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Research Framework – The implementation of Integrated Urban Drainage

Project: SC070064/R1

Local Government Association

UKWIR UK Water Industry Research Limited

Communities and Local Government

Flood and Coastal Erosion Risk Management Research and Development Programme

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Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

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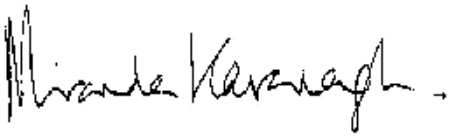

Miranda Kavanagh

Director of Evidence

Executive summary

To successfully manage flooding in urban areas in the future, the different responsible bodies will need to work together holistically to, tackle flooding from a risk management approach rather than traditional flood defence and drainage upgrading. Urban drainage will also need to address the three strands of sustainability: affordability, environmental capacity and social acceptability. However, integrated urban drainage is an emerging area and lacks an underpinning research infrastructure. Whilst legislation, regulation and incentivisation can do much to foster integrated working, this new approach to managing flood risk will not flourish without an underpinning science base.

This project starts to build that science base. Considerable research has already been carried out related to urban drainage but this has often not been joined up. We reviewed current and recent research to establish the gaps in our knowledge, and consulted researchers and practitioners on their views. One point that was made is that much good science has never found its way into professional practice, because of a lack of supporting framework for translating the research into guidance, training tools and demonstration projects. Research funders often do not work together when setting out their programmes which means that such investment may not always be used in the most cost-effective way.

This report outlines a number of basic areas of science where further work is needed, especially in the light of climate change adaptation. These are in rainfall (including measurement and climate downscaling), hydrology and flood risk modelling. We recognised the need to build capability in communication and stakeholder management and have set out proposals on data management, mapping and public engagement, as well as social science and health related to urban flooding. These include proposals for tool development, guidance and training activities. We have also identified the need for pilot projects in the more novel areas of IUD to demonstrate the practicality of the new approaches. We have allowed for both structural and non-structural measures in our proposals.

Over 75 research proposals were identified, of which 20 were shortlisted. The 75 projects are grouped into research clusters, to facilitate funding and delivery. These are shown in the figure below, with timeframes for carrying them out. We have linked these clusters to integrated urban drainage (IUD) implementation themes. Figure 1 indicates the benefits that each cluster brings showing the timeframe for delivery. We have identified short term deliverables (1-2 years), medium term deliverables (2-5 years) and long term deliverables (more than 5 years). Projects will be delivered at different times according to their duration and the time at which their outputs are needed. End users can easily see when the outputs from each cluster can be expected, and funders can see when they will need to consider different proposals in their forward programmes.

We estimate an outline contract cost of £30 million to carry out the proposed programme over a period of 10 years, a realistic amount when set against the required investment in integrated urban drainage measures in the future. The framework in which the proposed research programme sits has been designed to be continually updated. We recommend that the programme is reviewed every two years by an expert panel and updated accordingly. In this way, the long-term needs of IUD should be addressed and its successful implementation assured.

Cluster	Short Term Output, 0-2 years	Medium Term Output 2-5 years	Long term output greater than 5 years
IUD Coordination	Co-ordinating and managing existing information. This will lead to improved knowledge sharing and access for stakeholders in IUD		
Rainfall		Improving our understanding of rainfall distributions and predictions. This will lead to improved flood risk management of infrastructure renewal and emergency response	
Hydrological Processes		Improving our understanding of hydrological processes across catchments of different scales. This will lead to more knowledgeful implementations of surface water management options and what their long term impact maybe	
Modelling Reviews	Assessing existing modelling approaches and software. This will lead to guidance to support IUD modellers		
Modelling development	Improving IUD modelling tools and software. This will lead to more reliable and accurate assessment of flood risk as a result of overland flow or asset deterioration		
Mapping	Developing a consistent and agreed approach to mapping flood data. This will lead to greater clarity in the presentation of data and improve efficiency		
Critical Infrastructure	Developing guidance for the flood risk assessment and management of critical infrastructure. This will enable practitioners to improve the resilience of the asset and planning for emergencies		
Integrated flood risk assessment		Developing common standards (moving from probabilistic to risk based) with the supporting tools and methodologies. This will lead to flood risk being assessed in on integrated manner with consultancy between stakeholders including the costs and benefits of impacts and mitigation strategies	
Spatial Planning to manage flooding	Developing guidance on how flood risk management can be addressed within spatial planning. This will lead to flood risk being managed more holistically		
Working with the public	Developing tools and training for stakeholder engagement in integrated urban drainage. This will lead to an improvement in how different stakeholders work together and facilitate capacity building to help deliver integrated urban drainage management approaches		
Managing flood pathways	Understanding how existing above ground infrastructure (particularly highways) can be used to manage flood pathways and providing an evidence base of the impacts supported by engagement and dissemination. This will lead to the practical application of exceedence management techniques		
Surface water management	Developing guidance which is supported by demonstration projects for surface water management techniques. This will lead to greater confidence within practitioners of how to implement such measures and their impacts		
SUDS Implementation	Providing guidance to support the implementation, construction and commissioning of SUDs. This will lead to an improved confidence within the industry for using these drainage techniques		
Low cost monitoring & just in time monitoring		Developing low cost monitoring technologies linked with tools and software for real time and just in time management of our drainage systems. This will lead to practitioners having the knowledge and capability to actively manage flood risk	
Incident Management		Developing the tools and technology to provide reliable and accurate flood warning information for all sources of flooding. This will lead to improved emergency planning and management of flooding and its impacts	
Strategy and policy	Assessing and reviewing existing strategy and policy with the development of guidance where appropriate. This will lead to an improved understanding by stakeholders of implications whilst facilitating changes in the future		
Assessing receptor impacts		Understanding social, health, safety, and pollutant impacts, with the development of predictive tools. This will lead to the improved planning and management of flooding consequences	

Figure 1 IUD research framework roadmap with proposed research development clusters and their benefits and timescales.

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This project has been developed under the Defra / Environment Agency Flood Risk Management Science Programme. The work was guided by a Steering Group:

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Contents

1. Introduction

1.1. Project background

Flooding in urban areas can arise from rivers overtopping their banks, coastal defences being breached, overloaded drainage systems, high groundwater levels and direct run-off from surface areas. For historical reasons, the responsibility for drainage is spread across various organisations depending on the source of flooding and the areas affected. This means that it is difficult to determine the risk of flooding in urban communities, to identify who is responsible for the flooding and to develop holistic solutions that can manage flood risk effectively and affordably. These deficiencies were highlighted in the Pitt Review of the summer 2007 floods in England. The Review has stimulated various activities to create a more joined up approach to dealing with urban flood risk, and much has been achieved since 2007, though some work had already started prior to these floods, as set out below. The forthcoming Floods and Water Bill will provide the legislative framework for a more integrated approach where all partners work together to tackle the problem.

The Government's *Making Space for Water* strategy (Defra 2004) identified integrated urban drainage (IUD) as a key area for policy development and improvement in operational practice in England. The Government subsequently started the project HA2 on *Urban Flood Risk and Integrated Drainage*. This culminated in the publication of an IUD scoping study (Balmforth *et al.* 2006a).In 2008, the Government issued its publication, *Future Water* (Defra 2008a) which sets out its vision for water management through the water cycle for the 2030s. In the context of surface water management, this includes having more adaptable drainage systems that reduce the burden on the sewer system and manage flows on the surface (through conveyance and storage). The Government also recognises the importance of working with the public to ensure they appreciate the causes of flooding, and understand how they can help to minimise the consequences of surface water run-off.

In 2008, the 15 IUD pilot studies set up by the Department for Environment, Food and Rural Affairs (Defra) were completed (Gill 2008). These pilots investigated various areas of IUD from stakeholder engagement to technical solutions. Following this work, The Government is developing guidance on producing surface water management plans (SWMP). In parallel with this, other research into IUD has recently been completed or is ongoing, in programmes ranging from blue sky (basic) to applied research. Following the floods in the summer of 2007, publication of the Pitt Review (Pitt 2008) and the Government's Response (Defra 2008b), IUD has become much more important in managing urban flood risk.

A sound scientific base, new tools, guidance and demonstration projects are needed to develop integrated urban drainage within the required timeframe. Significant investment from agencies sponsoring research and development is needed to sustain the development, and this investment needs to be coordinated and targeted. Therefore, in April 2008, the Environment Agency initiated this project, with the support of Defra, Water UK, UKWIR, CLG and the LGA, and commissioned MWH, CIRIA and the University of Exeter (under the Defra/Environment Agency Flood Risk Management Science Programme) to produce a research framework for integrated urban drainage (IUD). We have jointly produced a prioritised programme of research, development and dissemination to benefit organisations and agencies responsible for IUD.

This report summarises the results of that project, including a summary of recent research in IUD (summer 2008), a framework to identify and support research in the

future and a prioritised programme of future research and development projects linked to the short- and long-term needs of IUD. This is based on our understanding of current research programmes including:

- CRUE ERA-NET (http://www.crue-eranet.net/about_programme.asp)
- Joint Defra/Environment Agency Research and Development (http://www.defra.gov.uk/environ/fcd/research/)
- UKWIR (http://www.ukwir.org/site/web/content/programme/current-programme)
- FRMRC2 (http://www.floodrisk.org.uk/)

In developing the proposed research framework the views of leading EU and other related science teams and programmes were taken into account. In reviewing non-UK research on IUD we considered which were relevant to the UK. The framework was designed to avoid overlaps with existing research and wherever possible, we proposed projects that would be complementary to ongoing research in the EU and elsewhere.

To ensure this project achieved its goals, a project steering group (PSG) was set up representing a diverse range of stakeholders including Defra, DCLG, UKWIR, Water UK, Local Government Association, and research institutions. The steering group directed the work and validated the results.

1.2. Project Summary

This project developed a prioritised programme of research, development and dissemination to underpin the implementation of integrated urban drainage in England and Wales. We have accounted for the technical complexity of urban flood risk management and pollution control and the diverse roles and responsibilities of the relevant institutional stakeholders in order to address their policy or operational needs.

The specific objectives of this project were to:

- Review recently completed current and planned science projects related to integrated urban drainage.
- Review policy and planning, design and operational practice, including formal projects and development initiatives, outside the formal “science” arena, that relate to integrated urban drainage.
- Identify research, development or dissemination activities that support the implementation of integrated urban drainage and related stakeholder groups (e.g. Defra, Environment Agency, Water UK and local authorities).
- Align the above research, development or dissemination activities with appropriate responsible stakeholders
- Develop a decision making framework for urban drainage research that identifies and prioritises research options in terms of cost, benefit and practicality. Through this framework, define future research needs to match three-year, five-year and 10-year horizons and establish a work plan for the next five years identifying research, development or dissemination activities.
- Develop a prioritised programme of research, development or dissemination projects focussed on a short-term three-year horizon, but indicating broad longer term outcomes.

1.3. Defining integrated urban drainage

The term “integrated urban drainage” appears to have different meanings to different people. This project developed a definition of IUD that accounted for those different views as much as possible, and this is set out below.

Integrated urban drainage recognises the complexity of managing the risk arising from drainage and flooding in urban areas, within the context of good environmental management. Integrated urban drainage will deliver a full suite of techniques, adaptation and resilience measures (below and above ground) that integrate in a sustainable manner to manage this risk. This will be achieved through a coordinated approach from different stakeholders and the application of appropriate science and technology. Responsible stakeholders will clearly understand their role and the role of others, and work together under a legislative and regulatory framework to achieve more effective measures for urban flood management. The public will recognise the practical limitations of urban flood management and the role they have to play.

Integrated urban drainage can therefore be defined as:

- Management of the risk arising from drainage and flooding in urban areas (encapsulating surface water management planning) through a portfolio of approaches.
- Flooding in this context includes all sources e.g. pluvial, fluvial, coastal and groundwater.
- Urban defines an area substantially built up and of a minimum size normally encapsulated by “a village” but excluding hamlets and isolated settlements.
- Drainage relates to all forms of conveyance and storage of surface run-off and flood water whether by formal drainage system (e.g. sewers, watercourses) or informal systems (e.g. ad-hoc surface flood pathways).
- Management includes stakeholder management, data management, assessment (risk and performance), drainage development (new and existing), flood risk management, climate change impacts, operation and maintenance and emergency response.
- Timescales cover present day, and future planned based on new development, growth and urban creep.
- Includes emergency planning, disaster management, resistance and resilience.
- Is set in the context of managing water quality, the EU Water Framework Directive (WFD) and *Developing Better Places to Live*.

