to rely on English data* (for their analysis)*"*. A single respondent also noted that there is "no site specific rainfall data available". The absence of national guidance also features with approximately 22% of respondents citing this as a problem.

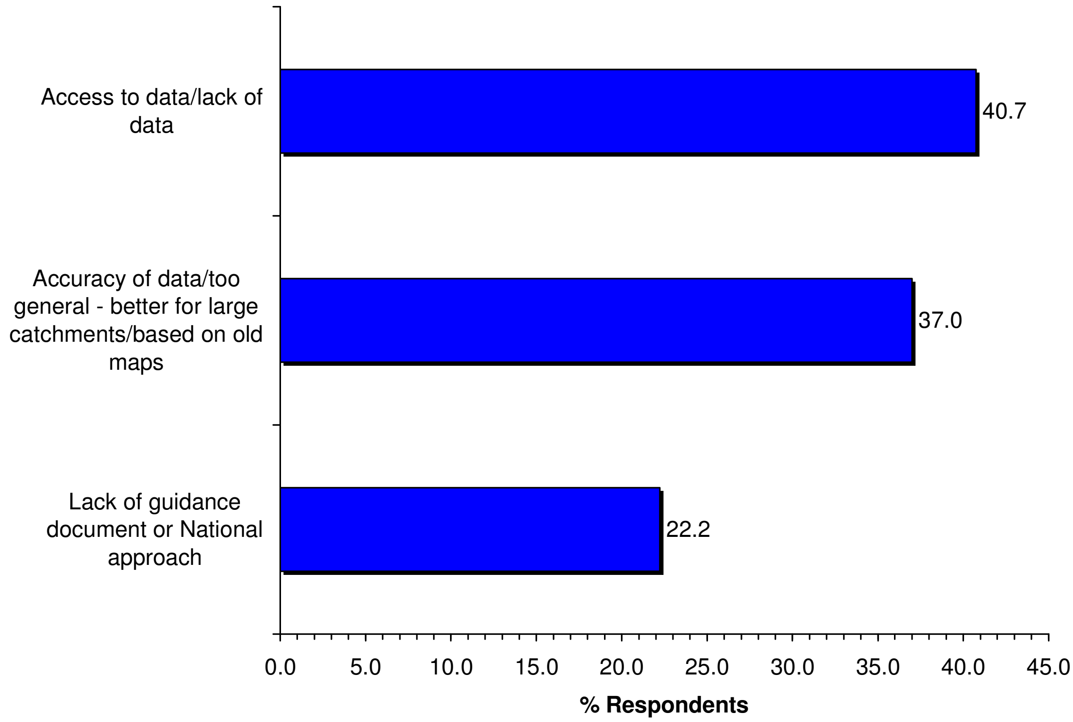

Figure 25 Reasons for respondents' dissatisfaction with available data for peak flow estimation

The need for improved data also came to the forefront during Focus Group meetings and in an attempt to provide more detailed information on the behaviour of typical catchments, the following were mentioned:

> *"We need more instrumented catchments. More emphasis should be given to measurement. A Measurement programme needs to be set up in existing catchments. In a rural area, people will say the OPW should be responsible. If it's an urban area, they'll say it's the Department of the Environment's responsibility. The latter wants to wash its hands of urban drainage. It's a historical legacy; you design a thing, and then don't bother measuring it. Few Local Authorities assume this responsibility."*

5.4 Design and Modelling of Stormwater Drainage Systems

5.4.1 Approach to Stormwater Management

Respondents were asked to specify the methods used in designing stormwater systems. A total of 37% of the survey sample utilise various software packages when designing drainage systems with manual and spreadsheet calculation methodologies accounting for the other approaches identified. The breakdown of methods is shown in Figure 26. A significant proportion of the 27% of respondents who do not use any prescribed methods in the design of stormwater systems were from the County Council and Local Authority target sectors. Furthermore, and as shown in Table 8 that shows the various approaches to stormwater system design by target sector, representatives in these target sectors also rely more heavily on manual calculations for design purposes than engineering consultants. This perhaps suggests that the role of practitioners in organisations of this type is not primarily a design role, at least not on a day to day basis, but may involve checking design values submitted by engineering consultants.

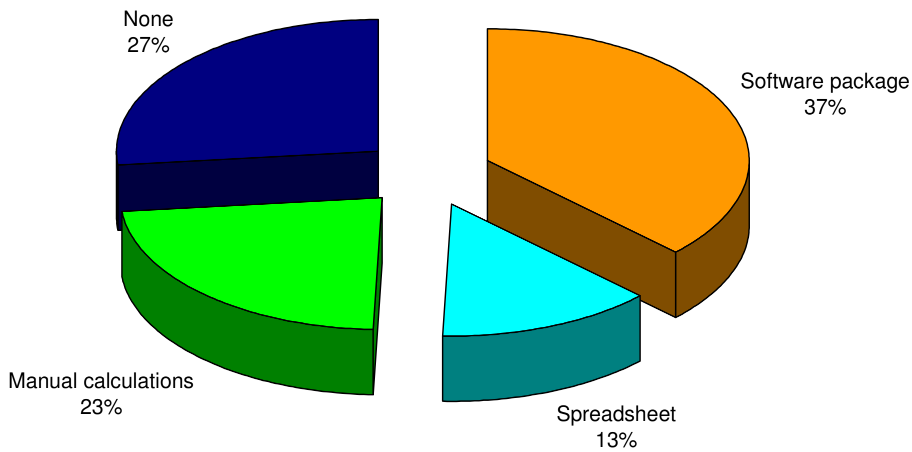

Figure 26 Approach to design of stormwater drainage systems adopted by respondents

Organisation type	Software package	Spreadsheet	Manual calculations	None
Contractor/Builder/Developer	1	-	1	4
Consultant	22	6	4	2
Public (Council, LA, Academic, ...)	5	3	12	12
Insurance	-	1	-	-
Architects/Planners/Urban Designer	-	-	-	2
Total	28	10	17	20

Table 8 Approaches to stormwater system design by target sector (by number of citations)

The methods of stormwater system design utilised by respondents were further investigated in the questionnaire to identify computer modelling/software packages that are most commonly used for design purposes. A list of commonly used software packages was provided in the questionnaire and responses are summarised in Figure 27.

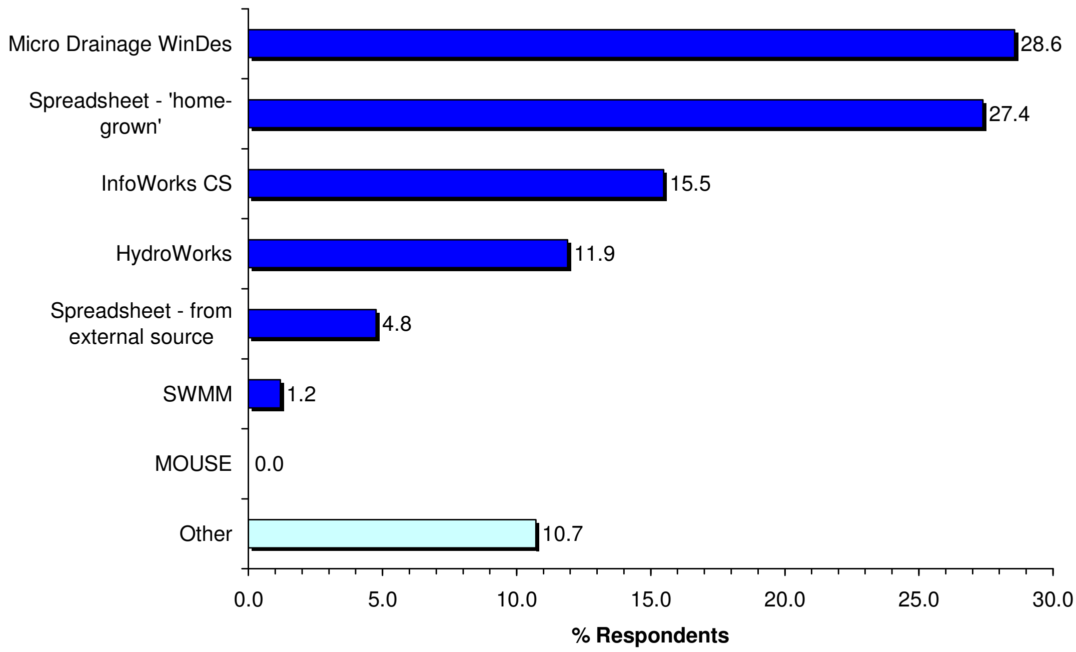

Figure 27 Percentage of respondents using Computer Modelling/Software packages in the design of stormwater drainage systems

Figure 27 indicates that *WinDes* is the most commonly used software package for stormwater system design in Ireland. This is supported by *'home-grown'* or company developed spreadsheet programs for calculating runoff volumes for design storms, the use of which was cited by in excess of 27% of respondents. The use of InfoWorks CS and HydroWorks is also popular with approximately 15% and 12% of respondents respectively having experience with these packages. Less frequently cited approaches involve the use of externally sourced spreadsheet packages and SWMM while 'other' methods cited by 10.7% of respondents included StormCAD, Eaglepoint, Hysten Exam ITWH (Germany), ISIS and HEC-RAS.

The most common software packages for stormwater system design used by organisations within the target sectors were also assessed and are shown in Table 9. Table 9 shows that the WinDes software and the use of *'home-grown'* spreadsheets form the basis for the majority of design work that is being undertaken.

Organisation type	Softwares						
	Win -Des	Home grown spreadsheets	Externally sourced spreadsheets	Info-Works	Hydro-Works	SWMM	MOUSE
Contractor/Builder/ Developer	-	-	-	-	-	-	-
Consultant	19	18	1	11	7	1	-
Public (Councils, LA, Academic, ...)	5	4	3	2	3	-	-
Insurance	-	1	-	-	-	-	-
Architects/Planners/ Urban Designer	-	-	-	-	-	-	-
Total	**24**	**23**	**4**	**13**	**10**	**1**	**-**

Table 9 Software packages used in stormwater system design by target sector (by number of citations)

In a further question, respondents were asked to state the main difficulties / limitations that they had experienced when using these software packages. The main limitations that were identified were arranged in seven groupings and are shown in Figure 28.

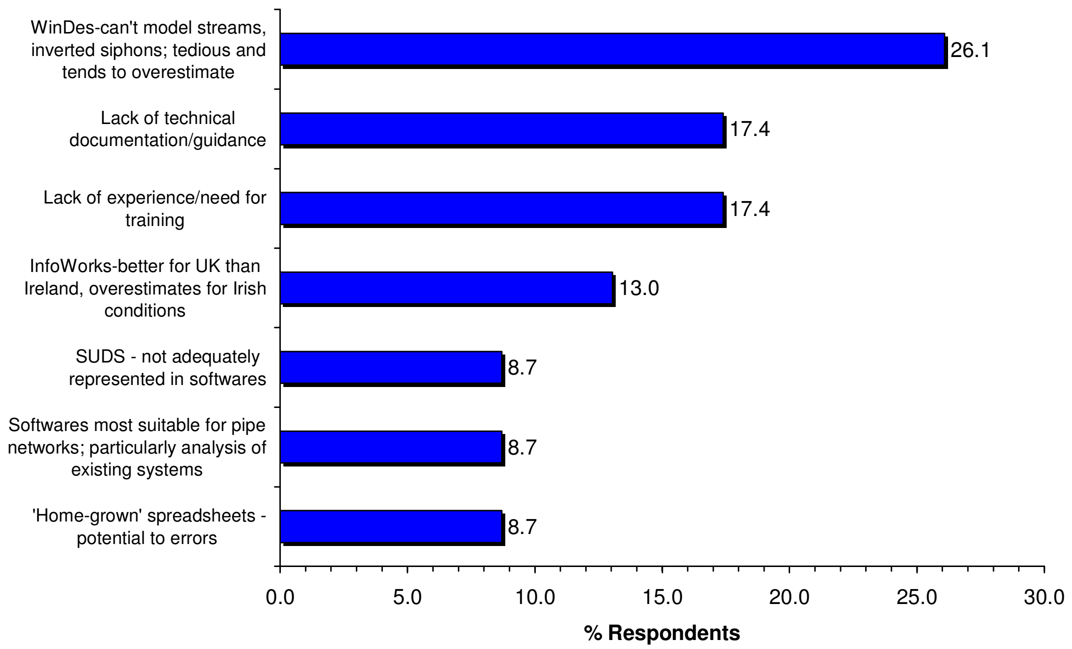

Figure 28 Main difficulties/limitations encountered by respondents when using listed software packages

In addition to the responses in Figure 28, the following specific comments were made in relation to software packages used by respondents:

- Records of infrastructure are not up to date.
- Lack of training and/or experience is not always provided.
- Spreadsheet packages are sometimes difficult to edit and accuracy is a concern. It was observed that errors are easily made with spreadsheet packages, particularly when copying and pasting of data is being undertaken.
- The *WinDes* package is only really suitable for pipe networks and it is difficult to include the impacts of streams and surrounding rural catchments in the design process. Practitioners in organisations don't always have access to the full range of *WinDes* modules. Furthermore, some respondents have noted that *WinDes* can overestimate storage requirements and can often be tedious and time consuming to use. Others noted, that although powerful for some situations, *WinDes* does not easily allow for the modelling of non standard situations and suffers from the lack of Irish rain profiles.
- HydroWorks/InfoWorks is complex and is more suitable for analysing existing systems than for designing new systems.
- Furthermore, it was noted that mistakes are easily made when using HydroWorks/InfoWorks and that these packages are not suitable for small networks.
- SWMM is slow to work with, and again, is more effective for analysing existing systems than for designing new systems.
- SUDS are not adequately represented in design software packages.
- ISIS suffers from a limited culvert modelling capability.

In addition, two respondents commented that any software package is only as good as the person using it!

5.4.2 Adequacy of Technical Documentation Supporting Software Packages

Respondents were asked to comment on the adequacy of the technical support documentation that is available for the software packages that are commonly used. Results are summarised in Figure 29.

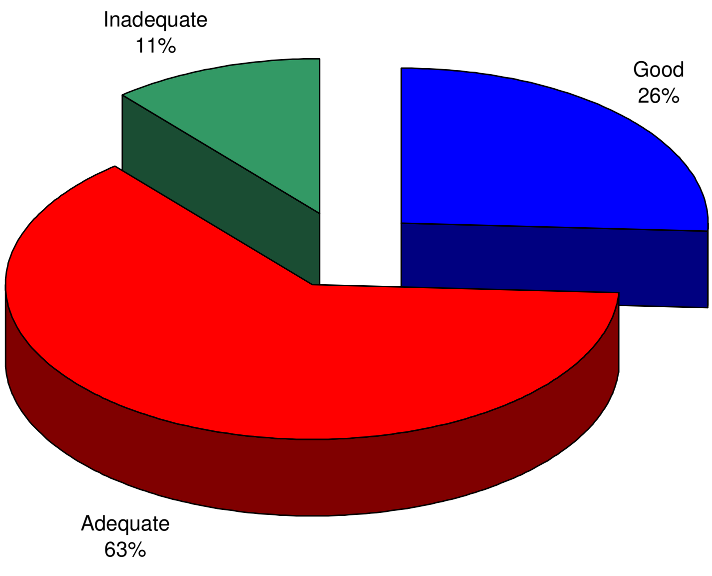

Figure 29 Respondents' opinion of the quality of technical support documentation available with software packages used in the design of stormwater drainage systems

Figure 29 indicates that while the majority of respondents considered the technical guidance on stormwater system design software to be adequate, only 26% describe the technical guidance as ‘good’. However, the 11% and 26% may reflect the level of training and/or skill.

5.5 Stormwater Management

Respondents were asked about the most commonly adopted structural method for attenuating stormwater and restricting outflows to pre-development runoff values. This was an open ended question to which 75 of the 83 respondents (approximately 90%) provided replies.

Among those who gave their opinions, 72% mentioned attenuation/storage tanks that are generally concrete and located underground in development sites. In most cases, respondents mentioned that these tanks are combined with the use of flow restriction devices such as hydro-brakes or flow control orifice plates. While not always considered to be structural measures, a number of respondents mentioned having experience with both the use of stormcell type structures and permeable pavements and with the use of standard SUDS implementations for stormwater attenuation. The full range of structural methods that were identified are summarised in Figure 30.

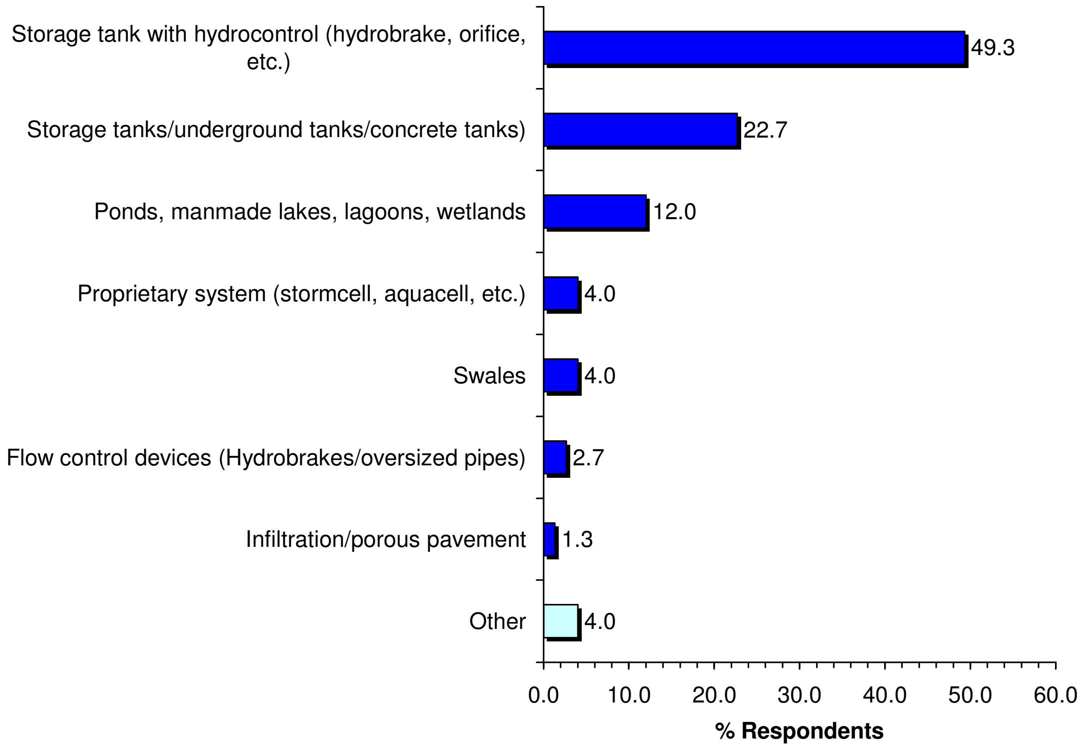

Figure 30 Most commonly adopted structural methods for attenuating stormwater and restricting outflows to pre-development runoff values

5.5.1 Involvement in SUDS Implementation

The level of respondent’ familiarity and experience with SUDS was assessed through two closed-form questions in the questionnaire. A total of 59 respondents replied to these questions. Around 88% of respondents stated that they were familiar with the term ‘Sustainable Urban Drainage’ (see Figure 31) while 73% have direct experience of being involved in urban development that required the use of SUDS systems.

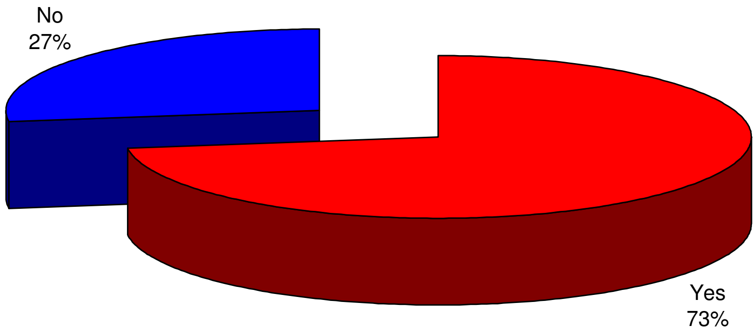

Figure 31 Have respondents been directly involved in an urban development that required the implementation of SUDS structures?

Focus Group meetings also recognised practitioner's awareness of SUDS and their promotion through Local Authority Planning Guidelines, with one participant nothing that:

> *"At a recent IAH seminar in Tullamore, even the wording* (in policy documents) *has changed. It has gone from 'you must consider SUDS as an option' to 'you must have SUDS as an option,' and if you don't, you must explain why not"*

The types of SUDS systems implemented by respondents in urban developments with which they were directly involved are summarised in Figure 32.

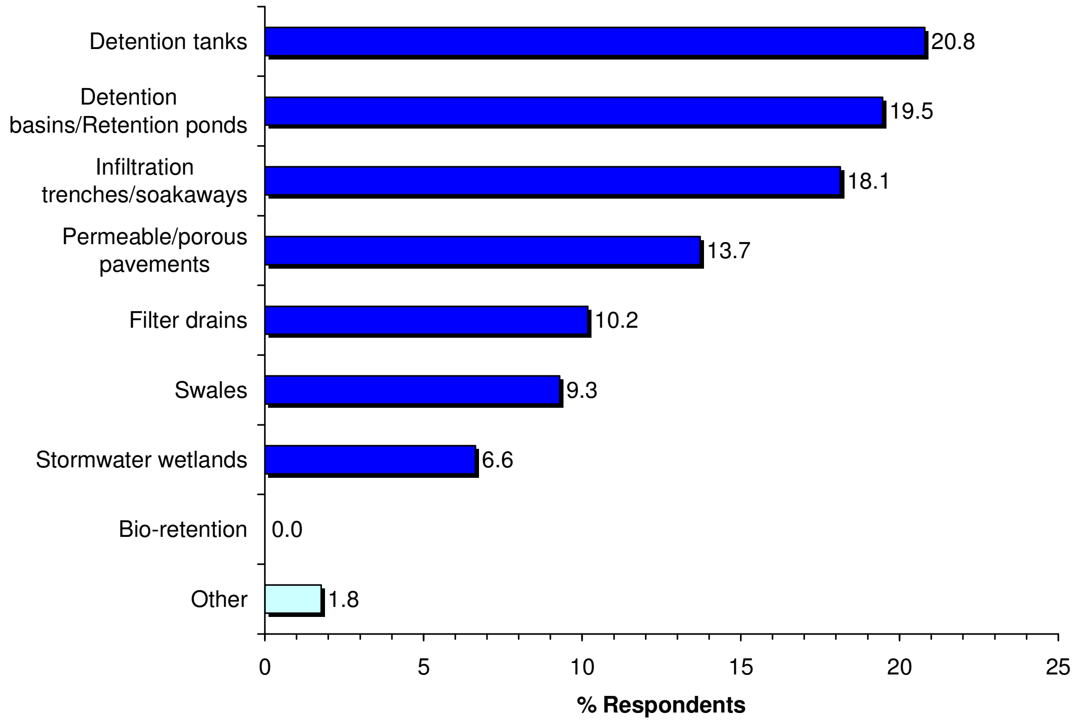

Figure 32 Percentage of respondents having direct experience in implementing specific SUDS structures

The use of detention and retention for management of stormwater is well represented in Figure 32 with the use of detention tanks and detention basins/retention tanks accounting for almost 21% and 20% of citations respectively. Infiltration of excess stormwater through trenches, drains and soakaways is also well represented. The low usage of swales and stormwater wetlands is, probably, a result of their large land-take; only about 9% and 7% of respondents have direct experience of implementing these systems.

Other methods mentioned by respondents include underground structures (Aqua-cells, Stormtech chambers), oversized pipes and roof gardens. Bio-retention measures that utilise soils and plants to remove pollutants from water runoff did not feature in any of the questionnaire responses, suggesting that respondents are either not particularly familiar with this method of stormwater management or have reasons why bio-retention measures should not be implemented. It may also indicate the perceived divide that exists regarding the quantity and quality aspects of stormwater control.

5.5.2 Importance of Different Factors in Affecting Selection and Design of SUDS

Respondents were asked to rank the importance of factors affecting the selection and design of SUDS on a scale of 1 to 5 (*where 1 is not at all important and 5 is very important*). Results are summarised in Table 10.

SUDS selection criteria	Importance by respondents (No. of citations with % of respondents in brackets)				
	Not at all important	Not very important	Neither important nor unimportant	Quite important	Very important
Provision of an amenity	0	13 (21.3)	15 (24.6)	30 (49.2)	3 (4.9)
Creation of wildlife habitat	1 (1.6)	12 (19.7)	15 (24.6)	30 (49.2)	4 (6.5)
Cost of construction	0	2 (3.3)	9 (14.7)	27 (44.3)	23 (37.7)
Cost of maintenance	0	0	4 (3.3)	22 (36.1)	38 (62.3)
Safety considerations	0	0	3 (4.9)	17 (27.9)	41 (67.2)
Soil conditions	0	2 (3.3)	10 (16.4)	24 (39.3)	25 (41.0)
Availability of land	0	0	6 (9.8)	19 (31.1)	39 (63.9)
Limiting volume of runoff	0	1 (1.6)	7 (11.5)	32 (52.4)	21 (34.4)
Water quality management	0	1 (1.6)	1 (1.6)	1 (1.6)	3 (4.9)

Table 10 Factors which influence respondent's selection of SUDS

All responses that were considered important and all those that were considered unimportant, regardless of degree, in the data in Table 10 can be represented graphically (see Figure 33).