Further background and information on IUD can be found in Appendix A.

1.4. The structure and scope of this report

This report covers the key outcomes of the project as follows:

- Chapter 2 outlines the research programme summarising how it was developed.
- Chapter 3 explains the benefits that the projects will bring set within each Research Cluster.
- Chapter 4 summarises the cost to complete the work.
- Chapter 5 describes the benefits of using the framework and completing the programme.
- Chapter 6 provides conclusions and recommendations.

Appendix A outlines how the framework and associated projects and clusters were developed. Appendix B summarises the stakeholder consultation process and results, and Appendix C summarises key messages from policy and research. Appendix D contains a summary of projects and reports reviewed. The remaining appendices contain information on the projects developed.

2. Research programme and research priorities

2.1. Need for a research framework and programme

IUD sets out a different approach for managing urban flood risk. It requires the different responsible bodies to work together to understand and quantify flood risk, develop measures (both structural and non-structural) and manage urban drainage systems. This should be achieved in line with the goals of affordability, environmental capacity and social acceptability. To underpin this new approach, we need to ensure that:

- the necessary scientific base is available to underpin the work;
- it is translated into best practice through guidance and training;
- supporting tools are developed;
- demonstration projects are implemented to prove that the measures work.

Many organisations and agencies sponsor research and development activities from Government through to private organisations. For IUD to be successful this work needs to be focused and coordinated and the outputs continuously monitored so that programmes can be revised and developed accordingly.

The framework set out here was developed with these goals in mind. A project steering group of IUD experts from universities, professional practice and project sponsors was established. We also consulted widely with end users (as reported in Appendix B) and reviewed the current state of research and development (Appendix C).

Our consultation showed that despite the welcome focus on IUD from Government and other stakeholders, there was little evidence of knowledge being turned into practice. Prior to this project, there was no overarching analysis of end user needs to form an evidence base where gaps in knowledge could be identified. Nor was there evidence of a shift in funding or support for research into IUD specifically. In reviewing the current state of research related to IUD, we found that despite broad basic research in urban hydrology and flood risk modelling, there were a number of notable gaps. In particular, we identified deficiencies in the following areas:

- governance of IUD to support a portfolio of responses for delivery
- practical integration of the different strands of IUD;
- social and cultural aspects of public engagement in IUD;
- data modelling and mapping;
- operational performance.

Practitioners were critical of the lack of material translating research findings into a more practical form for end users. More needs to be done to turn the outcomes of research into guidance, training and demonstration projects. This might be better achieved if the success factors for research were measured by the level of practical exploitation and an assessment by end users.

Conversely, some guidance has been produced but has not been adopted as there is currently no legislative or financial incentive to do so. *Designing for exceedance in urban drainage systems* (Balmforth *et al.* 2006b) is a good example of this.

Some recent research programmes have aimed to develop tools (including software) for practical use. However these tools have often been suitable only for an academic environment, with no mechanism to support their continued use and development. Such promising tools may thus fail to develop beyond the prototype stage.

We developed a framework for future research to address these shortcomings. The framework, developed jointly with the Project Steering Group, highlights research needs related to IUD and the time horizon over which research can be turned into benefits such as practical knowledge and tools. Particular benefits will be:

- providing practitioners with guidance, training and tools to underpin their work;
- enabling research funders to understand how they can best contribute to the advancement of IUD;
- helping researchers to develop IUD research proposals;
- identifying how policy can be supported by underpinning research, and how it can be used to develop new policy, legislation and regulation in the future.

2.2. Developing the research framework

2.2.1. Approach to developing the framework

The framework and proposed projects were developed in the following sequence:

- review of current research activity and publications;
- consultation with stakeholders and end users;
- assessment of needs;
- gap analysis, grouping and prioritisation;
- development of potential projects;
- grouping and prioritisation of projects.

In the course of this project, a large number of gaps in knowledge and capability were identified. It was thus decided to group ideas into themes that define IUD and categorise them according to the type of research and development proposed.

2.2.2. Developing IUD themes

The *IUD Scoping Study Report* (Balmforth *et al.* 2006a) set out a process for Defra's IUD pilot projects. This process was developed in the pilots and was then built into *Surface Water Management Technical Guidance* (Defra 2009).

Although the structure is set out differently in these two documents, in essence the IUD process covers:

- systems
- hydrological processes
- data (collection and management)
- flood and flood risk modelling
- flood and flood risk mapping
- risk and uncertainty
- spatial planning
- stakeholder management
- implementation measures
- operation and maintenance
- policy and governance
- social and health issues.

2.2.3. Defining "research"

There are many different definitions for research. In this project, we based our definition on the Frascati (OECD 2002) classification of research (see Appendix A). We have defined research to cover basic scientific research (blue skies research), applied research (near market research), capacity building (guidance and training), tool development and demonstration (pilot) projects.

2.2.4. Prioritising and grouping

Because of the large number of needs and projects identified during this work, we prioritised and grouped projects at various stages. This was done with the expert opinion of the Steering Group who tested the methodology to ensure it was objective and consistent. Further details of this are given in Appendix A.

2.3. Research programme and prioritised projects

This process described above initially identified 75 projects to help meet the requirements of IUD. A prioritised list of the top 20 projects is shown in Table 2-1.

These projects were scored as highest priority to progress IUD in the short term. The highest ranked project was setting up an IUD portal where existing and future research could be mapped with links to project details and outputs. This would not only provide funders, academics and practitioners with easy access to IUD research but also enable the IUD framework and programme to be easily reviewed in the future.

Table 2-1 Project titles and prioritised scores for the top 20 short term urgent projects.

Project Number	Project Title	Average Score
1	Setting up an integrated urban drainage research, development and dissemination portal	8.9
2	Mapping recorded flood incidents	8.8
3	Designing for exceedance - Engagement and dissemination	8.7
4	Designating and managing flood pathways - A practitioner's guide	8.7
5	The role of incentivisation in delivering integrated urban drainage	8.6
6	Training on stakeholder engagement for IUD	8.6
7	A standard agreement for data sharing between integrated urban drainage stakeholders.	8.5
8	Guidance on stakeholder engagement.	8.5
9	Implementing the Environment Agency Strategic Overview - Common guidance	8.5
10	Assessment of flood risk for critical infrastructure	8.5
11	Fact sheets on spatial planning and flood risk management	8.3
12	Capacity building for those involved in IUDM	8.2
13	Guidance on engagement with the public on IUD	8.2
14	Easy-to-use guidance on protecting your home from flooding	7.9
15	Developing risk-based standards for drainage components	7.8
16	Risk management framework for integrated urban drainage	7.7
17	Guidance on land and surface water management adaptation for redevelopment and regeneration	7.7
18	Performance of different modelling approaches for assessing flood risk in urban areas	7.6
19	Whole life costs of urban flood risk mitigation	7.5
20	Mapping flood risk in urban areas based on stakeholder responsibilities.	7.4

The 75 projects were grouped into clusters according to common or shared threads. The clusters were then matched to IUD implementation themes and types of research (based on the Frascati classification, see Appendix A). Some clusters focused on a single implementation theme whilst others spanned a number of themes. The timescales of the clusters were categorised according to short term (up to two years), medium term (two to five years) and long term (over five years).

This then set all the project clusters into a framework that was readily identifiable to end users and research sponsors alike. Because the clusters are linked to both implementation themes and research categories it will enable research sponsors to define their own research and development programmes and understand where collaboration might be fruitful. It will compliment and align with other research programmes such as the joint Defra/Environment Agency Research and Development programme and the UKWIR programme. It will assist end users in understanding when various outputs are likely to be available to assist in their work.

This framework will also help the programme to be monitored and subsequently updated to ensure it meets the ongoing needs of IUD as it develops (for example in response to changes in policy or legislation). The programme is summarised in Figure 2-1.

Project Cluster	Reference No.	Project Title	Research Type: Basic Research	Research Type: Applied Research	Research Type: Capacity Building*	Research Type: Demonstration Project	IUD Implementation Themes (end user application): Systems	Hydrological Processes	Data	Modelling	Mapping	Risk and Uncertainty	Spatial Planning	Stakeholder Management	Implementation Measures	Operational Management	Policy and Governance	Social and Health	Potential Funders	Output period: Short Term Output, 0-2 years	Medium Term Output 2-5 years	Long term output greater than 5 years	Project Duration: Less than 1 year	1 year to 3 years	Greater than 3 years
IUD Coordination		Summary			x	x	x	x	x	x	x	x	x	x	x	x	x	x	EA, Defra, UKWIR, CLG	x			x		
	1	Setting up an IUD research, development and dissemination knowledge portal				x	x	x	x	x	x	x	x	x	x	x	x	x		x			x		
	7	Identify and understand data that needs to be shared. Develop a standard agreement for data sharing between IUD stakeholders			x				x					x			x			x			x		
Rainfall		Summary	x	x	x			x	x	x		x			x	x			NERC, EPSRC, EA, Defra, UKWIR		x	x		x	
	31	Comparing the statistical distributions of urban rainfall, runoff and flooding. Improving land use modelling in 2D surface models for urban areas.		x				x	x	x		x									x			x	
	48	Guidance on the use of rainfall radar measurements in flood forecasting and real time control to assist with flood warning and event management		x	x			x	x	x		x				x					x			x	
	54	Further analysis of Met Office climate change model outputs to improve certainty of downscaling. Validation of hourly data and improved sub-hourly downscaling to remove uncertainties inherent in UKCIP Weather Generator.	x	x				x	x	x		x									x			x	
	55	Accounting for spatial effects of storms and storm tracking in modelling for Real Time Control applications		x				x	x	x		x			x						x			x	
	69	Improving the Reliability of Mid-term (1 to 5 day) Flood Forecasting for Urban Areas	x					x	x	x		x				x					x			x	
Hydrological Processes		Summary	x	x		x		x	x	x	x	x	x	x	x		x		NERC, EPSRC, EA, Defra, UKWIR		x	x		x	x
	52	Evaluation of the performance of SUDS during long duration rainfall events especially exceedance conditions		x				x	x	x					x							x			x
	58	Establishment of test urban catchments for the use in long term multi disciplinary research into IUD		x		x		x	x	x				x	x						x			x	
	59	Understanding the impact of SUDS on groundwater	x	x				x	x	x		x			x		x					x			x
	61	Development of assessment procedure and long term management strategies for groundwater flooding.	x	x				x	x						x		x					x		x	
	70	Integrated surface water and groundwater modelling.	x	x				x	x	x	x		x		x							x		x	
	71	Improved land use modelling in 2D surface models for urban areas	x	x				x	x	x											x			x	
Modelling Reviews		Summary	x	x	x			x	x	x	x	x							EA, Defra, UKWIR	x			x		
	18	Performance of Different Modelling Approaches for assessing Flood Risk in Urban Areas		x	x				x	x	x	x								x			x		
	28	Review of SUDS modelling software		x	x			x	x	x										x			x		
	66	Review methods available for integrating models of different drainage systems		x	x				x	x		x								x			x		

Figure 2-1 IUD Research Programme (part 1 of 4).