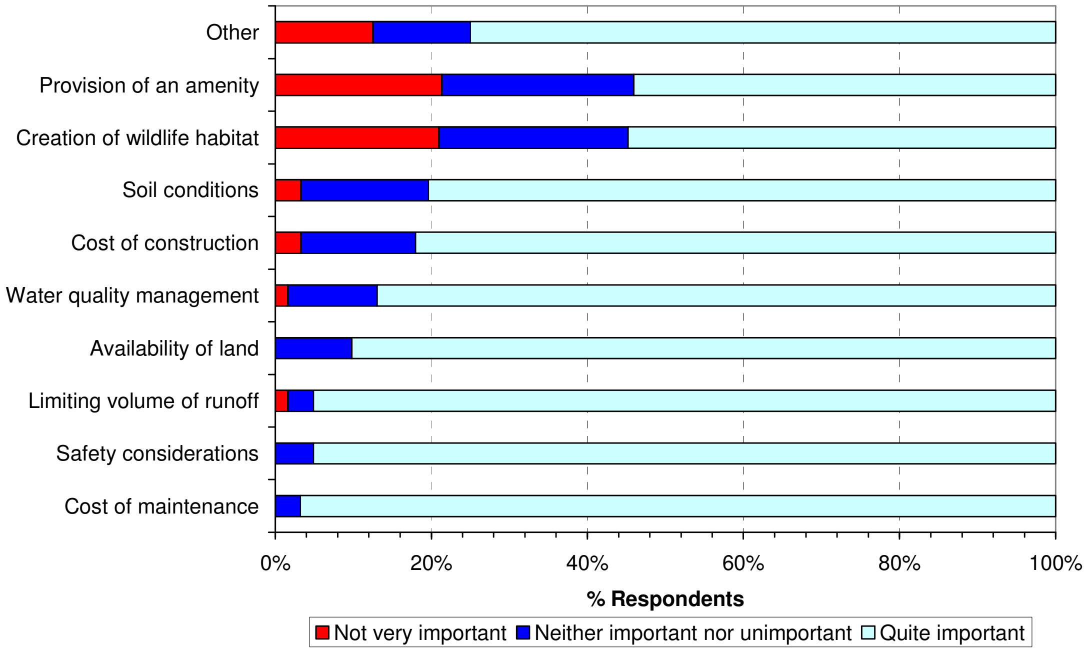

Figure 33 Importance of factors which influence respondents' selection of SUDS

Figure 33 indicates that approximately 55% of respondents consider <u>all</u> the factors listed in the questionnaire to be important with maintenance costs and safety considerations being the most important. Rather surprisingly however, the provision of an amenity and the creation of a wildlife habitat in SUDS were considered to be unimportant by over 20% of respondents with a further 20% being indifferent to these benefits.

5.5.3 <u>Deterrents to the Implementation of SUDS</u>

Respondents were asked to specify factors that might deter them from using or implementing SUDS. A comprehensive list of potential deterrents was offered and respondents were encouraged to select more than one deterrent. Of the 61 responses to this question, 17.2% and 15.1% respectively cited responsibility for maintenance and maintenance costs as the major deterrents. The full range of results are summarised in Figure 34.

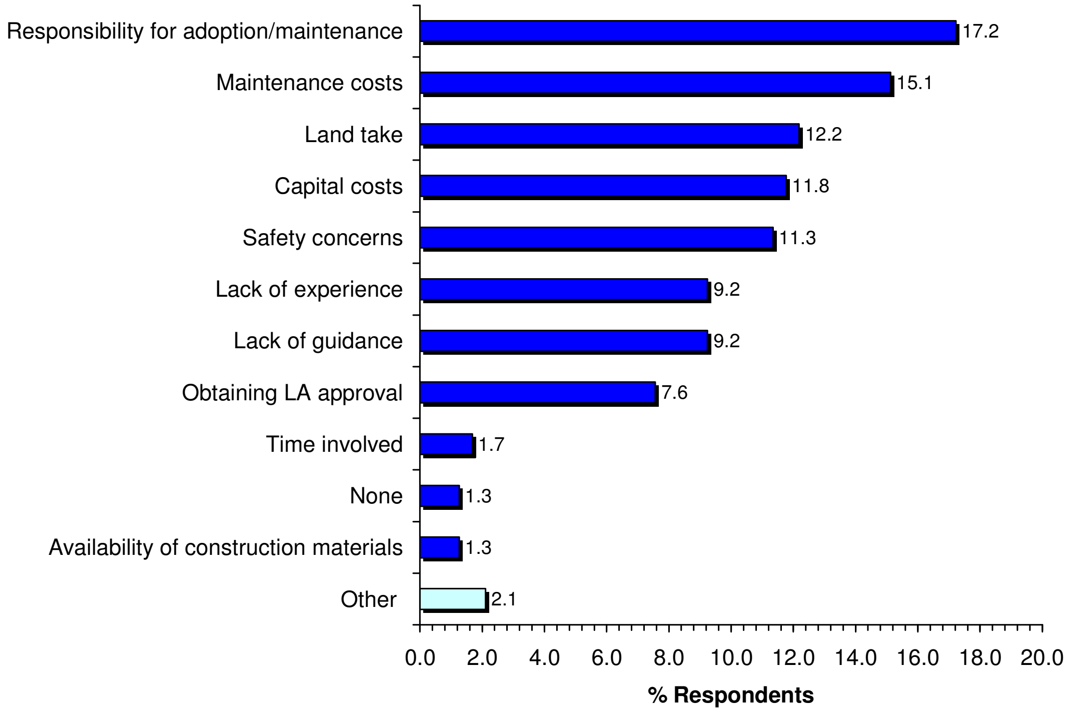

Figure 34 Perceived deterrents to the implementation of SUDS

Issues of SUDS maintenance and its responsibility were also reinforced at the Focus Group meetings with the following comments being made by participants:

> *"Long-term maintenance is another consideration"*

> *"SUDS have to be correctly designed. In ground* (taken to mean underground) *SUDS, there is less maintenance required. However, people are unwilling to spend money on integrating them* (into development schemes)*"*

> *"Local authorities don't want to be landed with more responsibility for maintenance. Some SUDS schemes may have to be undone if unsatisfactorily installed. The Authority has to be compensated if they take over* (take charge of) *SUDS"*

Costs associated with SUDS were also considered to be deterrents. About 12% of respondents identified both land costs and capital costs of the SUDS as being significant. This was reinforced at a Focus Group where it was noted that *"It becomes more economically advantageous to fill* (with stormwater) *a concrete box under the same development spaces* (than use extra land for other SUDS)*"*.

To overcome the increased costs associated with SUDS, the idea of reducing land-take by allowing a balance of both underground storage and SUDS was mentioned as a possible compromise:

> *"But even stick to the five year storm* (being stored) *underground and leave some sort of open space area* (for the remaining stormwater)*, you have some compromise. But just to have that amount of land* (being used for stormwater attenuation)*….land isn't cheap around Dublin"*

A lack of experience or familiarity with the concept of SUDS features and their benefits was cited by over 9% of respondents as being a deterrent. This lack of experience or familiarity with SUDS features applies mainly to developers where it was noted that:

> *"to most developers, this whole notion of SUDS is a very recent phenomenon…many are not familiar with it. I have to spend a lot of time over the phone explaining the basic concepts of a SUDS design with them"*

However, it was also noted that knowledge of SUDS in engineering consultancies and architectural practices can sometimes be poor:

> *"Lack of familiarity is a problem. Neither architects not engineers are familiar with it."*

Poor knowledge and lack of familiarity with SUDS installations is reflected by the absence of official guidance which was cited by over 9% of respondents as being a deterrent to their use.

While the quantitative and qualitative elements of this research focused mainly on the reasons why SUDS installations were not popular amongst developers, the benefits of some SUDS features in other countries were recognised when it was noted that they can:

> *"certainly sell* (development) *space in the US and Scandinavia where there's an area of water to look out on"*

A small number of respondents also identified the problem of impermeable boulder clay when implementing SUDS structures in the Greater Dublin area. Contractual obligations for signing-off fully functional SUDS installations were also identified as a potential deterrent.

5.5.4 Adequacy of Guidance Material for SUDS Design

Respondents were asked to identify sources of guidance that they have accessed in designing SUDS installations. The sources mentioned are summarised Figure 35.

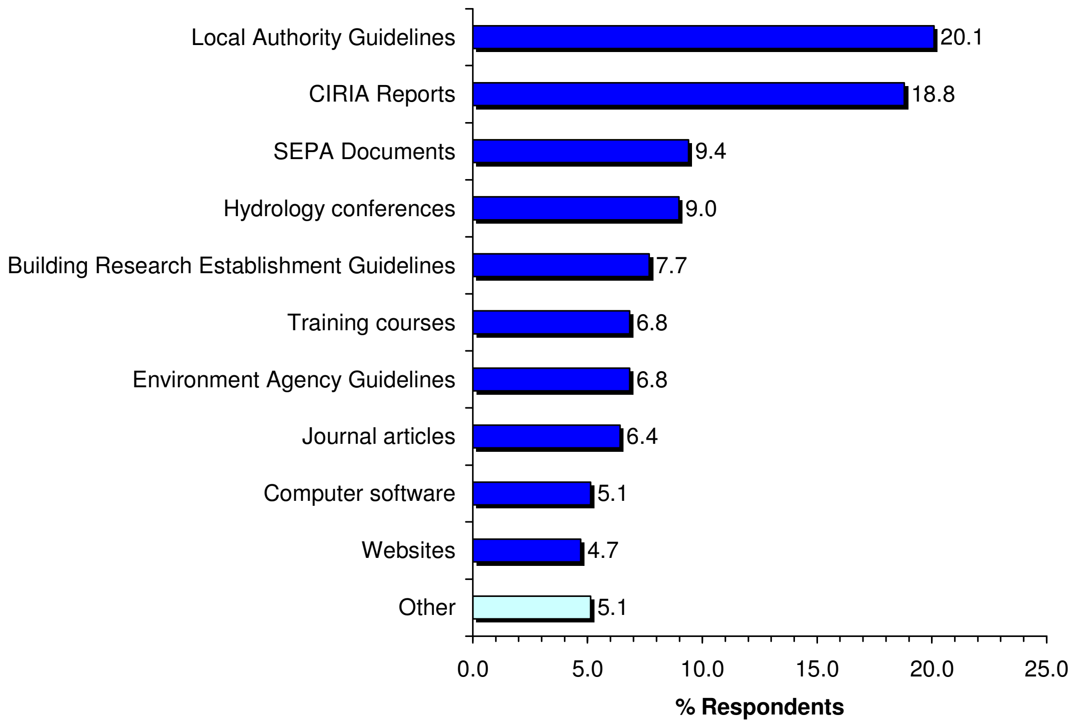

Figure 35 Guidance material commonly used by respondents in SUDS design

It seems that Local Authority Guidelines and CIRIA reports are the most commonly used documents for SUDS design in Ireland with approximately 20% and 19% of respondents having accessed these in the past. Less popular sources are also represented in Figure 35 but in addition, other references such as documentation from the manufacturers of SUDS, from the German Association for Water, Wastewater and Waste (DWA Germany), HR Wallingford reports and the Design Manual for Roads and Bridges (DMRB) Section 4 HA 103/01 – Vegetative Treatment Systems for Highway Runoff, were also cited. Respondents were given the opportunity to expand on the data in Figure 35 by offering specific references with which they were familiar. The most common references identified for use in SUDS guidance are:

- GDSDS (Vol. 2, Vol. 3);
- CIRIA reports – R123, R142, C521, C523, C582, C609, R180, R156, R142;
- Building Research Establishment (BRE) Digest 365;
- Dublin City Council – Stormwater Management Policy for Developers (1998).

Individual respondents also cited the Regional Drainage Policy, DMRB – HA103/01, DWA guidelines, Environment Agency (EA) Pollution Prevention Guidance, Waste Licence Requirements - suspended solids and surface water discharge, the EU Water Framework Directive - requirements for suspended solids concentrations, the website of the Scottish Environmental Protection Agency (SEPA), United States EPA fact sheets online, the Scottish Executive, OPW National Hydrology Seminars, Engineers Ireland, Institution of Civil Engineers (ICE) and Institute of Hydrology (IoH) courses on SUDS and general SUDS publications and websites were also cited by individual respondents.

Respondents were also requested to state how they became aware of the SUDS guidance available. Responses to this question are summarised in Figure 36.

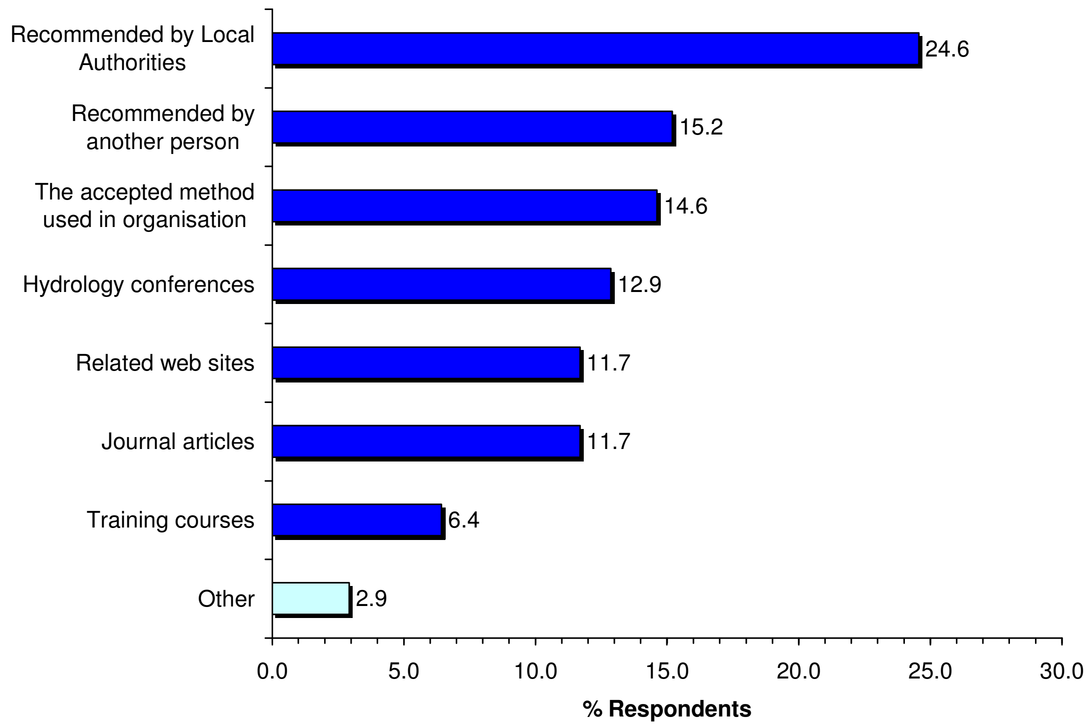

Figure 36 How respondents became aware of the guidance available (% of respondents)

Some respondents also mentioned that presentations from manufacturers/suppliers of SUDS installations and independent literature searches made them aware of SUDS guidance.