Project Cluster	Reference No.	Project Title	Basic Research	Applied Research	Capacity Building*	Demonstration Project	Systems	Hydrological Processes	Data	Modelling	Mapping	Risk and Uncertainty	Spatial Planning	Stakeholder Management	Implementation Measures	Operational Management	Policy and Governance	Social and Health	Potential Funders	Short Term Output, 0-2 years	Medium Term Output 2-5 years	Long term output greater than 5 years	Less than 1 year	1 year to 3 years	Greater than 3 years
			Research Type				IUD Implementation Themes (end user application													Output period			Project Duration		
Modelling development		Summary	x	x	x			x	x	x	x	x	x			x			EA, EPSRC, Consultants, UKWIR	x	x	x	x	x	x
	36	Improve the capability of below ground flood modelling (models flooding due to backing up through property connections).		x	x				x	x		x								x			x		
	45	Development of existing knowledge to improve rapid 1D overland flow modelling (tools).		x	x				x	x	x	x	x							x			x		
	53	Development of existing knowledge to improve speed and accuracy of 2D above ground flood modelling, (tools). Incl. data availability, sources and types.		x	x				x	x	x	x	x								x			x	
	64	Develop the software and guidance to ensure that high intensity rainfall can be modelled correctly replicated (performance of models in extreme events).		x	x			x	x	x		x									x			x	
	65	Assess the use of rainfall threshold criteria in predicting urban flooding events, to assist in predicting potential flooding locations		x					x	x	x									x			x		
	72	Drainage asset deterioration modelling	x	x	x				x	x	x	x				x						x			x
Mapping		Summary		x	x				x		x			x				x	EA, Defra, UKWIR, CLG	x			x	x	
	2	Mapping Recorded Flood Incidents		x	x				x		x									x			x		
	20	Mapping flood risk in urban areas based on stakeholder responsibilities		x	x				x		x			x				x		x				x	
Critical Infrastructure		Summary		x	x						x	x	x	x	x	x			EA, Defra, UKWIR, CLG, Utilities	x				x	
	10	Guidance for the flood risk assessment of critical infrastructure, where and what it is.			x						x	x	x	x	x	x				x				x	
	27	Development of guidance on the management of critical infrastructure as part of emergency response (during the planning phase).			x							x		x	x	x				x				x	
Integrated flood risk assessment		Summary		x	x				x	x		x	x	x	x		x		Defra, UKWIR, EA, CLG, Water Companies		x	x		x	x
	15	Develop a framework for drainage performance (risk based) standards for different drainage components		x	x				x	x		x		x			x				x			x	
	16	Developing a common language for integrated urban drainage and risk. Develop a consistent, common and coherent framework for assessing flood risk form all sources in the urban area		x	x				x			x		x			x				x			x	
	19	Collection and assessment of WLC data on urban flood risk mitigation and/or remediation interventions		x					x			x	x	x	x						x			x	
	40	Develop integrated tools for modelling flood risk (from all sources) to include full damage costing and cost benefit analysis for assessing remedial measures		x	x				x	x		x		x	x							x			x
	60	Develop methodologies for assessing impacts (eg cost, flooded area) arising from different forms of flooding with different probabilities		x	x				x	x		x		x	x						x			x	
	62	Using uncertainty in assessing and managing flood risk, where and how it will be used, and how it effects solutions		x	x							x			x							x		x	

Figure 2-1 IUD Research Programme (part 2 of 4).

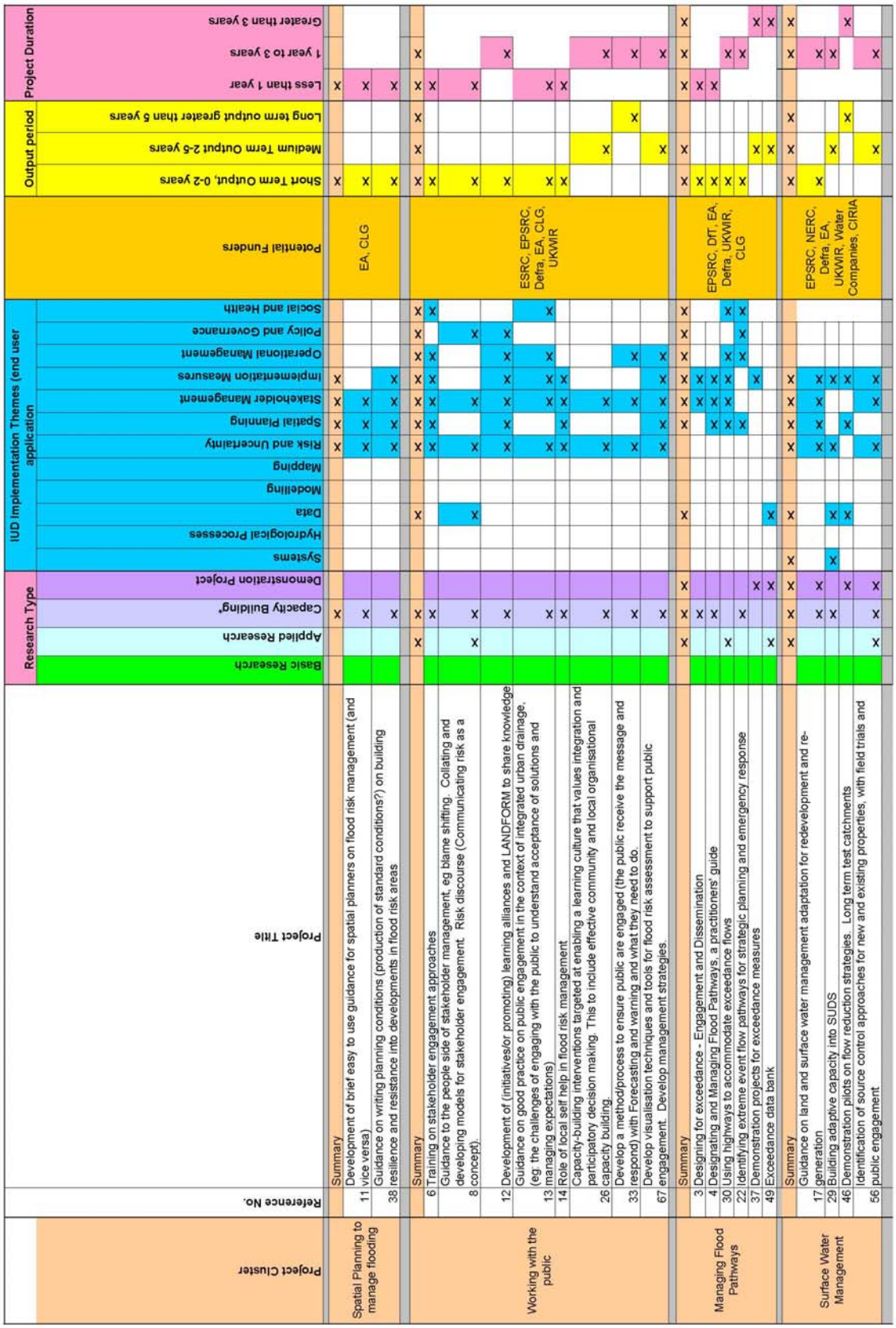

Figure 2-1 IUD Research Programme (part 3 of 4).

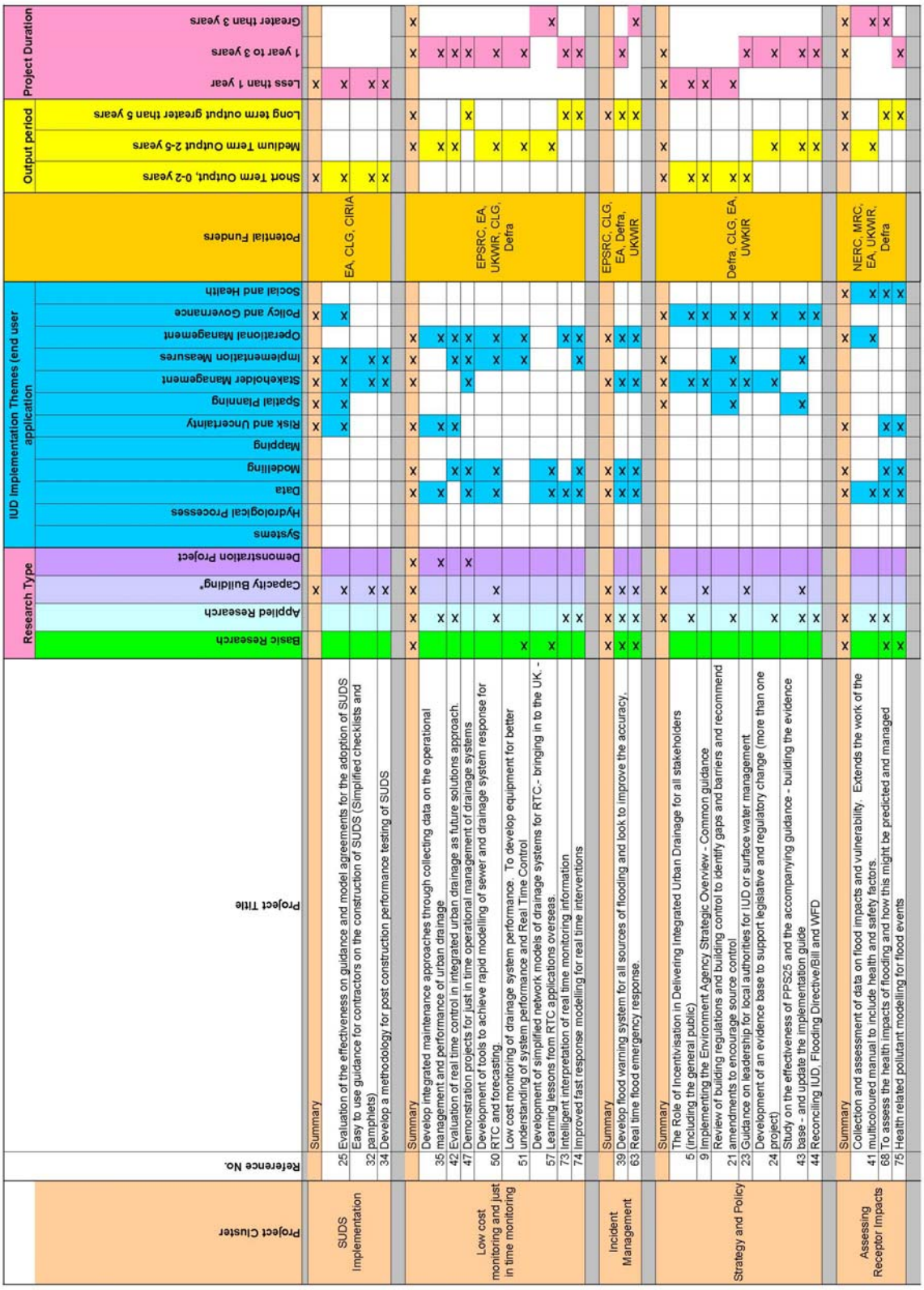

Figure 2-1 IUD Research Programme (part 4 of 4).

3. Research clusters

Proposed research projects were grouped into the following clusters. A number of projects are also closely aligned with other clusters (sharing some commonality). How these relate to the IUD implementation themes and delivery time scales is shown in Figure 3-1. Figure 3-2 summarises the potential short, medium and long term benefits that could be realised from completing the projects. Both figures are shown at the end of this chapter. The clusters are described below with the projects referenced by their project number.

3.1. Research cluster: IUD coordination

This cluster aims to address how data is shared and managed in the short term. It addresses a key request by practitioners who were unclear on where to go for information on IUD. In particular, it includes the setting up of the research, development and dissemination portal (1). This should provide greater access and sharing of research information and outputs on IUD, and enable the framework to be reviewed.

3.2. Research cluster: Rainfall

A good understanding of present and potential future rainfall patterns is essential for flood risk management. There is substantial evidence that rainfall patterns in the UK are changing, especially in the intensity and spatial variation of more severe events. The UK Climate Programme (Jenkins *et al.* 2009) demonstrates the need to better account for the effects of climate change, especially for short duration high intensity storms in urban areas. The Weather Generator (Jones *et al.* 2009) will help here, but will not fully address all future needs of rainfall downscaling from climate models.

Cost constraints and the need to control carbon emissions are likely to limit investment in future capital schemes. Operational measures are therefore likely to become more importance. Real-time control of urban drainage may become more prominent, so predicting rainfall over short lead times and better understanding spatial effects will be more important.

This cluster of projects aims to boost our understanding of how rainfall will impact on different aspects of integrated urban drainage. It addresses missing research in this area and focuses on improving the prediction of climate change effects (Project 54), rainfall forecasting (48 and 69) and the influence of real-time control to manage flooding and incident management (55). It also looks to understand the spatial distribution of rainfall (31 and 55). Understanding rainfall better will boost accuracy and confidence in flood risk assessment and subsequent flood risk management measures whilst supporting better control of drainage systems (above and below ground) and advanced warning. The outputs would be expected over the medium term. Without this, rainfall information used in research will become progressively out of date as weather patterns change due to climate change.