Respondents were also asked to specify how they rated the technical guidance available on the design and performance of SUDS. Only 60% of respondents felt that current guidance was adequate as shown in Figure 37.

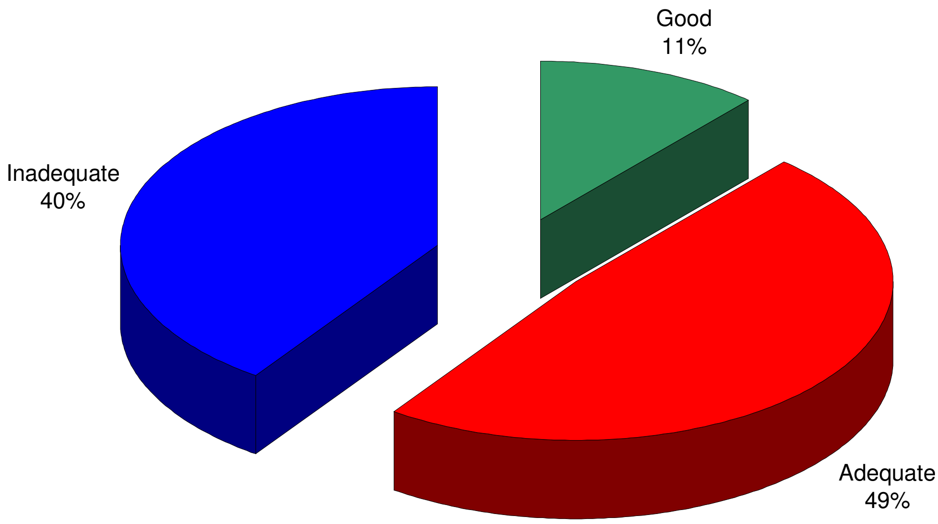

Figure 37 Respondents' rating of the technical guidance that is available on the design and performance of SUDS

The lack of guidance was further discussed at the four Focus Group meetings and in these discussions it became apparent that the actual design of various features of SUDS, was reasonably well covered in guidance from agencies such as CIRIA and SEPA but that the deficiency in available guidance from an Irish perspective was primarily related to determining flow and volume calculations from developed catchments. In this, a large overlap exists with the results that have been presented in Section 5.3. Regarding these flows, the following comments were made:

> *"Some guidance on the Greenfield runoff is also necessary. What is the increase likely to be if there is development?"*

> *"I'd like more guidance on the urban fraction and the best size to use for a particular catchment"*

> *"The problem is the size of the catchments as some of these catchments are very small. There is no guidance in Ireland on how to treat different size catchments"*

Respondents were asked whether more technical guidance on the design and performance of SUDS would assist in choosing a SUDS device for stormwater management. Not surprisingly, and following from the results in Figure 37, 87% of respondents felt that further guidance would be of assistance (Figure 38).

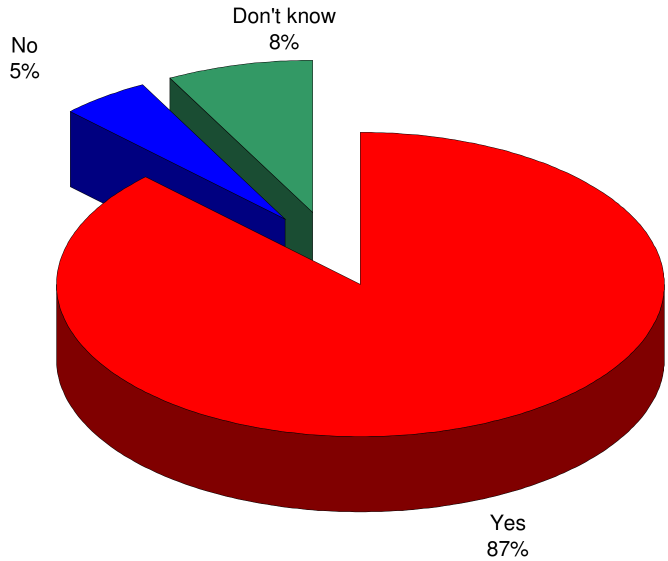

Figure 38 Whether additional guidance would assist respondents in choosing a SUDS installation for stormwater management

5.5.5 Familiarity with Source, Site and Regional Control

Respondents were asked whether they had familiarity with a number of different approaches/concepts to stormwater management. The options provided were site, source and regional control and an Australian approach known as Water Sensitive Urban Design (WSUD). With regard to these stormwater management approaches (see Figure 39), 30% of respondents were familiar with the principle of 'source control', about 40% had encountered 'site control' and 12% had an understanding of 'regional control'. WSUD, in which the re-use of 'greywater' is a major component, was recognised by about 18% of respondents.

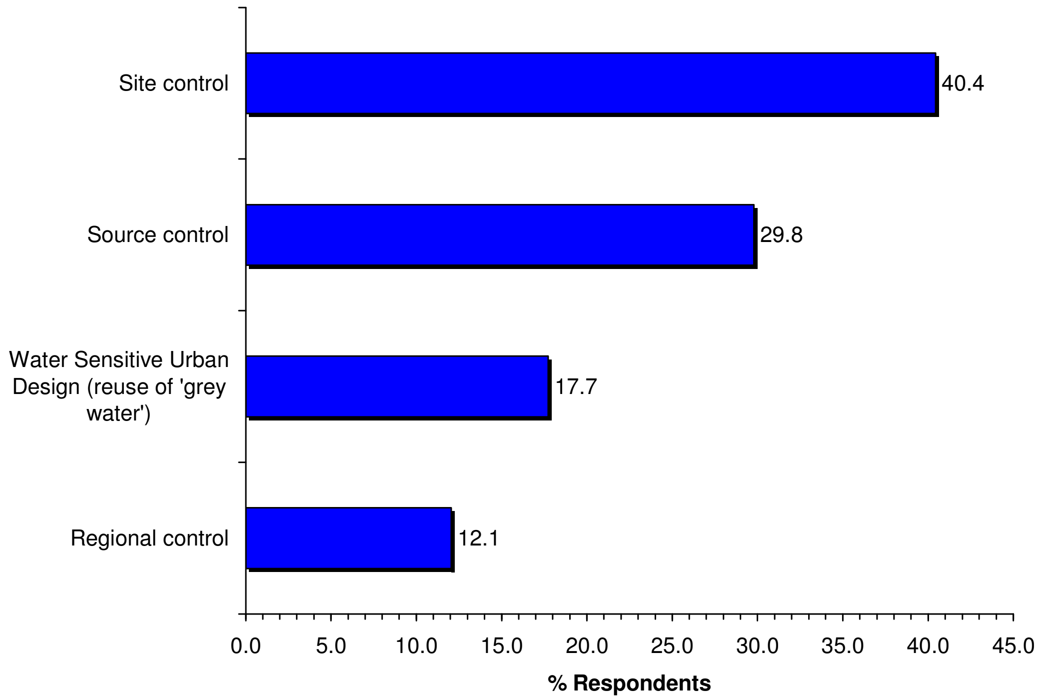

Figure 39 Respondents' familiarity with different approaches to stormwater management

5.5.6 Additional Comments

Finally, survey participants were given an open ended question requesting further comments on urban catchment flood analysis and stormwater management. Only 50% of respondents provided this additional information. All comments made were collated and grouped into common themes, results of which are shown in Figure 40.

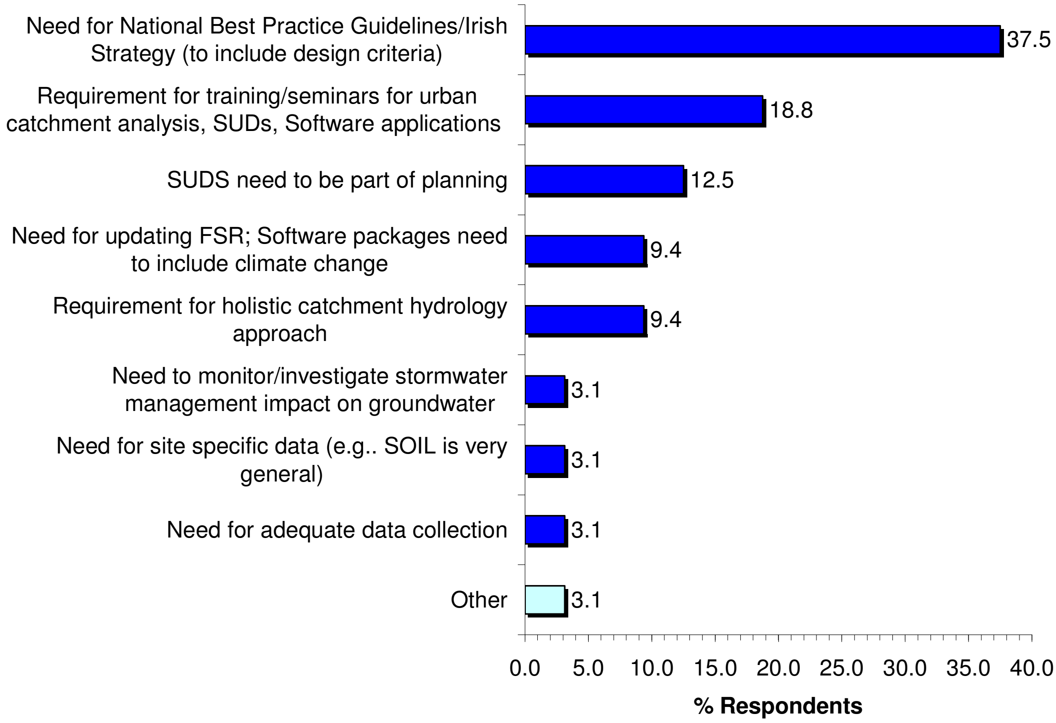

Figure 40 Summary of additional information provided by questionnaire respondents

The majority of comments made (37.5% of respondents) relate to the need for a national guidance document for urban catchment flood analysis and stormwater management. A further 19% of respondents cited the need for additional training for flood analysis, SUDS and software applications through the provision of courses and seminars.

Catchment management and the need for a more holistic approach that includes the provision of SUDS were also well represented in responses.

Deficiencies in FSR methodologies and the need for these to include climate change impacts were considered important to over 9% of respondents.

Another participant mentioned that the priority focus should be on water quality rather than on stormwater management and at the very least, an integrated approach that promotes treatment of stormwater quantity and quality together should be considered. This, it was stated could be achieved by compulsory use of SUDS and would be in line with best practice elsewhere in the world.

One person voiced a concern over the safety of open ponds and swales when implemented in residential developments.

Other points mentioned were the need to monitor/investigate the stormwater management impact on groundwater and the need for site specific data where the point was again made that SOIL index values are very general and require more detail. This issue has been addressed in Section 5.3.1 of this report. The need for improved data collection was also mentioned in some 'additional information' responses.

6 Conclusions and Recommendations for Further Research and Development

6.1 Introduction

This report contains the findings of a scoping review of currently used methodologies for analysing flooding in urban catchments that are currently used in Ireland. Approaches to stormwater management were also assessed in the study. The work forms part of the Flood Studies Update (FSU) Programme that was initiated in 2005 by the OPW in conjunction with interested state, semi-state and other relevant organisations and in this context represents the initial Work-Package (4.1) in Work-Group 4 that is addressing urban catchment flood analysis.

The research was practitioner focused and comprised both quantitative and qualitative elements to gauge practitioner's opinions of urban flooding issues that are important in their work. The quantitative element of the work involved the circulation of self-completion questionnaires to organisations in recognised target sectors that deal with urban flooding issues, and from these responses, participants were recruited for the qualitative element of the work that comprised Focus Group meetings. In keeping with the project brief where the requirement for the scoping study to review flood issues across Ireland was recognised, four Focus Groups were held in the major conurbations of Dublin (2 groups), Cork and Galway. A total of 291 questionnaires were circulated, both electronically and by post. A total of 100 questionnaires were returned equating to a 34% response rate and 24 of these respondents participated in Focus Group meetings. The majority of questionnaires (82 in total) were returned from engineering consultancies and public bodies (Local Authorities, County Councils, City Corporations etc.) indicating that these organisations lead in the design, planning and implementation of all aspects that relate to urban flooding. Results suggest that only minor inputs to urban flooding issues are made by engineering contractors, architects and planners.