3.3. Research cluster: Hydrological processes

Urban drainage modelling is moving towards replicating two-dimensional surface effects more accurately. This should help the industry understand minor/major system

interaction and effects during extreme events. Proper representation of the rainfall-run-off process will be important, to understand how land use can help manage flood risk. This includes measures to manage surface water (Defra 2008a). Moves to control surface water will alter urban run-off patterns. SUDS in particular will influence hydrology and their catchment-wide effects need to be better understood.

There is growing concern over the potential effects of rising groundwater and its effect on flood risk, particularly when combined with other sources of flooding.

This cluster therefore aims to boost understanding of the hydrological processes. This will lead to more holistic surface water management solutions in the long term. The proposals include basic research on land use effects (71), SUDS performance during extreme events (52), and projects related to groundwater flooding (59, 61 and 70). This needs to be underpinned with demonstration projects and long-term test catchments (58 and 59), with outputs expected in the medium to long term. Such sites can provide data for research projects, which without stakeholders may lack the necessary confidence to invest in new applications and approaches to reducing risk.

The outputs will lead to better practical techniques for managing risks associated with groundwater flooding and greater implementation of SUDS.

3.4. Research cluster: Modelling reviews

This cluster aims to address the short-term need of practitioners for guidance and advice to improve urban flood modelling for SWMP. It arises directly from the criticism of practitioners that research findings and latest technological developments often do not find their way into practice. The cluster includes guidance on how different approaches perform in assessing flood risk (18), evaluation of SUDS modelling software (28) and how models are integrated (66). These short-term outputs will support Surface Water Management Planning and will ensure that end users do not use inappropriate methods that lead to incorrect results.

3.5. Research cluster: Modelling development

A major programme of flood modelling research has been run under the Engineering and Physical Sciences Research Council's Flood and Coastal Risk Management research initiative and related EU programmes. This has run in parallel with modelling development by consultants and software firms. Investment and research in this area should be coordinated to prevent overlap, and structured to ensure that all the gaps in knowledge and understanding are covered. We propose a cluster of research projects that range from developing basic modelling capability (18, 64 and 65), improving overland flood modelling in 1D/2D (45 and 53) and SUDS performance (28) and asset deterioration (72).

Outputs are expected over the short to medium term. They will support the development of cost-effective flood risk management measures arising from SWMP. Without this work, practitioners will lack the tools to bring such plans to fruition.

3.6. Research cluster: Mapping

A key requirement of the EU Floods Directive is the publication of flood risk and hazard maps in a form that is easily understood by the public and underpins the subsequent development of flood risk management strategies. The work proposed here is needed

to avoid unnecessary complexity in results and to assist in communication. It will deal with recording historic flood incidents (Project 2) and the results of flood risk modelling (20). These projects will provide a consistent approach which over a period of time will benefit those responsible for recoding this information and sharing it with others. Experience gained in the IUD pilots showed the importance of partner and public engagement in successful integrated approaches to managing urban flood risk. Mapping is central to surface water management and emergency planning.

3.7. Research cluster: Critical infrastructure

The Pitt review flagged the importance of managing flood risk at critical infrastructure sites. Many utility companies are now carrying out an initial flood risk assessment of their critical assets. Whilst reasonable information is available on river and coastal flood risk, there are shortcomings in information to asses risk from other sources of flooding. Indeed, evidence shows that current assessment methods would fail to identify much of the critical infrastructure affected by flooding in 2007 as being at risk.

We also need to improve the way in which critical infrastructure is managed during floods. This cluster therefore aims to generate, in the short term, guidance to assess critical infrastructure for flood risk (Project 10) and how it can be better managed during a flood incident (27). This will help practitioners to improve the resilience of critical infrastructure assets and emergency planning, to provide greater security and reduced consequence of failure. The guidance is urgently needed if the impacts of the 2007 floods on critical infrastructure are to be avoided in the future.

3.8. Research cluster: Integrated flood risk assessment

The draft Floods and Water Bill highlights the need for an agreed framework of standards for urban drainage against which new flood risk management measures can be planned. Future solutions need to be able to adapt to future uncertainties such as climate change. These standards will need to reflect that need and uncertainty. A consistent approach to assessing flood risk needs to be adopted by all stakeholders to avoid misunderstanding and to foster collaboration.

This cluster will address how flood risk is assessed by different stakeholders. In particular, Projects 15 and 16 will provide a common framework for flood risk assessment from all sources of flooding, dealing with the statistics of multiple probabilities associated with different sources of flooding. Other benefits include the development of methods (19, 60 and 62) and tools (40) to assess the cost damage and cost benefit of measures, to help decision-making. These outputs will enable users to properly manage uncertainty, assess flood risk objectively, and understand the cost-benefit implications of alternative flood risk management methods. Without this work, there is a danger that organisations responsible for implementing measures will be unclear about the future problems they face and adopt a short-term approach. In due course, these measures may have to be reworked if they prove to be unsuitable for longer term needs.

3.9. Research cluster: Spatial planning to manage flooding

We need to create space to safely manage flooding on the surface and increase the flood resilience of urban communities. This places flood risk management at the heart of urban design. Planners will be central to this process and need the necessary skills and understanding to discharge their responsibilities in this respect. This cluster (Project 11 on building capacity for spatial planners and 38 to support planning conditions) will address the gap of knowledge in spatial planning on flood risk and vice versa by providing guidance. This will support early consultation between different organisations to realise developments (both new build and regeneration) that manage flood risk whilst being attractive places to live. The Inter-Institutional Panel on Flood Risk, chaired by the ICE, is currently developing a shared policy on this, and the guidance will bring a consistent approach across all built environment professions.

3.10. Research cluster: Working with the public

Some of the best practical examples of surface water management planning have been achieved by fully engaging local communities in the process. This often leads to innovatory solutions but more importantly ensures the lasting success of interventions and measures. Public engagement should become central to development and implementation of measures. Practitioners need the skills and capacity to make this happen. This cluster therefore addresses how the necessary capability in public engagement can be built amongst stakeholders. The aim is to improve the general public's awareness, understanding and capabilities relating to flood risk management in the urban area through stakeholder training and guidance (6, 8, 12 and 13), self-help and learning (14 and 26) and procedures and tools (33 and 67).

3.11. Research cluster: Managing flood pathways

There is good guidance on designing for exceedance in CIRIA's report of the same name (Balmforth *et al.* 2006). The proposed projects build on this, demonstrating how existing flood pathways can be used to manage flood risk and convey flow on the surface (3, 4 and 22). It will be of substantial benefit to practitioners and stakeholders responsible for flood risk management in urban areas. It will address stakeholder concerns of using highways to manage exceedance and creating sacrificial flood storage areas, by providing the vital evidence base (30). This work will also improve awareness of available measures amongst different stakeholders to improve their uptake, supported through demonstration projects (37) and associated information (49). These outputs are expected over the short to medium term.

3.12. Research cluster: Surface water management

Direct surface run-off was identified by the Pitt Review as one of the primary causes of the 2007 floods, and its management is central to the effective delivery of integrated urban drainage. SUDS are a well-established measure for controlling surface water, starting at source, but they need to be more adaptive to future climate change, and guidance is needed on retrofitting surface water management measures. This cluster will address the wider issues of surface water management and flow reduction in combined sewers, in particular through the retrofitting of measures in the urban area

(Project 17, which has been taken forward as a priority project by the Environment Agency), building adaptive capacity in SUDS (29), and public engagement in field trials (56). This requires demonstration projects on test catchments (46) and will link with other long-term tests in the hydrological processes cluster. This cluster will benefit a wide number of stakeholders by providing practical knowledge and guidance over the short term, with surface water management options tested over the short to medium term, and demonstration projects providing long term results. This will provide confidence to stakeholders on how and what measures can be successfully implemented in specific situations.

3.13. Research cluster: SUDS implementation

Closely linked to surface water management, this cluster will support the uptake in SUDS by providing guidance for constructors. It builds on the extensive range of guidance already available on the selection and design of SUDS, by evaluating its effectiveness (25), simplified checklists and pamphlets for contractors (32) and post-construction performance testing (34). This is likely to be particularly important for stakeholders named in the Floods and Water Bill to own and manage SUDS in the future. These short-term outputs should provide a minimum standard of construction to help avoid some performance issues that have arisen from early SUDS schemes.

3.14. Research cluster: Low-cost monitoring and just-in-time monitoring

The effective operation of all drainage systems is important if their long term effectiveness is to be assured. The development of low-cost/low-power monitoring equipment now makes real-time monitoring an affordable prospect for drainage systems. This cluster seeks to exploit this opportunity and develop integrated operational management for drainage systems (Project 35 and 51), real-time control measures (42), and the necessary software tool development (51 and 73). These will be supported by demonstration projects (47) and will explore the potential for “just in time” responses to address problems as and when they arise (73 and 74). The long-term benefit will be the knowledge, tools and capability to manage flood risk and predict impacts, therefore supporting emergency response planning. In particular the demonstration and monitoring projects will help to build the necessary confidence and capacity in stakeholders with operation and maintenance responsibilities.

3.15. Research cluster: Incident management

Non-structural measures will play an important part in urban flood risk management. The first strand of these is forecasting as the first stage of emergency response. Project 39 will address the need for accurate flood warning for all sources of flooding, and how best to get this information to those most likely to be affected. To complement this, Project 63 looks to develop more effective real-time emergency response. Together these projects will improve the capacity of urban communities to prepare and respond to flood emergencies, and will assist stakeholders in public engagement. The work will build on the rainfall and low-cost monitoring clusters. The output from this cluster is expected over the long term and will provide the tools and technology for practitioners to more effectively plan and manage the impacts of flooding.

3.16. Research cluster: Strategy and policy

For IUD to progress, investigations and response measures need to be set within a strategy and policy framework. The projects in this cluster will support the development of that strategy and policy. This includes assessing and reviewing existing strategy and policy (21, 43 and 44), and providing guidance, for example for the Environment Agency's strategic overview role (9) and local leadership for flood risk management in local authority areas (23). This will ensure that IUD is approached in a structured manner and will provide the evidence base for legislative and regulatory change (24). This will benefit stakeholders, including the Environment Agency and local authorities who will work in their new role. The outputs are expected over the short to medium term, and of all the clusters may be open to the greatest change as policy evolves. Completing this cluster will lead to an improved understanding by stakeholders of the changes being considered or implemented through strategy and policy.

3.17. Research cluster: Assessing receptor impacts

This cluster will address the lack of understanding of social, health, safety and pollutant impacts of flooding. It will extend the valuable information and guidance in the Multi-Coloured Manual (Penning-Rowsell *et al.* 2005) (Project 41) and provide guidance on the assessment and management of health aspects (68 and 75). It builds on work completed after the 2007 floods. Over the medium to long term, this should lead to the development of predictive tools for practitioners to better manage the consequences of flooding.