6.2 Main Findings

A number of issues relating to urban catchment flood analysis and stormwater management have been raised in the course of this study. In all cases these have been presented, and where appropriate, supported by Focus Group comment in Chapter 5 of the report. A more comprehensive summary of Focus Groups meetings (prepared by Social and Clinical Research Consultants) has also been included in Appendix D. The main findings of the work have been grouped and are summarised as follows:

- Need for a National Guidance Document for Peak Flow Estimation

  It has been identified by the majority of participants in this scoping study that the absence of national guidance documents or policies in relation to peak flow estimation in urban and small rural catchments for effective design. While it is accepted that a *'one size fits all'* approach to catchment analysis would, because of the variability across Irish catchments, constitute poor practice and would not ultimately be sustainable, it is clear that huge levels of uncertainty exist within the range of peak flow estimation methodologies that are currently used. These uncertainties exist for both urban and greenfield sites.

Practitioners require a nationally produced and supported document or handbook that would provide guidance on peak flow estimation methodologies that are applicable for a range of catchment conditions, for a variety of catchment sizes and represent both the geographical and geological variations in Irish catchments. Such guidance should be similar to that used in Australia, Malaysia, South Africa and in some states in the US and should be supported by worked examples and design approaches.

It is clear that Rational and Modified Rational Methods are very extensively used in estimating peak flows in urban catchments and that the IoH No. 124 equation and to a lesser extend, the 3-Variable equation in FSSR No.6, are used for analysing small greenfield catchments. These greenfield equations are based on regression studies for catchments with areas that range from 20km^2 to 25km^2. However, the scale of urban or urbanising catchments analysed for development are often less than 1km^2 and this calls into question the 'one size fits all' approach often applied to urban drainage issues in Ireland. Furthermore, while most participants to this study were aware that uncertainties exist in the application of the various peak flow estimation methods to greenfield catchments, there was little evidence of a deeper understanding of where these uncertainties originate. As an example, respondents using the IoH No. 124 equation were aware that a difficulty with the method lies in extracting catchment descriptors from poor resolution FSR mapping. While this is without doubt the case, a greater uncertainty when using this equation may well result from the regression study on which it is based and particularly the range of soil types in the catchment sample (refer to Section 3.3), a point not raised by any respondents. This supports an assertion that methodologies in many cases are being applied on a prescriptive basis without due consideration to the catchment characteristics that will influence the runoff processes.

Practitioners also expressed concerns that methodologies for peak flow estimation that are currently used do not account for the predicted future impacts of climate change. It was however, generally accepted that climate change multipliers are included in most designs but that these are arbitrary and are applied on an ad-hoc basis with no recognised or standard procedure being followed by Local Authorities. This, it was felt, needs to be addressed. On this theme, the request for developing software that would accompany any national guidance document was made. This software should have the capability to model the full range of predicted climate change scenarios.

Research indicates (see Chapter 2) that Rational and Modified Rational Methods are being successfully used to analyse urban and small greenfield catchments elsewhere in the world. Application of these methods tends to be based on a well developed understanding of catchment behaviour and runoff processes for different regions. Results of this study indicate that catchment responses to rainfall events are not particularly well understood in Ireland. The project team feels that scope exists for developing flow estimation methodologies for small catchments within the framework of a Rational Method approach. Such methods would require calibration to Irish conditions and as such, particular attention, in terms of supporting such an approach should be focused on accurate estimations of rainfall-runoff coefficients and concentration times for a full range of catchment characteristics. This should be supported on an ongoing basis by the type of research recommended in Section 6.3 (1) and (2) below.

Any guidance, whether for existing, revised or new peak flow estimation methodologies should be developed from research on observed data (supported potentially from findings of other Work-Packages) in a particular region where regions should be realistically chosen to represent flood characteristics. Regional methods that are developed should attempt to account for catchment characteristics with effects that can be identified in the observed data and consequently, should represent broad-scale differences in catchment characteristics across the region, such as physical, geological and soil features in addition to the types of runoff processes that are involved.

- Need for a National Guidance Document on Stormwater Management

The need to have an integrated national approach to stormwater management was identified by participants in this study. This approach should address issues relating to stormwater quantity and quality in line with recognised best practice elsewhere in the world and should be supported by appropriate guidance and documentation. While participants to the scoping study were reasonably familiar with SUDS, it was generally accepted that unless they become a compulsory method of stormwater management, their use will remain somewhat limited. The main deterrents to the use of SUDS that were identified by participants were maintenance costs and responsibilities and excessive land-take. It is likely that SUDS will be part of the programme of measures required by the Water Framework Directive and their flood attenuation capabilities should be integrated into flood management. For this to happen, extensive performance information on the flood attenuation capabilities of various SUDS measures is required for design purposes.

Up to now, practitioners have relied heavily on UK documentation for the design of SUDS features, with particular reference being made to the CIRIA and SEPA design guidelines. The benefits of an Irish guidance document in this regard were highlighted. Furthermore, the need to integrate such a document with guidance on peak flow estimation in urban and greenfield sites was made.

- Need for Better Data

The availability of high quality and high resolution data is significant in terms of the accuracy of peak flow estimation in both urbanising and greenfield catchments. However, it is generally felt by participants in this study that data for Irish applications is insufficient and inadequate. While the need for an improved, widened and technologically more advanced monitoring infrastructure was recognised, most dissatisfaction is associated with the low accuracy and poor resolution of FSR catchment maps. The SOIL parameter in particular, because of its significance in flow calculations combined with poor map resolution and difficulties in delineating small catchments is of most concern.

Practitioners feel that efforts must be made to improve on the quality of this hydrological data and while it is accepted that new SOIL maps are being produced in 2006, the relationship of these to hydrological catchment characteristics is uncertain.

- Need to Define Scale and Scope of Catchment Management and Integrate with Planning Legislation

Many participants to this study believe that the current approach of 'postage stamp' development within catchments is unsustainable. Most participants, while unfamiliar with the 1945 Arterial Drainage Act, identified the need for a more holistic approach to catchment management and indicated that this approach should be included in an updated legislative framework.

6.3 Recommendations for Further Research and Development

A primary objective of this scoping review was to recommend items of further Research and Development with a view to delivering improved and generally applicable methods of urban catchment flood analysis.

While requirements in a number of areas pertaining to urban flooding issues were identified, the authors of this report feel that much of the future Research and Development should be focused on bridging the deficit in data quality, availability and resolution with reference to soil indices. For this, a two-pronged approach is recommended. The first of these involves attempting to develop the hydrological capacity of the new soil maps that are being produced by Teagasc later this year. The second is on a similar theme and involves assessing the relationship, if any, that exists between infiltration and percolation and investigating whether percolation and infiltration values are consistent with specific catchment characteristics. These are presented in (1) and (2) below and are followed by other areas where Research and Development is required.

1) Developing Hydrological Capacity of New Irish Soil Maps

   Teagasc is currently compiling new soil maps for the 26 counties of the Irish Republic. These maps are due to be issued later in 2006 and are an update of the maps last issued in 1980. The new maps will classify Irish soils in terms of 44 associations, each association being a proportioned composite of other soil types.

   While each soil association will be accompanied by a brief description of its hydrological characteristics, this information in terms of catchment analysis will be insufficient. Catchment analysis in the urban context is typically concerned with small catchments. Catchments of this size, in the greenfield condition, can be accurately modelled by Rational type formulae. This approach is adopted elsewhere in the world and has been shown to work reasonably well. However, its success is based on having access to accurate runoff coefficients and concentration times for different catchment types. Insufficient data of this type currently exists in Ireland.

   It is recommended that further work should be undertaken to investigate whether any consistent relationships between these new soil maps and rainfall-runoff coefficients and concentration times can be established.

2) Site Specific Characterisation Studies

   It is recommended that a suite of simple tests (quick and cheap) that can be used to characterise the runoff behaviour of individual sites, be developed and validated. For instance, Teagasc, in combination with all Local Authorities, have at their disposal a large body of soil percolation test results that would have accompanied planning applications for developments that included, for example, septic tanks. This data is currently not available on any database that could assist Irish hydrologists. The authors are aware that from a catchment analysis perspective, percolation test results will apply only to the ground level layers at a localised point in a catchment and will therefore not represent catchment infiltration. However, the authors feel that merit exists in examining percolation values for a range of catchment types to investigate the relationship, if any that may exist between percolation, infiltration and runoff.

   If relationships are shown to exist between percolation and infiltration, scope exists for collating all percolation values into a GIS based national database that could be continuously updated by the results of new tests.

The idea of obligatory infiltration tests (similar to percolation tests that are required for some development) being imposed on developers was received positively in the Focus Group meetings that were undertaken as part of this research. This would provide site specific information at the location of proposed developments from which accurate runoff coefficients could be developed. Such data would facilitate an accurate application of Rational type formulae to determine pre-development runoff rates as is done elsewhere in the world. It is accepted that percolation tests will not necessarily provide infiltration and runoff data and therefore, potential exists for making the development of a suitable test, the focus of further work.

In addition, there may be other factors, such as depth of subsoil, depth to water table, presence or absence of field drains which may be relevant for green or brown-field sites.

It is felt that considerable scope would exist for using the findings of this recommended work [(1) and (2)} to support the "Need for a National Guidance Document for Peak Flow Estimation" identified in Section 6.2 above.

<u>Validation of Hydraulic Modelling Approaches</u>

Participants in this scoping review provided information on a number of software packages that are commonly used to support stormwater system design and analysis. While it was accepted that the technical support for these software packages when applied to Irish catchments was generally deficient, little comment was made on the perceived accuracy and variability of the general modelling approach. Previous research, undertaken at CWRR identified significant differences between measured and modelled floods, both in the magnitude and timing of flood peaks (Bruen and Yang, 2006). Thus, the authors feel that research should be undertaken to validate these modelling methodologies for Irish catchments to assess the magnitude and sources of errors (including deficiencies in the description of the hydraulic network), the dependency of these errors on the input parameters and the sensitivity of the design floods to these errors. Assessing the deficiencies in descriptions of hydraulic networks may require investigation of as-built drawings).

This should not be an exercise in validating the commonly used models but rather, should form the basis of a critical appraisal where the validation of the modelling approach is verified for Irish catchments. Within this, it would be necessary to undertake case studies on existing or new instrumented drainage systems.

<u>Design Implications of Spatial Progression of Urban Floods</u>

In designing flood protection and management strategies for major urban areas it is important that the dynamics of the build-up, progression and recession of the flood be understood. For instance, access of emergency services vehicles to affected areas can depend on the periods for which specific depths of water are exceeded. There is a need for guidance on methodologies to model the spatial progression for specified flooding scenarios. This would support the flood management initiatives advocated in the report of the Flood Policy Review Group (2004).

<u>Flood Warning Systems</u>

Current international practices involve the integration of flood defences with non-structural management strategies. Adequate flood warning systems are a necessary component of such integrated approaches to flood management. This is especially important in urban areas, where lag-times are short and where the potential for damage and injury is high.

Educational Needs

Results of this study indicate that a deficit exists between the actual and what would be perceived to be an acceptable level of understanding in urban catchment flood issues and in particular, in the manner in which flow estimation methodologies are applied to these catchments. It would appear that this is done on a *'one size fits all'* or *'black box'* basis where methods are applied on a prescriptive basis without due consideration being paid to the catchment characteristics that influence the rainfall-runoff process. The over-reliance on spreadsheet calculations and software packages does not necessarily help in this regard.

The project team feel that there is an onus of responsibility for Irish academic institutions, in conjunction with Engineers Ireland (the Irish Professional Engineering body), to provide courses / seminars to assist in the educational needs of the engineering community regarding these flood issues. Courses of this type should be provided through a Continuing Professional Development (CPD) framework and sustained through support from engineering organisations.

7 References

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Appendix A
(Self-Completion Questionnaire)

The Office of Public Works & University College Dublin
Urban Catchment Flood Analysis – Practitioners Questionnaire

INTRODUCTION

The Office of Public Works (OPW) in conjunction with interested state, semi-state and other relevant organisations have initiated a review and update of the 1975 Flood Studies Report (FSR). The Centre for Water Resources Research (CWRR) in UCD Civil Engineering has been appointed to undertake a scoping study of urban flooding issues and requires an assessment of methods used and problems experienced by practitioners in the area. Recommendations for future Research and Development that will ultimately improve Urban Catchment Flood Design will evolve from the review and through inputs from practitioners, will be linked to specific problems encountered on the ground.

The study is keen to identify methods of flood estimation in urbanised catchments currently in use in Ireland and assess deficiencies generally encountered with urban runoff control. OPW has asked CWRR to contact a number of practitioners in the field to seek opinions on Urban Catchment Flood Analysis and stormwater management in Ireland.

We believe your experience and opinion are important. It would be greatly appreciated if you could spare the time to complete this questionnaire. Full confidentiality and anonymity for individual responses is assured.

It is intended that your answers should reflect your own personal opinion and experience.