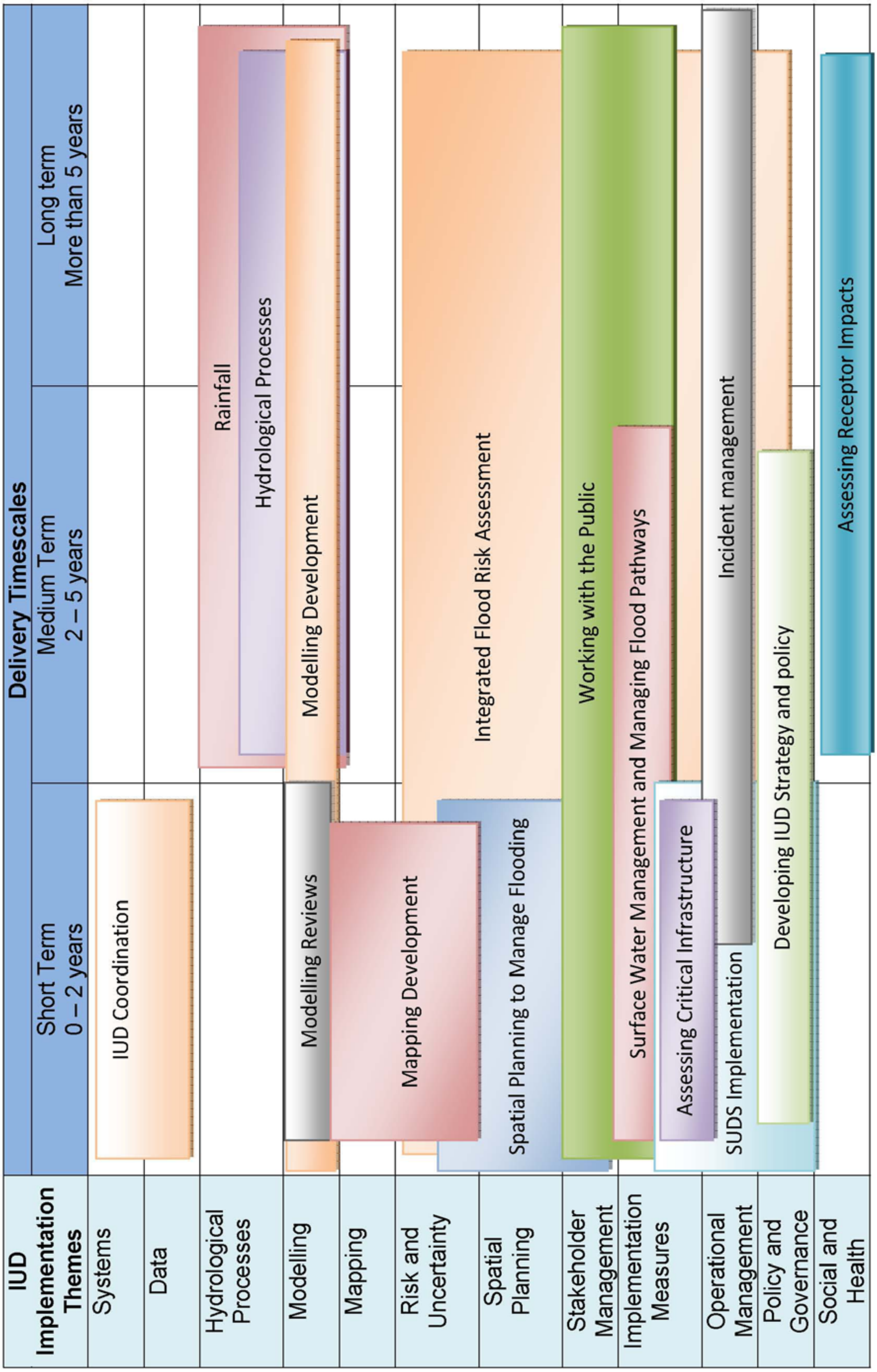

Figure 3-1 IUD research framework with proposed research development clusters aligned to the key IUD Implementation themes and delivery timescales.

Cluster	Short Term Output, 0-2 years	Medium Term Output 2-5 years	Long term output greater than 5 years
IUD Coordination	Co-ordinating and managing existing information. This will lead to improved knowledge sharing and access for stakeholders in IUD		
Rainfall		Improving our understanding of rainfall distributions and predictions. This will lead to improved flood risk management of infrastructure renewal and emergency response	
Hydrological Processes		Improving our understanding of hydrological processes across catchments of different scales. This will lead to more knowledgeful implementations of surface water management options and what their long term impact maybe	
Modelling Reviews	Assessing existing modelling approaches and software. This will lead to guidance to support IUD modellers		
Modelling development	Improving IUD modelling tools and software. This will lead to more reliable and accurate assessment of flood risk as a result of overland flow or asset deterioration		
Mapping	Developing a consistent and agreed approach to mapping flood data. This will lead to greater clarity in the presentation of data and improve efficiency		
Critical Infrastructure	Developing guidance for the flood risk assessment and management of critical infrastructure. This will enable practitioners to improve the resilience of the asset and planning for emergencies		
Integrated flood risk assessment		Developing common standards (moving from probabilistic to risk based) with the supporting tools and methodologies. This will lead to flood risk being assessed in on integrated manner with consultancy between stakeholders including the costs and benefits of impacts and mitigation strategies	
Spatial Planning to manage flooding	Developing guidance on how flood risk management can be addressed within spatial planning. This will lead to flood risk being managed more holistically		
Working with the public	Developing tools and training for stakeholder engagement in integrated urban drainage. This will lead to an improvement in how different stakeholders work together and facilitate capacity building to help deliver integrated urban drainage management approaches		
Managing flood pathways	Understanding how existing above ground infrastructure (particularly highways) can be used to manage flood pathways and providing an evidence base of the impacts supported by engagement and dissemination. This will lead to the practical application of exceedence management techniques		
Surface water management	Developing guidance which is supported by demonstration projects for surface water management techniques. This will lead to greater confidence within practitioners of how to implement such measures and their impacts		
SUDS Implementation	Providing guidance to support the implementation, construction and commissioning of SUDs. This will lead to an improved confidence within the industry for using these drainage techniques		
Low cost monitoring & just in time monitoring		Developing low cost monitoring technologies linked with tools and software for real time and just in time management of our drainage systems. This will lead to practitioners having the knowledge and capability to actively manage flood risk	
Incident Management		Developing the tools and technology to provide reliable and accurate flood warning information for all sources of flooding. This will lead to improved emergency planning and management of flooding and its impacts	
Strategy and policy	Assessing and reviewing existing strategy and policy with the development of guidance where appropriate. This will lead to an improved understanding by stakeholders of implications whilst facilitating changes in the future		
Assessing receptor impacts		Understanding social, health, safety, and pollutant impacts, with the development of predictive tools. This will lead to the improved planning and management of flooding consequences	

Figure 3-2 IUD research framework roadmap with proposed research development clusters and their benefits and timescales.

4. Costs of the framework

This report assessed at a very high level, the costs for the research programme to be completed. Many of the projects outlined are short summaries, therefore estimation of the programme cost should be considered as indicative only, requiring much greater detail for each project to develop a full cost assessment. The estimated programme cost is in the region of £30 million over an eight- to ten-year period. This does not include project management or publication costs. We recommend that this cost estimate be revised in periodic reviews of the programme, and as projects are developed in greater detail.

5. Benefits from using the framework

Development of the research framework and programme will benefit a range of stakeholders. A summary of how different stakeholder groups can use the framework is summarised below. For this to provide a long term benefit and assist in all stakeholder planning cycles we will need to update the programme from time to time.

5.1. Funding organisations

Funding organisations commonly request and receive proposals for research projects. In the area of IUD, there has not been an overarching understanding of the gaps and end user needs. The research framework and programme set out here addresses this. It should allow national and international funding organisations such as the Environment Agency, research councils, UKWIR and CRUE ERA-NET to understand how proposals fit into the wider IUD need.

The framework and programme will help organisations that sponsor research to target their programmes accordingly. As there is currently no common focal point for IUD research, the structure of the programme and background information provide a starting point for funders to agree areas of common interests, on a cluster and project level, and identify where funding is required to improve IUD. This will provide greater knowledge for forward planning of IUD-related projects for funders, both individually and jointly. It should enable greater collaboration and strategically planned funding between different partners over the short, medium and long term.

As the programme will be periodically updated, it will support the continuous research planning cycles. The update will inform funding organisations of the next set of requirements within the industry, as well as indicating any improvements achieved.

5.2. Research institutions and capacity building organisations

The framework and programme offer research institutions a structure to understand the needs of IUD, and guide projects. Although some projects are only outlined here, prospective users will be able to see how their collective expertise could be used to address different clusters and projects, and at the appropriate time. The programme will support institutions in planning and formulating proposals, with a greater understanding of the end user gaps and benefits. For example, medium- or long-term projects requiring the underlying science base can be identified and proposals developed swiftly using the evidence base collected here.

Research institutions provide the underlying science, and the programme should help align different institutions to work together to meet IUD implementation requirements. This has recently been seen with larger consortiums completing research programmes across flood risk areas.

The programme also clearly shows where capacity building is needed. It will stimulate those organisations engaged in training and the production of guidance by identifying what is required and by when. The programme identifies clusters and projects that

require funding to build capacity. It should therefore enable such organisations to work closely with agencies responsible for implementing IUD, end users, policy advisors and research institutions.

5.3. Policy, strategy and regulatory development organisations

Agencies involved in policy and regulatory development need to understand the knowledge gaps and how they can be filled. The research programme enables such users to understand research needs related to IUD and the time horizon over which research can be turned into benefits such as practical knowledge and tools. The framework will therefore be useful in identifying how policy can be supported by underpinning research, and how it can be used to develop new policy in this area.

5.4. Stakeholders responsible for implementing IUD

Stakeholders responsible for delivering IUD, such as the Environment Agency, local authorities and sewage undertakers need to understand how gaps in knowledge will be addressed and when. This will enable them to plan investment strategies and implementation over the short, medium and long term. These stakeholders review and influence progress of research through the ongoing development of the framework and the associated programmes that support research projects. On a national scale this will include UKWIR's and the joint Defra/Environment Agency programmes. It will also avoid inappropriate guidance and tools being developed, research efforts being duplicated, and outputs arriving in a random manner.

The main bodies responsible for managing urban drainage will be able to use the framework and programme to identify where and when investment is needed on tools and guidance as well developing pilot projects and demonstration sites (Projects 46, 47 and 58). The increased visibility of research should also inform their own research policy and agenda, offering the opportunity for greater collaboration and efficiencies.

5.5. IUD practitioners

A key focus of the framework and programme is the end user. These are the people who will have to practically plan, investigate, design, implement and manage measures to achieve IUD. Such practitioners will work within client, consultancy and contracting organisations. Those engaged in implementing IUD can see how guidance and tools are to be developed and when they can expect these to become available (Project 1). For example, practitioners who wish to know how to retrofit surface water management measures in the urban area (Project 17) can understand when such a project would finish. Since we have linked outputs specifically to long-term needs, end users can be confident that research outputs will be available in the right form and at the right time to meet their needs.

5.6. Delivery timeframe

The following sections set out the broad deliverables of the proposed programme in the short, medium and long term.

5.6.1. Short Term Deliverables

In the next two years, the framework will bring substantial support to those responsible for delivering IUD and practitioners. In particular it will:

- create a web portal to coordinate and disseminate future research and development
- foster collaboration between stakeholders to deliver integrated solutions to urban flooding;
- improve how data and knowledge is shared and managed;
- provide a common framework for mapping flood risk across different groups;
- provide guidance to assess and protect critical infrastructure;
- provide guidance to help planners understand flood risk and enable flood risk practitioners to better understand planning issues;
- address how the industry engages and communicates with stakeholders and the general public;
- give greater confidence in using highways to manage flood flows;
- support the implementation and uptake of SUDS;
- enable research funders to plan research investment and collaborate with each other.

5.6.2. Medium Term Deliverables

In the next two to five years, the framework will deliver substantial support to practitioners of IUD and those developing policy and strategy. In particular it will:

- provide a greater understanding of rainfall forecasting, to support the proactive management of drainage systems and incidents;
- build confidence in the translation of research outputs into business processes, through demonstration and test catchments across all areas of IUD;
- improve the speed and accuracy of overland flow modelling for risk assessment and solution development;
- provide common risk-based standards and methods across all aspects of IUD, that includes a better assessment of receptor impacts;
- develop cost-beneficial approaches, tools and products to enable drainage systems to be managed to mitigate flood risk.

5.6.3. Long Term Deliverables

The long-term benefits of the framework will:

- increase understanding of hydrological processes to support modelling and mapping and reduce uncertainty in the long-term performance of measures;
- develop and consolidate experience in real-time monitoring and management of drainage networks;
- provide an operational flood warning protocol that accommodates all sources of flooding as part of a broad framework of flood resilience measures.

6. Conclusions and recommendations

6.1. Conclusions

This project has developed a comprehensive and well-structured framework for IUD research, and within that a programme of prioritised projects linked to implementation themes of IUD. This was achieved by developing a sound evidence base from a review of research and development related to IUD and consultation with researchers, stakeholder organisations and practitioners.

The research framework and programme provide an opportunity for research sponsors, researchers and end users to collaborate on work and investment in integrated urban drainage. IUD is an emerging area and lacks the foundation and underpinning research of more established areas. There is an overall need for investment of some £30 million over the next 10 years to implement the programme proposed here. When set against the large investment in urban flood risk management measures foreseen, we believe this to be a reasonable amount.

Benefits of adopting the proposed framework include:

- Making greater use of and sharing knowledge and data between all those involved with IUD.
- Helping those responsible for IUD to plan investment strategies and implementation plans over the short, medium and long term.
- Enabling practitioners and those responsible for IUD to have the confidence that the tools, methods and guidance will be available to meet their needs and providing new techniques that are proven.
- Providing a process for continually reviewing and updating research to address the needs of practitioners in developing IUD.
- Providing funding organisations with guidance on urgent areas to be funded and enable greater forward planning.
- Giving researchers visibility and direction in the research required to support IUD and the need for more targeted dissemination of outputs which are also transferable to industry.
- Supporting policy makers in the direction and implementation of policy.

Without this framework, it will be difficult to provide the evidence base to support investment. Also, research sponsors are likely to continue to work in an uncoordinated way. Perhaps most importantly, however, end users will not have the tools, training and guidance to build capability. This will mean that the Government's ambitions of addressing the recommendations of the Pitt Review and benefiting from the implementation of the Floods and Water Bill may not be realised.

Because the future is uncertain, we recommend that the framework and programme be regularly reviewed and updated. Further details are given in the following section.

6.2. Recommendations

We make the following recommendations for the ongoing development of the framework and research programme:

1. The research framework and projects should be reviewed biennially and updated as necessary by a multi-agency steering group.
2. A multi-agency steering/advisory group should be established to provide a focus for this work and manage the resultant programme.
3. Funders including members of the multi-agency steering group should meet regularly to agree common interests in research to improve collaboration.
4. Research alone will not enable IUD to work: regulatory and policy change must also be addressed.
5. Research project planning must have the end user in mind and understand clearly how it will benefit the delivery of IUD.
6. Dissemination activity should continually be improved.
7. The decisions that steer future research should be based on sound evidence.
8. Priority projects identified here should be actioned as soon as possible and projects and clusters considered by funders across short, medium and long term planning.
9. All research when completed and disseminated should be reviewed and assessed for its impact and benefit in the context of the objectives of this framework.

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A Appendix A – Developing the framework

To date, there has not been a recognised national programme of research on integrated urban drainage (IUD). The summer 2007 floods brought integrated urban drainage to the forefront. Solving IUD problems requires a joined-up approach, where the various responsible bodies work together to provide affordable solutions.

The Government is now promoting this integrated approach to ensure the public is better protected from flooding. The Department for Environment, Food and Rural Affairs (Defra) commissioned a study to explore how this new approach might be adopted. Partnership working was thought to improve flood risk management, water quality and water resources planning, and provides much-needed clarity in roles and responsibilities for the public. The scoping study produced the methodology to support 15 pilot projects across England (Balmforth et al 2006a). The pilot projects showed that an integrated approach was indeed viable and could potentially bring all the benefits originally envisaged.

The Pitt Review of the extensive floods of 2007 reinforced this view. It identified a lack of joined-up action and responsibility as the main reasons for poor planning of flood risk management. The Review recommended new responsibilities for lead organisations, but in essence advocated the same integrated approach set out by the Government in *Making Space for Water*.

In 2008, the Environment Agency completed the mapping of areas susceptible to surface water flooding in England and Wales (Chapman *et al.* 2008). This identified through modelling rainfall only (not the below-ground system) areas of high surface water risk.

In February 2008, the Government launched its *Future Water* vision, looking ahead to 2030. *Future Water* in particular considers how surface water can be managed more sustainably. It also considers integrated planning for new development. The aim is to use surface water management plans (SWMP) to improve the assessment and management of urban surface water together with coordination between stakeholders (this has been developed and follows on from the HA2 project). The Government also wants to promote sustainable drainage by clarifying responsibilities and providing incentives for developers and property owners. A key aspect of this is the surface water management consultation (February to April 2008). The consultation was broken down into three parts in line with Sir Michael Pitt's review of the flooding summer 2007.

The Government's response to the Pitt Review was published in December 2008 (Defra 2008b). It highlighted work already completed in the interim since the Pitt Review was published. It responded to the 92 recommendations set out in the Pitt Review, including those linked to IUD. These responses set out how the Government will respond to the challenges set by Pitt, which will ultimately move integrated urban drainage forward to meet the *Future Water* vision (Defra 2008a).

A.1 Developing the research, development and dissemination framework

A.1.1 Research process and need for framework

Research is essential to help society deal with the challenges of modern living. Because research deals with the unknown, outcomes can be uncertain, and sometimes investment in research does not appear to produce valuable results. To ensure that research has the best chance of success it needs to be set in a framework where uncertainty can be managed and where outputs can be effectively translated into best practice.

The hierarchy that traces basic research through to practical implementation is shown in Figure A-1. It is founded on what is often referred to as basic or “blue sky” research. This generates the basic scientific understanding and knowledge which supports the rest of the framework.

Basic research in the UK is often undertaken within universities and research organisations. Lead times can often be long, typically stretching over five years from initial concept through to final outputs. Research councils provide major funding for this work and outputs are commonly in the form of research reports and peer-reviewed journal papers. These journals contain the intellectual output which is then built upon by applied research. In the UK, cross-fertilisation between academic researchers and practitioners has been relatively weak though more recently research councils have sought to encourage industry participation in research programmes.

Connected to this underpinning programme is near market or applied research. This is often a spin-off from basic research and may be funded collaboratively from research grants and industry sponsorship. Government departments and the European Union have been major players in this category in recent years. As its name implies, it tends to address more specific market needs and industry often contributes to its funding. Indeed, industry bodies have been specifically established to manage this type of research. Research in this category tends to be more collaborative with shorter lead times (except in the case of major European projects). There are some near market consultancies who actively engage and lead research for their own competitive advantage that could limit the benefits of common interest programmes. Typically useful outputs can be obtained within a year on smaller projects.

Leading on from basic and applied research are dissemination and capacity-building activities. These range from consultancy services with specialist teams through to guides, tools, training and stakeholder engagement. Consultancy may be carried out by teams of academics that have worked on related basic research, specialist companies offering consultancy services or a combination of both. Work in this category is normally funded on the basis of payment for specified services or products. Timeframes can be quite short, measured in months, or much longer where large programmes are involved.

Where new knowledge is to be applied across an industry sector, the development of guidance is often a preferred route. This has proved particularly beneficial in training practitioners in new methods. A number of bodies have been set up to develop industry guidance and their products are well respected. Major funding is often needed to convert basic research into best practice guidance, as this can be a complex process requiring many iterations. Once achieved, however, it can have a major impact on the performance of an industry sector, turning new knowledge into practice, and supporting training and engagement. Linked to this are application tools which often convert basic tools, for example system modelling tools developed as part of basic research, into

user applications. These are best delivered by organisations able to provide ongoing support for users. A purchase price, licensing and support fees are usually charged to support the development of such tools.

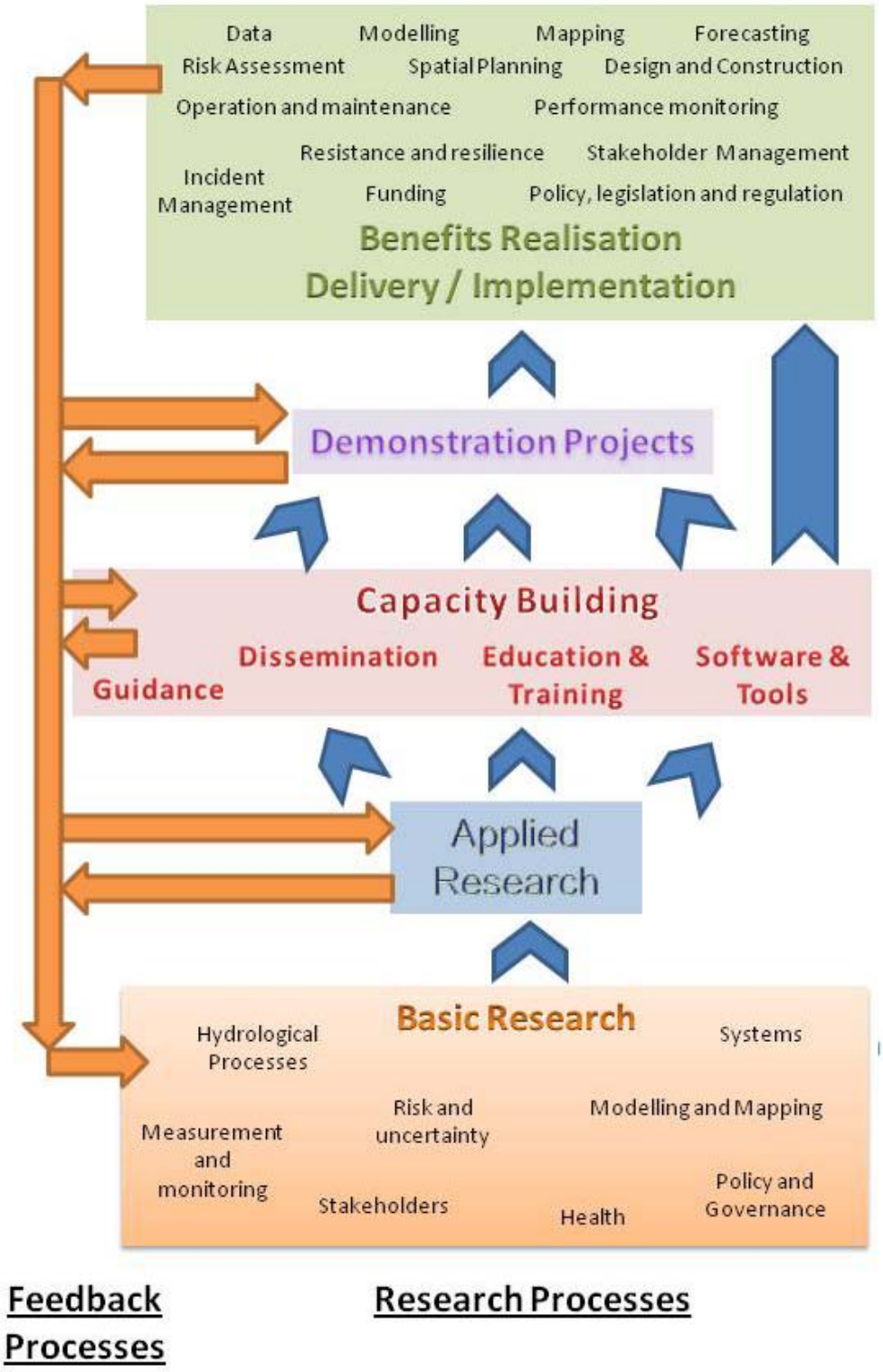

Figure A-1 Indicative hierarchy of research in IUD.

Pilot studies or test catchments offer the advantage of demonstrating research in its final application, enabling end users to explore the potential impacts, risks and benefits. Ultimately such sites can provide the necessary confidence and belief to stakeholders.

Targeted training is often overlooked. When it is well designed and focused on specific outcomes, such training can offer exceptional value for money. Training should always be considered alongside the development of any new guidance or tool. Funding is often a problem since it usually involves dissemination groups rather than those that have been engaged in research or developing the guidance/tool.

Stakeholder engagement is the final category at the top of the hierarchy. This has not been widely developed within the industry, yet it holds the key to successful change. In the case of IUD, effective stakeholder engagement must influence what happens at the bottom of the hierarchy and each stage above that. Therefore, there must be feedback loops at all stages so that higher levels influence what happens in the underpinning stages.

A.1.2 Developing the research framework

The overarching research framework developed here relies on a four-phase process (Figure A-2) which, as indicated above must occur regularly if an ongoing programme of research, development and dissemination is to be achieved. The framework must enable a structured and documented approach to be taken that provides the evidence base for developing such programmes.

We approached the research framework in four stages. Firstly, we assessed research and good practice to date and ongoing. Secondly, we consulted policy makers and practitioners to understand the barriers to IUD and what improvements are necessary. Thirdly, we compared needs identified during the consultation with current knowledge and capability, gaps between the two and the most urgent areas for attention. Finally, we used our knowledge and experience to identify research projects that would need to be developed to enable IUD to be achieved.