Please send your completed questionnaire back in the stamped, addressed envelope or alternatively fax your completed survey to Dr. John O'Sullivan on (01) 7167399 **no later than Friday 3rd February 2006.**

If you have any queries regarding the completion of this questionnaire please contact Dr. John O'Sullivan at CWRR in UCD Civil Engineering on (01) 7167321.

INFORMATION

NAME: ______________________

ORGANISATION: ______________________

ADDRESS: ______________________

____

E-MAIL: ______________________

TEL NUMBER: ______________________

DATE: ______________________

What is your position in your organisation?

1 How would you classify your role in Urban Catchment Flood Analysis? Would you say it is ….? ***Please circle all that apply***

Planning	1
Design	2
Reviewing	3
Construction/Implementation	4
Management	5
Insurance	6
Other (Please specify ↓)	7

IMPLICATIONS OF URBANISATION

2(a) Are issues relating to urban flooding of particular concern in your work? ***Please circle one response only***

Yes	1
No	2

2(b) If you answered 'yes' to Question 2(a), please expand.

3 Using the scale of 1 to 5 where 1 is disagree strongly and 5 is agree strongly, how much do you agree or disagree with each of the following statements, regarding your opinion of the effects of increasing, non-attenuated urbanisation? ***Please circle one response only in each row***

	Disagree strongly	**Disagree slightly**	**Neither agree nor disagree**	**Agree slightly**	**Agree strongly**	**No opinion**
Urbanisation results in a greater proportion of incident rainfall appearing as direct runoff	1	2	3	4	5	6
Urbanisation results in stormwater being conveyed through the drainage network more rapidly	1	2	3	4	5	6
Urbanisation can affect the shape of runoff hydrographs	1	2	3	4	5	6
Urbanisation can result in hydrographs that are faster to peak and faster to recede	1	2	3	4	5	6
Urbanisation can result in hydrographs with increased peak rates of flow	1	2	3	4	5	6
Urbanisation may reduce baseflows in receiving watercourses	1	2	3	4	5	6
Urbanisation can have an adverse affect on water quality in the receiving watercourse	1	2	3	4	5	6

PEAK FLOW ESTIMATION IN GREENFIELD CATCHMENTS

4(a) Have you ever calculated, or used a calculated peak flow for a greenfield site (pre-development)? ***Please circle one response only***

Yes	1	Please continue with Question 4(b)
No	2	Please go to Question 5

4(b) With which equations/methods for **calculating peak flows for a greenfield site** are you most familiar? ***Please circle all that apply***

The Rational Method	1
Institute of Hydrology Report No. 124 equation	2
Flood Studies Supplementary Report No. 6, 3-variable equation	3
Flood Studies Report, 6-variable equation	4
Flood Studies Report, 3-variable equation	5
Flood Studies Report, 2-variable equation	6
Flood Studies Report, 1-variable equation	7
Flood Frequency methods	8
Unit Hydrograph methods	9
ADAS Report No. 5 method	10
Prescribed rate (e.g. in $ls^{-1}ha^{-1}$)	11
Other (Please specify ↓)	12

4(c) Please indicate how you implement the above method(s), identifying any software that you use.

4(d) What are the main difficulties/limitations, if any, that you have encountered when using these equations/methods? Please specify clearly the equation/method that you are referring to in your response.

PEAK FLOW ESTIMATION IN URBAN CATCHMENTS

5(a) Have you ever calculated, or used a calculated peak flow for an urban catchment (post-development)? ***Please circle one response only***

Yes	1	Please continue with Question 5
No	2	Please go to Question 10

5(b) With which methods/models for **calculating peak flows for an urban catchment** are you familiar? ***Please circle all that apply***

The Rational Method	1
Modified Rational Method	2
Transport and Road Research Laboratory method	3
The Wallingford Procedure	4
Flood Studies Report rainfall-runoff method	5
Flood Studies Supplementary Report No. 5 version of Flood Studies Report rainfall-runoff method	6
Flood Studies Supplementary Report No. 5 version of Flood Studies Report statistical method	7
Flood Studies Supplementary Report No. 16 variation of Flood Studies Report rainfall-runoff method	8
Other (Please specify ↓)	9

5(c) What are the main difficulties/limitations, if any, that you have encountered when using these methods/models? Please specify clearly the method/equation that you are referring to in your response.

GUIDELINES FOR PEAK FLOW ESTIMATION IN EITHER GREENFIELD OR URBAN CATCHMENTS

Questions 6 – 9 are only to be answered if you have calculated, or used a calculated peak flow from a greenfield or urban catchment (if you have answered 'yes' to either Question 4(a) or Question 5(a))

If not, please go to Question 10

6(a) What sources of reference have you accessed for guidance on calculating peak flows for either greenfield or urban catchments? ***Please circle all that apply***

Standard hydrology textbooks	1
The Flood Studies Report	2
Local Authority guidelines	3
HR Wallingford reports	4
Journal articles	5
Hydrology conferences	6
Training courses	7
Related web sites	8
Other (Please specify ↓)	9

6(b) Please provide details of specific references, if any, that you have used?

7 How did you become aware of the guidance available? ***Please circle all that apply***

Recommended by Local Authorities	1
Recommended by another person	2
The accepted method used in organisation	3
Journal articles	4
Hydrology conferences	5
Training courses	6
Related web sites	7
Other (Please specify ↓)	8

8(a) Do you consider current guidelines for peak flow estimation for either greenfield or urban catchments to be adequate? ***Please circle one response only***

Yes	1
No	2
Don't know	3

8(b) If you answered 'no' to Question 8(a), please indicate the guidelines that you are referring to and the deficiencies that you experienced?

9(a) Are you satisfied that the basic data for calculating peak flows for either greenfield or urban catchments is readily available? ***Please circle one response only***

Yes	1
No	2
Don't know	3

9(b) If you answered 'no' to Question 9(a), please expand.

DESIGN AND MODELLING OF STORMWATER DRAINAGE SYSTEMS

10 In the context of designing stormwater drainage systems, what approach do you use? ***Please circle one response only***

Software package	1	Please continue to Question 11(a)
Spreadsheet	2	Please continue to Question 11(a)
Manual calculations	3	Please go to Question 13
None	4	Please go to Question 13

11(a) What software have you used when designing stormwater drainage systems? ***Please circle relevant sources***

Micro Drainage *WinDes*	1
HydroWorks	2
InfoWorks CS	3
MOUSE	4
SWMM	5
Spreadsheet - homegrown	6
Spreadsheet – from external source	7
Other (Please specify ↓)	8

11(b) What are the main difficulties/limitations, if any, that you have encountered when using software? Please specify clearly the package/spreadsheet that you are referring to in your response.

12 How do you rate the technical documentation for the software? ***Please circle one response only***

Good	1
Adequate	2
Inadequate	3

STORMWATER MANAGEMENT

The current approach to stormwater management in Ireland promotes the restriction of runoff from new developments to the greenfield rates that would have occurred prior to development.

13 In your experience, what is the most commonly adopted structural method for attenuating stormwater and restricting outflows to pre-development runoff values?

14 Are you familiar with the term ‘Sustainable Urban Drainage’?. ***Please circle one response only***

Yes	1
No	2

15 Have you been involved in any urban development which required the use of Sustainable Urban Drainage Systems (SUDS)? ***Please circle one response only***

Yes	1	Please continue to Question 16
No	2	Please go to Question 23

16 What SUDS devices have featured in your urban developments? ***Please circle relevant features***

Permeable/porous pavements	1
Filter drains	2
Infiltration trenches/soakaways	3
Swales	4
Detention tanks	5
Detention basins/Retention ponds	6
Stormwater wetlands	7
Bio-retention	8
Other (Please specify ↓)	9

17 Using the scale of 1 to 5 where 1 is not at all important and 5 is very important, in your opinion, how important are each of the following factors in the selection and design of SUDS devices? ***Please circle one in each row***

	Not at all important	**Not very important**	**Neither important nor unimportant**	**Quite important**	**Very important**
Provision of an amenity	1	2	3	4	5
Creation of wildlife habitat	1	2	3	4	5
Cost of construction	1	2	3	4	5
Cost of maintenance	1	2	3	4	5
Safety considerations	1	2	3	4	5
Soil conditions	1	2	3	4	5
Availability of land	1	2	3	4	5
Limiting volume of runoff	1	2	3	4	5
Water quality management	1	2	3	4	5
Other	1	2	3	4	5

18 In your opinion, which of the following factors would deter you from using a SUDS device? ***Please circle all that apply***

Responsibilities for adoption / maintenance	1
Land take	2
Obtaining approval from Local Authorities	3
Safety concerns	4
Maintenance costs	5
Capital costs	6
Lack of guidance	7
Lack of experience	8
Time involved	9
Availability of construction materials	10
None	11
Other (Please specify ↓)	12

19(a) What sources of reference have you accessed for guidance on the design of SUDS devices? ***Please circle all that apply***

Local Authority guidelines	1
CIRIA reports	2
SEPA guidance documents	3
Building Research Establishment guidelines	4
Environment Agency (England and Wales) guidelines	5
Training courses	6
Computer software	7
Hydrology conferences	8
Journal articles	9
Related websites	10
Other (Please specify ↓)	11

19(b) Where possible, please give specific details of relevant references.

20 How did you become aware of the SUDS guidance available? ***Please circle all that apply***

Recommended by Local Authorities	1
Recommended by another person	2
The accepted method used in organisation	3
Journal articles	4
Hydrology conferences	5
Training courses	6
Related web sites	7
Other (Please specify ↓)	8

21 How do you rate the technical guidance about SUDS devices? ***Please circle one response only***

Good	1
Adequate	2
Inadequate	3

22 Would more technical guidance on the design and performance of SUDS assist you in choosing a SUDS device for stormwater management? ***Please circle one response only***

Yes	1
No	2
Don't know	3

23 In your work, have you encountered any of the following concepts/approaches to stormwater management? ***Please circle all that apply***

Source control	1
Site control	2
Regional control	3
Water Sensitive Urban Design (reuse of 'greywater')	4

24 Are there any other comments that you would like to make with regard to urban catchment flood analysis or management?

A series of Focus Groups will be organised in strategic locations across Ireland to discuss specific issues / areas of deficiency in the analysis of urban catchment flooding. These will be identified from the questionnaire returns.

25 Would you be willing to attend a Focus Group discussion? ***Please circle one response only***

Yes	1
No	2

Thank you very much for taking the time to complete the survey.

Please send your completed questionnaire back in the enclosed stamped, addressed envelope provided or alternatively fax your completed survey to Dr. John O'Sullivan on (01) 7167399 no later than Friday 3rd February 2006.

Appendix B
(OPW Letter of Support)

Design Section
Engineers' Branch
OPW
17/19 Lower Hatch Street
Dublin 2

Telephone 01- 6476743
Fax. 01- 6761714

Wednesday, 18th January 2006

Address 1
Address 2
Address 3
Address 4
Address 5
Address 6

Re: Scoping Study for Urban Flooding Issues for the Flood Studies Update

To whom it may concern:

I am writing to seek your assistance in relation to the Flood Studies Update (FSU) Programme, an initiative being undertaken by the Office of Public Works (OPW) to carry out an update of the Flood Studies Report.

Flood estimation in Ireland has generally been undertaken in the last 30 years using the methodologies and data provided in the Flood Studies Report, or FSR (NERC, 1975) and from the various national hydrometric databases. The FSR resulted from an extensive UK – Irish research programme that is widely appreciated as having been a significant step forward in flood estimation. While other techniques are available, the FSR, which was developed using data, technology and techniques available up to and including 1969, remains the standard methodology for use in Ireland.

The OPW, in conjunction with interested state, semi-state and other relevant organisations, have now initiated a review and update of the Flood Studies Report (FSR). A significantly greater volume of data is now available to extend the lengths of record, which are of particular importance in the estimation of extreme events. The data available now more accurately reflect current climatic and catchment conditions, including dramatic urbanisation, than the pre-1970 data used for the FSR. Technologies and techniques are also now available and better developed for analysis, presentation and usability of flood estimation packages. This programme of study for the development of new or recalibrated flood estimation methods in Ireland could therefore significantly improve the quality and facility of flood estimation for the purposes of flood risk management.

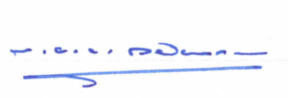
The works for the Flood Studies Update Programme comprise Research and Development in six specific Work-Groups. The Centre for Water Resources Research (CWRR) in University College Dublin (UCD) Civil Engineering has been appointed to undertake the first Work- Package in Work-Group 4 that deals with urban catchment flood analysis. This Work-Package involves a scoping study of all urban flooding issues to identify areas where the FSU, or associated research, could improve urban flood management design.

In order to scope areas for future Research and Development in this area, it is necessary to identify problems experienced by practitioners in the area of flood estimation in urbanised catchments currently in use in Ireland, and assess any deficiencies generally encountered with urban runoff control. The identification of such issues will determine Research and Development recommendations for urban catchment flood analysis, which will therefore be linked to specific problems encountered on the ground. OPW have asked CWRR to consult a number of practitioners in the field to seek their opinion on existing practice and issues in the field of urban catchment flood analysis and stormwater management in Ireland. This is being done in the form of a questionnaire.

This is a significant component of the FSU Programme and it is because of the importance of the project that I am writing to you to ask you to support it by according this request a high priority in your office's work programme and, in particular, to ensure that the questionnaire being sent to your offices by The Centre for Water Resources Research is completed and returned at the earliest possible date.

I would be very grateful if you could support and assist this initiative.

Yours sincerely,



Mark Adamson
Flood Studies Update Programme Director,
Engineer Grade I,
Design Section (Flood Relief),
The Office of Public Works.
Email: mark.adamson@opw.ie

Appendix C
(Focus Group Topic Guide)

Proposed Topic Guide for Focus Groups in Work-Package 4.1 of Flood Studies Update Programme

Warm Up

Explain research process, tape recording, confidentiality and group topic ie we will be looking at aspects of urban catchment flood analysis.

- Introductions
  - ✓ Names
  - ✓ Organisations
  - ✓ Day to day work responsibilities

Topic 1 – Peak flow estimation in greenfield catchments

(To be accompanied with slide of frequencies of methods used in peak flow calculations for greenfield sites)

As mentioned, this Focus Group is a qualitative analysis of results obtained from all returned questionnaires. Show slide and ask the following:

- The various deficiencies/limitations of the methodologies have been identified from questionnaire responses. Major shortcomings would appear to be the quality, availability and resolution of the data that is required. Would you agree that these are a problem? *Prompt – why*. Any direct experiences of this? What data sources do you use?

  (Note: the above question can be accompanied with a breakdown of the deficiencies/limitations that were identified)

- How do these shortcomings impact on the catchment analysis that you are doing?
- You have mentioned difficulties relating to the resolution of SOIL indices within catchments. Would an obligatory in-situ percolation test assist in this regard or would temporary instrumentation help)? *Prompt - why/why not.*
- Besides the problems with the data, what other problems have you encountered when applying estimation methodologies to greenfield sites?
- What might be done to improve the situation?

Topic 2 - Peak flow estimation in urban catchments

(To be accompanied with slide of frequencies of methods used in peak flow calculations for urban sites)

Show slide and ask the following:

- The various deficiencies/limitations of the methodologies have been identified from questionnaire responses. A major shortcoming would appear to be the quality, availability and resolution of the data that is required. Would you agree? What sources of data do you use?
- How do these shortcomings impact on the catchment analysis that you are doing?
- Besides the problems with the data, what other problems have you encountered when applying estimation methodologies to urban sites?
- What needs to be done to improve the situation?

(Obviously, similarity exists between Topic 1 and Topic 2. Would it be better to combine these? It should be noted however, that while data is a problem for both greenfield and urban catchments, other reasonably significant problems were identified for urban catchments that were not recorded for greenfield catchments)

Topic 3 – Sources of guidance that are available

It has been mentioned that the absence of a national guidance document containing a structured approach to all aspects of urban catchment flood analysis currently hinders engineers in their work and results in a lack of consistency in the types of analysis undertaken across the country. If a national guidance document was to be prepared, what type of information would you like it to contain?

Topic 4 – Stormwater Management

It would appear that most engineers have experience with using oversized pipes and attenuation tanks for stormwater management but less have direct experience with using SUDS structures. Why do you think this is the case? *(Explore all main reasons given)*

Concerns over the maintenance responsibility of SUDS structures would appear to be a major deterrent to their implementation. Would a formalised arrangement where SUDS structures are 'taken over' by Local Authorities assist in this regard? *Prompt – how would it assist/not assist?* Would a fomalised arrangement whereby the developer retains responsibility for SUDS structures help to raise standards?

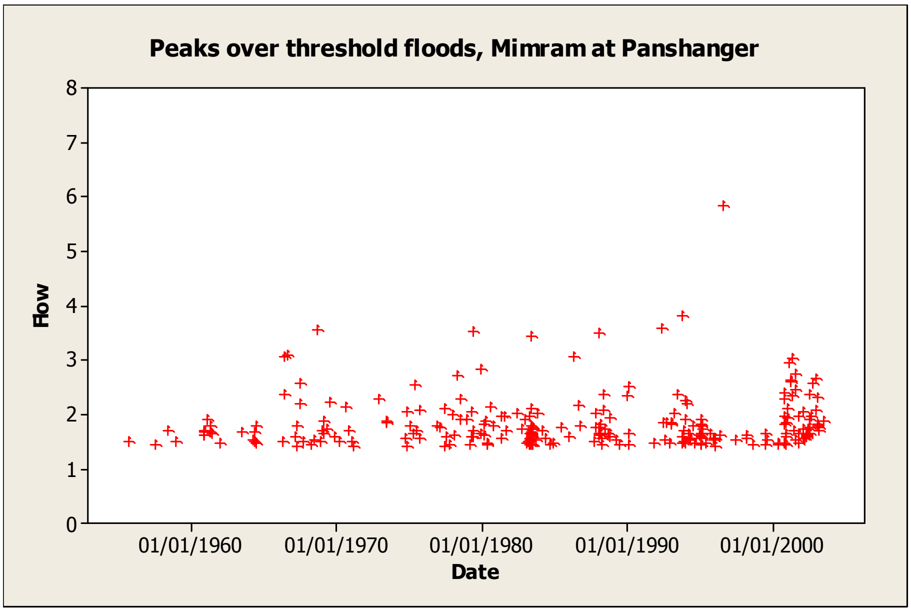
Topic 5 – Catchment Management

The Arterial Drainage Act (1945) advocates a holistic approach to drainage where catchments are analysed in their entirety as opposed to the 'postage stamp' analysis that is currently the norm for individual developments. Do you think that this approach to catchment analysis should be enforced? Is this feasible? How could it be enforced? Are you familiar with the Arterial Drainage (Amendment) Act, 1995 and the impact of this on issues relating to urban hydrology? Are you familiar with the

Report from the Flood Policy Review Group and what this means for urban hydrology?

Other impacts of Urbanisation that may be discussed:

POT Series of Mimram at Panshanger (shown below). By nature, it's a highly permeable chalk catchment. But it has been steadily urbanised in parts of the lower reaches.



1. Urbanisation increases the frequency of flooding not just the flood magnitudes
2. Urban effects on river flooding can be large, i.e. drainage provision has historically failed
3. Interaction between urbanisation and soil/geology is important
4. Interaction between SUDS design and soil/geology is important

Appendix D
(Summary of Focus Group Meetings)

<u>Summary of qualitative study on</u>
<u>Work-Package 4.1 of Flood Studies Update Programme</u>

The focus groups were conducted as part of an effort to assess the methods used and problems experienced by practitioners. The focus groups were used to complement the quantitative study by seeking practitioners' opinions on Urban Catchment Flood Analysis and stormwater management in Ireland.

Twenty-four practitioners participated in the qualitative study. Respondents to the quantitative questionnaire were asked to indicate if they would be willing to participate in a focus group in their area to elaborate on the topic under study. Volunteers were then clustered geographically and focus groups held in Cork, Dublin, and Galway.

Topic 1 – Peak flow estimation in greenfield catchments

(Slide of frequencies of methods used in peak flow calculations for greenfield sites and identified deficiencies/limitations from quantitative study were shown to participants)

- *The various deficiencies/limitations of the methodologies have been identified from questionnaire responses. Major shortcomings would appear to be the quality, availability and resolution of the data that is required. Would you agree that these are a problem? Why? Any direct experiences of this? What data sources do you use?*
- *How do these shortcomings impact on the catchment analysis that you are doing?*
- *Difficulties relating to the resolution of SOIL indices within catchments were mentioned in some focus groups. Would an obligatory in-situ percolation test assist in this regard (or perhaps temporary instrumentation to establish time of concentration)? Why/why not?*
- *Besides the problems with the data, what other problems have you encountered when applying estimation methodologies to greenfield sites?*
- *What needs to be done to improve the situation?*

Methodologies

In general, participants were not surprised with the quantitative results in terms of the methods used in peak flow estimations. However, caution was expressed by some that the analysis should consider the combination of methodologies used. One participant indicated that he thought it best to use the rational method when dealing with small areas of less than 10 hectares and the ADAS method for larger areas. Another participant noted that in culvert design for example, the approach adopted was to calculate the mean annual flow, multiply this by the Regional growth Curve Factor of 1.96 to determine the 100-year peak and further increase this flow by including the standard factorial error of 1.5 in accordance with FSR guidelines. Most agreed that they used a combination of methods either together or for different areas.

Some considered the DCC IoH 124 to be the best method – it refers to a 50 hectare catchment but could be scaled down. The IoH equation was considered 'handy and quick for small scale projects'. The Rational method is a 'quick, conservative, underestimate' according to participants. One participant noted that 'many urban drainage sites are not natural catchments; many of the formulae here are for natural catchment areas such as mountains. The rational method does not assume that you are in a natural catchment area...an unnatural catchment area is truncated, and so will not extend to a boundary'.

In most groups, there was a discussion about the various methods with some asking 'Is the conservative method best?' Responses to this included: 'The conservative method is best, it was used by the old Dublin county council.' 'Don't be a slave to any particular kind of equation. I'd be concerned about rational methods, they're too conservative and give big underestimates'. 'Conservative measures are an inaccurate method.'

One participant referred to the employment of these methods as a 'glorified guess with equations' and suggested taking three and averaging the results. Some felt that 'targets are misinterpreted'. Another noted that 'There's no standard approach, but I'm aware that the results I use are pretty primitive'. Another participant stated 'Our main problem with the methodologies is that there's so many of them. If there was a unified methodology for the whole country, it would be easier'.

When asked if anything surprised them about the results, one of the participants said that a misreading of factors could distort runoff. 'No-one in this country funds research such as that in the UK. It's very hard to get funding here unless the research is attached to a project.' Another noted 'I was surprised that the prescribed method used the IoH 124 Equation which is the best approximation.'

Deficiencies/Problems

A problem noted with using Report Number 5 in small catchments is that 'you don't have a stream frequency or a main stream slope (S1085) value that you can use, it's basically a small stream going through the site. It doesn't appear on the 1 in 50,000 (Ordnance Survey Discovery Series) mapping either. Your only choice is to choose one of the three equations given in hydrology. They're quite good, but the soil parameter is very general from mapping'. It was acknowledged that the new soil maps will help improve the situation.

Participants highlighted the need for runoff estimates and a dataset with regard to smaller catchment areas. 'Then you have the problems with karst and the indeterminate nature of underground flow as well as runoff. They're characteristic of Irish catchments, but we often have to rely on English data'. One participant noted 'greenfield runoff is zero. Water may not go where the drainage is'.

According to one participant, the problems with methodologies are 'linked to the absence of a holistic approach to catchment analysis'. The quality of the result is related to the relevance of the formulae used and the catchment size. Other problems encountered by participants include databases, availability in planning files, data confidence and growth curves.

One participant raised a problem with digital maps - 'If you want to work with digital maps, the problem is that the OS charge a lot for these. People are hampered in using them, so they won't use them. They also lack experience in using these maps. The OS should make them available to university students'. 'The data we need is not coming from the government. Engineers use paper maps, other data has to be paid for. If you want map data for outside the area in question, it's very expensive to get it.'

'There is a lack of particular information on streams that you would be looking at on the greenfield site. You can't use a six-term equation if a stream does not appear on the 1 in 50,000 (Ordnance Survey Discovery Series) maps. Information on stream frequency is based on (the) six term equation. I would say though that the three-term equation where I've used it is a factor (of) safety, I haven't had any comeback because I may have over designed.'

However, 'cost problems are always a consideration in any new project, whether you're building a bridge or a house. If you over design, then that pushes up cost'.

A noted difficulty is that 'There's no agency dealing with this at all…the OPW once had a very good hydrology department, but that closed down… There are measurement stations placed along rivers alright, but these are not repaired immediately when they break down'.

Soil attenuation was viewed as 'one of the most important things' when designing new developments and greenfield sites and commented 'The consultants can pick the right method, but it can still be very arbitrary'. There ensued a discussion of the accuracy of data from Met Eireann and the need for local topography data. It was agreed that there was a need to address rainfall data.

When surprised was expressed by the TRL result of 20%, one participant responded: 'Read between the lines. I have to do my own tests and there are some discrepancies. I can only do a quick assessment on it. I'd have to go on a packages course. I confront this on a daily basis.' 'We opted for the Wallingford Method and we got into trouble'.

Problems encountered included:
'Getting the wrong pipe size would be a concern.'
'Use of a system you're not au fait with can lead to errors.'
'There are a lot of drainage systems used by people who aren't that familiar with them. We'd like to think this will become a more specialised area. It's a concern for us.' - There was a lot of agreement within groups on this point.
'The DOE don't want to take it on board. It should be done as a national concept. The department hasn't really accepted it.'

Soil Indices/Percolation Tests

It was noted that in-situ percolation test depends on design, test stage and size, where runoff comes out and developer putting in drainage. One participant considered that 'the percolation test would not yield too much data, but it tells you how quickly water would drain away in the event of a flood. You are forced to dig and so can gain more information on the subsoil'.

One participant felt that soil should be classified, from hard rock down to sand 'because it's another specific variable. If Ireland is small enough to classify the soils, then they could calculate infiltration rates. A new soil map should be developed' Another added that 'Soils can vary over a catchment, even if you have a map. The hydrologist should understand if he has impervious clay or a pre-draining material and be able to have some guidance on how to classify that himself. You should walk the site. It's a knowledge thing'.