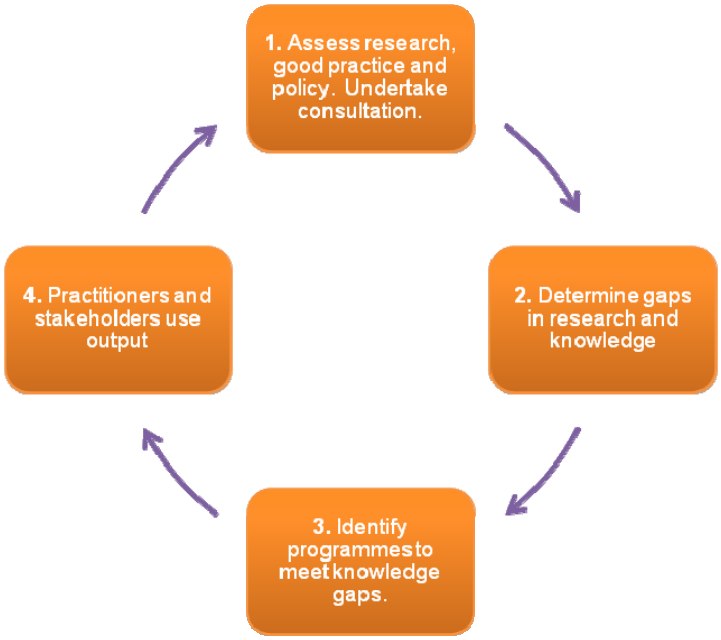

Figure A-2 Overarching research framework.

A.1.3 Review of current research and best practice

We reviewed the current state of knowledge in IUD by searching publications, research programmes (such as the Joint Defra/Environment Agency R&D, UKWIR, CRUE ERA-NET, FRMRC2) articles, guidance documents and notes, policy statements and completed (or part completed) IUD projects. The *IUD Scoping Study Report* (Balmforth *et al.* 2006a) provided valuable information. Projects were assessed and categorised by research type based on the Frascati classification of research (OECD 2002) and the IUD implementation themes (Table A-1). Some projects fitted entirely within themes, whilst others spanned a number of themes. The findings are summarised in Appendix C. Detailed summaries of the documents reviewed are included in Appendix D.

Table A-1 Project types and IUD themes used to categorise the knowledge review.

Frascati classification		R&D	R&D	R&D / Non R&D	Non R&D	Non R&D	Non R&D	Non R&D	Non R&D
Project Types (includes intiatives and catalysts to projects)		Basic research	Applied Research	Guidance	Dissemination	Education and Training	Capacity Building	Software and Tools	Demonstration / pilots
Timescale		*L*	*M/L*	*S/M*	*S*	*S/M*	*M/L*	*S/M*	*S/M*
IUD Theme	Systems								
	Hydrological Processes								
	Data (Collection and Management)								
	Flood and Flood Risk Modelling								
	Flood and Flood Risk Mapping								
	Risk and Uncertainty								
	Spatial Planning								
	Stakeholder Management								
	Operation and Maintenance								
	Implementation Measures								
	Policy and Governance								
	Social and Health Issues								

A.1.4 Identifying and prioritising knowledge gaps

In this stage we identified the basic components of integrated urban drainage. We consulted practitioners, especially those involved in Defra's IUD pilots. These practitioners, research leaders in universities and experts on the Project Steering Group were asked to identify research needs and gaps in knowledge and capability inhibiting the development of IUD. We held a workshop and conducted surveys by e-mail and face-to-face interviews.

The consultation process revealed that:

- Basic research in IUD is largely uncoordinated with similar projects not linked together. This is probably due to the wide range of bodies sponsoring research.
- In some cases research work has been duplicated, or important topics missed.
- The system of dissemination is poor.
- The link between research and industry is poor (although it is improving).
- Research outputs can take considerable time to turn into practical information for the end user. This in part may be a result of vested or commercial interests and lack of a common interest programme.
- Greater strategic links with industry are required to address end user needs.
- Where up-to-date research outputs are being used, they are often limited to one organisation or project team.
- There is a general concern that many of the bodies responsible for urban drainage lack the skills and capacity to develop IUD effectively.

Thus, the lack of a coordinated framework for IUD research appears to be inhibiting the development of IUD.

In the next step we compared the current state of knowledge with the needs identified in our consultations. This enabled us to pinpoint research gaps.

In all, over 370 gaps were identified. Each gap was given a unique code according to its origin (questionnaire, interview) and its sequence (1, 2, 3 and so on). Gaps were then grouped into 67 individual categories. For example, all policy and system gaps were placed under the heading *Establish policies/system to enable IUD to be implemented (including regulation)*. These were numbered A1, A2 and so on. However, this still left too many categories for workable analysis, so they were grouped a second time into 28 categories. This gave a workable number of gaps to prioritise and to build a research programme. These groups were numbered B1, B2 and so on. An audit trail was kept so that the content of each group could be traced to the originally identified gaps. Full details of the gap analysis with the 67 categories are given in Appendix E.

Gaps were then categorised in three ways. Firstly, we aligned the gaps to the IUD implementation themes. We then assembled these groups according to the component parts of the IUD process and the source-pathway-receptor classification (Table A-2).

Using the scoring system set out in Table A-3, B groups were prioritised using experts on the Project Steering Group. The results of this are shown in Table A-4. We also

assessed each knowledge gap to identify who would benefit from filling the gap and who might fund this (see Appendix F). Inevitably, not all gaps could be assessed, given that some would involve a change in legislation, regulation, funding or governance.

Table A-2 Table for classifying gaps with IUD themes and SPR model.

IUD themes\ component	Source	Pathway	Receptor	Other (drivers and responses)
Data collection and management				
Hydrological processes				
Systems				
Flood and flood risk modelling				
Flood and flood risk mapping				
Risk and uncertainty				
Spatial planning				
Social and health issues				
Implementation measures				
Operation and maintenance				
Policy and governance				
Stakeholder management				
Other				

KEY	DESCRIPTION
	Boxes shaded purple are not considered to be a main or primary source, pathway, receptor or other (including drivers and responses).
Source	Are weather events, or sequences of events, that may result in flooding (e.g. intense rainfall and storm surges) and local surface run-off, including minor drainage channels at the level of the individual contributing area.
Pathway	Are mechanisms that convey floodwaters, including drains, sewers, watercourses, culverts, rivers, estuaries and certain SUDS elements, to where they may impact on receptors (e.g. flows in and out of river channels and urban overland flows).
Receptor	Are people, businesses and the built and natural environments that are affected by flooding. Surface flood pathways are included in the definition of receptors rather than pathways.
Drivers	Are phenomena that may change the state of the flooding system, such as climate change, urbanisation or changing agricultural practices.
Responses	Are changes to the flooding system that are implemented to reduce flood risk, such as flood defences.

Table A-3 Scoring and prioritisation for knowledge gaps.

Criteria	Score	Weighting	Description
Relative importance	0 or 1	5	This considers which gaps should first be filled to enable integrated urban drainage to be achieved. Top 10 gaps are scored with one, the rest with zero.
Value	1 to 5	2	This considers how filling the gap will help lead to integrated urban drainage. Extent to which filling the gap meets the overall vision, if it meets all aspects, scored as five.
Stakeholder spread	1 to 5	1	This considers how many stakeholders will benefit from the gap being filled (one stakeholder scores one, five or more stakeholders scores five).
Need for new knowledge	1 to 5	1	This identifies whether filling the gap requires substantial new knowledge, or whether most of the knowledge already exists (one = wholly new knowledge, five = no new knowledge required).
Potential project timescale	1 to 5	1	Identifies the potential timescale for a project to fill the gap. If the gap be can be filled within one year = five, five years or more to resolve = one.
Timeliness	1 to 5	1	Considers when the gap needs to be filled. If immediately needed = five, if could be deferred for four years = one.

Table A-4 Prioritised gap groups.

Gap No.	Gap	Score
B3	Major lack of awareness of roles and responsibilities of stakeholders and lack of understanding of who is responsible above certain standards and how stakeholders can work together to bridge the gaps	8.1
B20	Lack of integrated flood risk plans (covering all sources of flooding) and the need for a consistent approach to model/map overland flows and flood risk in urban areas.	8.1
B1	Unclear (and could be improved) legislation to surface water management for planning and for the implementation of integrated urban flood risk management in existing and new developments.	7.9
B11	Lack of awareness of available research, guidance, tools, generally as a result of untargeted dissemination.	7.6
B2	Need for accountable regulation that enforces legislation for all stakeholders, in particular covering environmental, flood risk and building control.	7.5
B5	Lack of planning policies to ensure surface water management is achieved with the appropriate drainage types.	7.4
B22	Current funding mechanisms must be reviewed if money for urban flood risk management is to be available at the right time for the right stakeholders	7.2
B25	Lack of knowledge (technical, implementation, stakeholder management and capital and operational costs) generally in the industry of surface water management and particularly in local authorities for spatial planners and emergency planners.	7.1
B24	Lack of capacity available (particularly in local authorities) to undertake integrated urban flood risk management.	6.9
B10	Lack of data/knowledge/awareness of surface water assets and where surface water flooding occurs.	6.9
B9	Need interaction with the right stakeholders to achieve urban flood risk management, with the best ways to do it and what to avoid	6.8
B16	Lack of an agreed method/approach to share data between stakeholders	6.6

Gap No.	Gap	Score
B12	Lack of understanding of which critical infrastructure is at risk as a result of the drainage system performance and how that infrastructure should be protected especially in dense urban areas.	6.6
B14	Lack of integrated maintenance plans (where one stakeholder impacts on another without knowing when carrying out maintenance).	6.6
B21	Lack of understanding of how rainfall run-off and subsequent flows in the urban drainage system impacts further downstream in an integrated manner and how systems interface and interact.	6.4
B26	The lack of awareness and understanding in the general public of flood risk, what is sensibly achievable, and what measures can be personally taken to reduce risk.	6.4
B27	Not all stakeholders are involved in the development process (for drainage and flood risk) from the start of the project, often resulting in drainage being considered later during the project life cycle	6.3
B13	Lack of leadership/legislation for the implementation and adoption of SUDS.	6.3
B28	Missing guidance on surface water management in urban areas for all drainage types.	6.3
B8	Lack of suitable pilot/case studies to demonstrate urban flood risk management.	6.1
B6	Need greater evidence to demonstrate the impacts, issues and benefits of using highways as flood channels and ensuring that all flood channels are protected in the future.	5.8
B23	Lack of knowledge of the costs of all drainage types against the benefits they bring (capital and operation costs).	5.5
B15	Lack of a flood warning system predicting impacts from non-fluvial sources.	5.3
B17	Need for a more common/consistent approach for dealing with planning submissions in local authorities.	5.1
B18	Need for clearer guidance, standards and consistency for planning liaison offices in the Environment Agency.	5.0
B7	Lack of quality in the design and construction of SUDS.	5.0
B4	Allowance for climate change varies between different responsible organisations.	4.7
B19	Need for better tools to asses water quality from different sources and the impact on different receptors.	4.0

A.1.5 Identifying and developing the research projects

Once a prioritised set of research gaps (needs) had been identified, we could develop a research programme to address these gaps. Aligning gaps with potential research projects, and in particular agreeing priorities was not straightforward. Research ideas were brainstormed but needed several iterations to fully develop them. This was because not all the needs or gaps directly aligned with all potential projects. Also several of the proposed projects addressed more than one need. We recognised that different types of research projects would need different approaches, take different lengths of time to complete and require very different levels of funding. In some cases further work was needed to align proposals more closely with the requirement of different funding organisations.

We then developed an agreed list of criteria and scores to categorise the research and prioritise potential projects. This was to ensure a balance of projects that reflected the overall needs expressed by the gaps identified in the previous stage. We had to distinguish between those projects that would be relatively easy to define and could be delivered with certainty over a fairly short time scale, from those where a longer and more uncertain development period would be needed. The agreed prioritisation criteria is summarised in Table A-5 below. Please note that the gap priority score is carried forward into the process of scoring potential research projects.

Table A-5 Research project prioritisation criteria.