It was noted that 'Hydrology is a highly developed science. Rivers are fast flowing. Runoff is critical. An understanding of the history of the flooding of the area is critical. That's what I've been looking for here and am not able to find'.

Some issues were identified by participants: 'The time factor there is a problem; you mention it to a developer, the percolation test is quite easy to do, but they say 'I haven't time for that' but 'all you have to do is dig a hole and watch the water drain through'.

'The management authority would also be afraid of liability. They would then have to be responsible for draining the whole site…'

Some felt that planning permission should outline the position on drainage for developers.

When asked in 'In terms of soil, are obligatory impromptu tests a possible solution?' It was noted site specific data was important and 'should be part of it'. 'This could supplement the existing soil tests'. A national data bank was considered beneficial.

Solutions

A national document is required. While it was acknowledged that the publication of flood maps would not be popular with land owners or developers as the land value could be seriously reduced, they would be very useful.

It was noted that 'hydrologists should be interested in catchments, different size catchments react differently to storm conditions'.

One participant indicated the difficulty obtaining 'history reports. I've tried and I've got water levels in some rivers, but that hasn't helped'.

Another commented that 'Quality as opposed to quantity is important in information on water-related issues'.

It was suggested that the OPW could do a manual that could be sent around to county councils, a code of accepted practice. Another noted that 'If the OPW do get involved, they'd have to update their data'.

It was noted in one group 'We're seeing some change in rainfall patterns and measurement of these is where the problem lies. There also needs to be analysis of rainfall duration…we need more updated regional statistical analysis of rainfall. The last records to do this were produced in 1958. That formula is not used extensively, but it's still a good check.'

Others felt that there was a need to:
'Establish a data set for a smaller catchment size.'
'Produce more accurate soil data as well.'
'Have catchment specific growth curves rather than national ones. Apply these to similar catchments.'

One participant noted that 'There's very little confidence in peak flow rates unless there's a recorder somewhere near' while another asked 'Is anyone aware of the FSR curve for Dublin?' (a reference to the revised Regional Growth Curve for the east coast of Ireland).

Other comments in this regard were:
'We're looking at improved soils data. Growth curves-there's a difference between catchment area and runoff issues.' 'Design your defences for a higher catchment.'

Topic 2 - Peak flow estimation in urban catchments

(Slide of frequencies of methods used in peak flow calculations for urban sites and identified deficiencies/limitations from quantitative study were shown to participants)

- *The various deficiencies/limitations of the methodologies have been identified from questionnaire responses. A major shortcoming would appear to be the quality, availability and resolution of the data that is required. Would you agree? What sources of data do you use?*
- *How do these shortcomings impact on the catchment analysis that you are doing?*
- *Besides the problems with the data, what other problems have you encountered when applying estimation methodologies to urban sites?*
- *What needs to be done to improve the situation?*

Many of the participants noted that their comments above were relevant here.

In addition, it was noted that there was an 'optimum number of variables and uncertainty in the regression equation for small green catchments. It was noted that there is no access to micro drainage- it is a paper exercise.

When commenting on runoff prediction, one respondent said 'We need more instrumental catchments. More emphasis should be given to measurement. A measurement programme needs to be set up in existing catchments. In a rural area, people will say the OPW should be responsible. If it's an urban area, they'll say it's the Department of Environment's responsibility. The latter wants to wash its hands of urban drainage. It's a historical legacy; you design a thing, and then don't bother measuring it. Few local authorities assume this responsibility'.

It was noted that 'some floods are better documented than others' and that the ESBI are trying to produce a series of maps tracking flood events.

In one group, a participant noted 'The big question is the return period…one has to make a distinction as to what is the nature of the connection between a natural stream and a storm… It could happen every five or ten years'.

Another commented 'My problem with that is when it comes to designing a stream culvert for an urban catchment and the OPW may only have calculations for a 100 year period. A network in an urban area won't be designed to take a 100 year flow. There will be over flooding as urban networks are only designed for a two-year or 30 year period'.

One group noted that 'For Cork CC, a new sewerage scheme, you'd be looking at a two-year return without surcharge in the sewerage system and a five-year return period without flooding. You'd be looking at a 50 year return for a public scheme'.

It was agreed in one group that different engineers trying to calculate flow for the same catchment would arrive at different results.

Topic 3 – Sources of guidance that are available

It has been mentioned that the absence of a national guidance document containing a structured approach to all aspects of urban catchment flood analysis currently hinders engineers in their work and results in a lack of consistency in the types of analysis undertaken across the country. If a national guidance document was to be prepared, what type of information would you like it to contain?

When commenting on what should appear in a guidance document, one participant said 'It should be in handbook form without being overly prescriptive. It should give worked examples and solutions. It should also give examples of jobs and likely problems from start to finish, but the book should also allow engineers to have independence of judgment. The book would become *de facto* if respected.'

Other calls were for 'consistent formula with correct parameters for areas' and the inclusion of 'a small catchment approach and a big catchment approach'.
'The problem is the size of the catchments as some of these catchments are very small. There is no guidance in Ireland on how to treat different size catchments'.

One participant indicated that he would 'need a set of steps. At the moment, it's grey on what you do or don't need to design for'.

It was noted that ‘Guidelines are needed. It doesn’t have to be the OPW who comes up with these, the local authority could do it as well.’

The difficulty with obtaining data from ‘two different directions’ with regard to rainfall and soil was noted – ‘we’d need it to be unified’.

‘The data available for large rivers is quite good (even though the Shannon is the most difficult river to predict), but a lot of runoff is diverted into smaller river channels; I don’t want to call them drains, but very small streams, they’re not as well charted’.

Contents requested were the results of monitored catchments, rainfall and evaporation; runoff rates, and soil.

Some others elaborated on their requests:
‘..to see a heavy emphasis on soil management. Retention on site should be considered first, then maybe attenuation. What’s available at the moment literally takes it for granted that water runs into the sewer and then we forget about it’.
‘..some guidance on the greenfield runoff is also necessary. What is the increase likely to be if there is development?’
‘..more guidance on the urban fraction and the best size to use for a particular catchment.’
‘documented references, the formula and the background’.
‘Regression equations. Monitors for small greenfield catchment areas would be good.’
‘Correct parameters for the area is the most important thing.’
‘Dealing with extreme flood events’

Some felt that ‘Water quality is not necessary relevant’.

Two participants referred to the information available in other countries - ‘We are behind the UK in that they have flood information for the last 30 years’. ‘[Texas] has a drainage manual with clear criteria. It works well for urban catchments’.

Topic 4 – Stormwater Management

It would appear that most engineers have experience with using oversized pipes and attenuation tanks for stormwater management but less have direct experience with using SUDS structures. In your opinion, why do you think this is the case? (Explore all main reasons given).

Concerns over the maintenance responsibility of SUDS structures would appear to be a major deterrent to their implementation. Would a formalised arrangement where SUDS structures are ‘taken over’ by Local Authorities assist in this regard? How would it assist/not assist?

When asked in one group ‘Is there much experience in using SUD structures?’ much laughter ensued. Participants agreed that there is a reluctance to use SUDS and in many cases it is a case of being ‘told to use’ them. ‘Lack of familiarity is a problem. Neither architects not engineers are familiar with it’. ‘Long term maintenance is another consideration’. It was noted that serial guidance was required as was the need to develop competency in the area. Some felt that ‘structural specialists’ are required in the area – at the moment ‘many are doing drainage design’ without appropriate knowledge. ‘SUDS have to be correctly designed. In ground SUDS, there is less maintenance. People are unwilling to spend money on integrating them.’ One participant noted that ‘If people came up with a reason for not wanting to use SUDS, then we’d understand their rationale.’

Most participants thought that the guidance for the design of SUDS that is available is accurate.

Some felt there was an issue with safety in regard to ponds and wetlands and the lack of consistency across country was noted. There is also an economic issue as a 'large depressed area is not in the open space calculation..and permanent ponds reduce house density'. However others were of the opinion that 'Permanent ponds are the answer. They help to sell houses in other countries.'

'Local authorities don't want to be landed with more responsibility for maintenance. Some SUDS schemes may have to be undone if unsatisfactorily installed'. Some felt that the local authority should be compensated if they take over SUDS. 'Taking charge of everything is a huge issue at the moment. We're trying to introduce a proper inspectorate for all the local councils, but it'll take a few years.'

Another felt that 'If the local authorities were to take over SUDS, there would have to be standardization, the same as for building roads'.

'In order for a SUDS application of attenuation to produce good quality water status, you have to have particle size distribution information from the soil. You do have to have very specific soil data from a site at a very early stage. You will need it in the future. Developers won't be able to avoid doing their investigations in advance'. Another participant noted that ''There is a design as to the amount of volume that's required and that's based on the rate at which the runoff is soaked up. If there's a local river, you're obliged not to discharge storm water, any faster than what the guidebook says'.

Other comments concerning developers and SUDS were:
'To most developers, this whole notion of SUDS is a very recent phenomenon, many are not familiar with it. I have to spend a lot of time over the phone explaining the basic concepts of a structure design with them.'
'SUDS wasn't used because developers didn't think they'd be adopted by the local authority. Developers are being asked to consider SUDS.'
'When you adopt SUDS, you can build in what you see of the area likely to be flooded. Building pipes skirt around the problem. Engineers did this in order to cover themselves against accusations that they had left something undone. They did not want to be called to account for something years later. It's all to do with money; the smaller their expenditure, the bigger the fee. If the client can afford safety, then your reputation will depend on this. No-one minds paying an extra 20% to make a skyscraper safe. Safety in urban areas means that there should be no visible water on the streets'.
'There should be a system where we can modify things.'
'If the builder is responsible for SUDS, then he might go bust.'

Reference was made to the situation in Texas and Craigavon in which there is to be one regional pond to which people could contribute. 'If they were not able to do this on site, they would mitigate a fee'. It was felt by one participant that 'if you can start from scratch, you can regulate more easily and get everything right'. Another agreed with this sentiment stating 'Rezoning of major developments should be looked at collectively and integrate management more.'

One group raised the issue of the impact of high rise building: 'High rise as well, that's a huge problem. All the main drainage systems were designed for the planning area of the zoned development, and you should include at the very least half of the height of that building with your runoff. Has the building of a six-storey apartment block taken flooding into account?'

With regard to attenuation, one participant noted that 'most councils request it, but suggest no figure or method'. Another added 'Most councils condition you into putting in attenuations. They don't specify a method for greenfield calculation'.

Topic 5 – Catchment Management

The Arterial Drainage Act (1945) advocates a holistic approach to drainage where catchments are analysed in their entirety as opposed to the 'postage stamp' analysis that is currently the norm for individual developments. Do you think that this approach to catchment analysis should be enforced? Is this feasible? How could it be enforced?

Not all participants appeared to be aware of the Arterial Drainage Act. In one group, there was a discussion of the contents of various pieces of Government Legislation pertaining to catchment management. It was generally agreed by attendees of this Focus Group that the 1945 Act referred to agricultural catchments and that the 1995 amendment dealt with localized flood relief work. It was also noted that the new floods directorate considered the 'move back to catchments and interactions and how to integrate urban with catchment'. 'The 1945 Act addressed farm land rather than local flood relief. The Act localized relief work. FRAM studies have been done on the Lee and the Dodder on how to integrate urban runoff to local catchment areas'.

One participant considered that 'The holistic examination of a site is essential. You must ask the developer to look at the upstream of a river to see how their own work will impact on the flow. Since 1995, the OPW has insisted on the holistic approach'. However, it was noted by another that 'There is pressure on land from developers. People have to be protected from themselves' and one remarked that the Arterial Drainage Act 'needed to accommodate responses over time'.

While many agreed 'That's the way forward, to look at things from a local authority basis', they also felt that monitoring was required and that 'You need a lot of communication and shared resources to do that'. One participant highlighted that 'Local authority development should tie in with county and national development plans' but was unsure of 'what the practicalities of that operating on the ground are.'

With regard to feasibility of enforcement, it was felt that 'Yes, it's possible to enforce the ADA; just refuse planning permission if certain tests or estimates have not been done. Enforce it through planning permission; this will make developers more compliant'. One participant noted that 'In Dublin , it is in the development plans and therefore is mandatory'. Another commented 'We did all the nitty gritty, something the OPW isn't very good at. The Act is run by the OPW.'

Summary

Major problems confronting engineers was a lack of standardised data to assist in vital estimations of runoff, etc. in urban catchments. It was remarked that river and flood data was more readily available in locations such as the UK, South Africa, Australia and the USA. Such data, if available in Ireland, tends to come from differing sources such as Teagasc, Met Eireann and the OPW. The onus is then on engineers to consolidate such data with their own calculations. More uniform data and more pro activity from the OPW were also required.

The respondents agreed that a group of engineers trying to calculate data for the same catchment area would not always arrive at the same result which therefore renders it arbitrary. As development in urban areas becomes more intense, there is a greater need to have more accurate runoff and storm water calculations. This is further complicated by erratic fluctuations in coastal and tidal water.

The human element of developer resistance to a procedure as simple as a percolation test and SUDS was also cited as a difficulty. Much of an engineer's time is spent explaining these procedures to developers. Local authorities were generally thought to be quite good in their promotion of SUDS as a worthwhile, and indeed mandatory, method of design.