Criteria	Weighting	Scoring	Description/example
Stakeholder benefit	1	1 to 5	Which stakeholders and how many will benefit? (one stakeholder = one, five or more stakeholders = five).
Project objectives	2	1 to 5	Extent to which the proposed project addresses the strategic objectives. Score increased for multiple benefits.
Project timescale	1	1 to 5	Accounts for the duration of a project (one year or less = five, three years or more = one).
Cost	2	1 to 5	An indication of project cost per year (above £300,000 = one, under £100,000 = five).
Gap priority	1	1 to 10	Gap priority score brought forward.
Certainty of delivery	2	1 to 5	Assesses the certainty that the project can be delivered within the timescale and cost. Outline potential blockers. (Very uncertain= one, very certain= five)
Maturity of subject area	1	1 to 5	How well the subject area is currently developed (highly mature = one, completely undeveloped = five)
Total			Score given as a number out of 10.

We were careful to include the full range of potential research, including basic research, applied research, knowledge transfer, guidance, training and development or simply policy or regulatory requirements. We included project suggestions from the consultation stage and speculative project proposals based on expert opinion. We linked the projects to each identified gap in knowledge, and one or more of the IUD themes so as to identify explicitly how each proposal would contribute to knowledge and best practice. Projects in general fitted into the following categories:

- start-up projects which act as catalysts;
- stand-alone projects;
- initiatives, including policy or regulatory changes.

Duplicate projects were removed from the list, and we linked the remaining ones to different groups that were likely to benefit. We used the same structure for developing future research projects. Research projects were categorised by IUD implementation theme and research type (based on the Frascati classification, OECD 2002). By using research type we could align proposed projects against potential funding organisations.

In formulating and prioritising the projects, we carefully looked at the ongoing research programmes. However, we did not try to identify in detail the science centres and other institutions that could be allocated to listed themes, nor did we aim to assess whether there is sufficient capacity in the UK to conduct the proposed research programme. A more precise assessment of national capacity is beyond the scope of this project.

We also reviewed the urgency of addressing gaps from the consultation process and estimated the duration of different projects. This enabled us to set our proposals against a future time frame. We then prioritised projects using the criteria set out in Table A-5. The prioritised projects are listed in Table A-6.

Table A-6 List of proposed projects in priority order.

Project No.	Project Outline
1	Develop signposting system for research, development and dissemination (portal).
2	Combine mapping of recorded flood incidences (from different datasets and merging different data types). Develop guidance and give examples to collect and manage data on flood incidents and map. Look at different ways to present the data, for example to preserve confidentiality of individual property flood risk. GIS Mapping of drainage. Develop a meta database for use in IUD studies to identify type, format and ownership of data and to help data-sharing. Identify the data typically available and demonstrate how it can be usefully stored and shared.
3	Provide training on the assessment and management of drainage exceedance. Promote guidance to local authorities (such as highway engineers, landscape architects and drainage engineers) on designing for exceedance.
4	Briefly assess the legal issues associated with designating and managing flood pathways and disseminate (particularly to local authorities).
5	Review the potential of incentivisation in IUD to generate surface water management strategies and implementation. Review the potential of different business models to achieve IUD in new build and existing areas (this may include a risk-based approach to funding). Assess a polluter pays approach to surface water charging: How do we ensure owners of source of run-off are held accountable? What incentives can be put in place?
6	Offer training on stakeholder and public engagement approaches.
7	Produce a national agreement on the availability and sharing of data between different stakeholders. Develop guidance to bring together different stakeholders to share information, modelling and expertise on surface water flood risk management, to improve data sharing and establish how and who should manage the data, particularly if data has limitations and sensitivities. Recommend procedures for data updating and security.
8	Provide guidance to the people side of stakeholder management, collating and developing models for engagement and communicating risk as a concept.
9	Provide guidance on the Environment Agency strategic overview to ensure commonality across England and Wales, providing consistency in approaches, by disseminating what the Environment Agency is doing.
10	Provide guidance for the flood risk assessment of critical infrastructure.
11	Develop easy-to-use guidance for spatial planners on flood risk management (and vice versa).
12	Develop (initiatives/or promoting) learning alliances and LANDFORM to share knowledge.
13	Create guidance on public engagement in the context of integrated urban drainage (such as the difficulties of engaging with the public to understand and accept solutions and managing expectations).
14	Role of local self-help in flood risk management.
15	Develop a framework for drainage performance (risk-based) standards for different drainage components.
16	Developing a common language for integrated urban drainage and risk. Develop a consistent and coherent framework for assessing flood risk form all urban sources.
17	Develop guidance by collating case studies to demonstrate the integration of drainage in urban development, in particular for extreme event pathways and multi-functional design. Develop new guidance on how to incorporate flow reduction strategies (retrofitting surface water management).
18	Compare the performance of different urban flood modelling approaches (build on Pitt work) and provide guidance for different applications.
19	Develop a decision-support mapping tool to identify responsibilities for flooding.
20	Collect and assess Whole Life Cost data on urban flood risk mitigation and/or remediation.

Project No.	Project Outline
21	Review building regulations and building control to identify gaps and barriers and recommend amendments to encourage source control.
22	Pilot study to show extreme event flood pathways which need to be protected. Develop rapid visualisation tool which highlights flood pathways for use in strategic planning and emergency response.
23	Create guidance on leadership for local authorities for IUD or surface water management
24	Develop an evidence base to support legislative and regulatory change.
25	Evaluate the effectiveness of guidance and model agreements for the adoption of SUDS.
26	Create capacity-building interventions to enable a learning culture that values integration and participatory decision-making. This should include community and local organisational capacity building. Start with an assessment of the current state, before developing strategies to build capacity, followed by implementation.
27	Develop guidance on the management of critical infrastructure as part of emergency response (during the planning phase) (including knowing where flooding will occur and the movement of emergency vehicles).
28	Review the capabilities of modelling software and tools for replicating the performance of SUDS, to help end users.
29	Develop guidance to build adaptive capacity into SUDS for managing extreme events by altering the design philosophy by using (designed in) freeboard during extreme events (6W).
30	Develop detailed design guidance for highways to safely accommodate sustainable exceedance flows (conveyance or storage). Engage with highway engineers, test highways in good, medium and poor condition. Identify impacts for access and emergency services,
31	Evaluate the (extreme) statistical distributions of rainfall, run-off and flooding based on urban drainage models.
32	Produce easy-to-use guidance for contractors on the construction of SUDS (simplified checklists and pamphlets).
33	Develop a method/process to ensure public are engaged (people receive the message and respond) with forecasting and warning and what they need to do.
34	Develop a method for post-construction performance testing of SUDS.
35	Collate data on the operational management of urban drainage infrastructure and its impacts on performance to produce guidance on integrated maintenance approaches.
36	Improve the capability of below-ground flood modelling (models flooding due to backing up through property connections).
37	Set up demonstration projects for exceedance measures (including identification and collation of demonstration sites for exceedance measures).
38	Produce guidance on writing planning conditions (production of standard conditions?) on building resilience and resistance into developments in flood risk areas.
39	Develop flood warning systems for all sources of flooding and look to improve their accuracy, confidence and timeliness.
40	Develop integrated tools for modelling flood risk (from all sources) to include full damage costing and cost benefit analysis for assessing remedial measures.
41	Collect and assess data on flood impacts and vulnerability. Extend the work of the multicoloured manual to include health and safety factors.
42	Evaluate real-time control in integrated urban drainage as a future solutions approach.
43	Study the effectiveness of PPS25 and the guidance - building the evidence base - and update the implementation guide.
44	Reconcile IUD, Flooding Directive/Bill and WFD. Take on board water quality drivers when dealing with quantity. Identify commonalities and contentions between the drivers and ways to reconcile them.
45	Develop knowledge to improve rapid 1D overland flow modelling (tools).
46	Set up demonstration projects on flow reduction strategies (including existing/urban regeneration).
47	Set up demo project for' just in time' operational management of drainage systems.
48	Produce guidance on the use of rainfall radar measurements in flood forecasting and real-time control to assist flood warning and event management.
49	Collect exceedance data (possibly through monitoring as well as other sources) to build

Project No.	Project Outline
	a data bank to validate exceedance models.
50	Develop tools to achieve rapid modelling of sewer and drainage system response for real-time control and forecasting.
51	Low-cost monitoring of drainage system performance. Develop equipment to better understand system performance and real-time control (RTC).
52	Evaluate the performance of SUDS during long duration rainfall events, especially exceedance conditions.
53	Develop knowledge to improve speed and accuracy of 2D above-ground flood modelling, (tools). Include data availability, sources and types.
54	Further analyse Met Office climate change model outputs to improve certainty of downscaling. Validate hourly data and improve sub-hourly downscaling to remove uncertainties inherent in UKCIP Weather Generator.
55	Account for spatial effects of storms and storm-tracking in modelling for real-time control applications.
56	Self-help - retrofit/new source control technology - Identify source control approaches for new and existing properties. Then trial different technologies on a catchment and quality impact from long-term monitoring.
57	Develop simplified network models of drainage systems for RTC - bringing in to the UK. Learn lessons from RTC applications overseas.
58	Establish test urban catchments for long-term multi-disciplinary research into IUD.
59	Understand the impact of SUDS on groundwater.
60	Develop methodologies for assessing impacts (e.g. cost, flooded area) of different forms of flooding with different probabilities.
61	Develop assessment procedure and long-term management strategies for groundwater flooding.
62	Use uncertainty in assessing and managing flood risk, where and how it will be used, and how it affects solutions.
63	Real-time flood emergency response. Project aims to devise new technology to support dynamic modelling, by integrating hydrodynamic models with agent-based infrastructure and population models, to provide a new and practical approach to real-time sensing, management and immediate recovery from extreme flood events.
64	Develop the software and guidance to ensure that high intensity rainfall can be modelled correctly and replicated (performance of models in extreme events). Compare different methods, and make recommendations for different applications.
65	Assess the use of rainfall threshold criteria in predicting urban flooding events, to assist in predicting potential flooding locations.
66	Review methods available for integrating models of different drainage systems.
67	Develop visualisation techniques for flood risk assessment to support public engagement. Develop management strategies.
68	Assess the health impacts of flooding and how this might be predicted and managed.
69	Improving the reliability of mid-term (one- to five-day) flood forecasting for urban areas.
70	Integrated surface water and groundwater modelling.
71	Improve land use modelling in 2D surface models for urban areas.
72	Drainage asset deterioration modelling.
73	Intelligent interpretation of real-time monitoring information.
74	Improve fast response modelling for real time interventions.
75	Health-related pollutant modelling for flood events.

Having drawn up the prioritised list, we then prepared the top 20 project proposals in more detail, including title, aim, description, benefits, timescale and estimated cost. The next 12 projects (21-32) were worked up to include title, aim and description. We then re-scored the top 20 projects to include estimated cost. At each stage we checked the consistency of scoring between different experts in the project team and the project steering group. The titles of the top 20 urgent short-term projects are given in Chapter 2. Further details for the top 32 projects are given in Appendix G. The project steering group independently evaluated and critically assessed these 32 projects.

B Appendix B – Practitioner views on how to achieve integrated urban drainage

B.1 Consultation process

Gaining the views of practitioners regarding integrated urban drainage was an important part of the project. This helped us to identify gaps in knowledge, what was preventing integrated urban drainage being achieved, the future requirements of the industry and what was required to develop the research framework.

The aims of the consultation process were to:

- Understand the problems of implementing and embedding good practice IUD.
- Help identify important research and development projects.
- Identify any lessons learnt and future research requirements from current projects, government initiatives and consultations (e.g. the Defra IUD pilots, the Pitt Review).
- Identify key areas for urban drainage research, guidance and implementation support, spanning spatial planning, stakeholder engagement, design, risk assessment and management, asset management and operation.
- Identify gaps in knowledge, expertise, guidance, techniques, tools and processes related to urban drainage.
- Obtain feedback and support from stakeholders on research required to develop a framework.
- Help prioritise and develop a future research programme.
- Disseminate findings and raise awareness of the agreed framework.

We used a variety of consultation approaches to collect views on the developing research framework and addressing the problems of IUD. We used an online questionnaire, consultation workshop and interviews. The consultation process summarised in this section occurred in the summer of 2008, with the backdrop of discussions surrounding the Pitt Review of the 2007 flooding and the upcoming Floods and Water Bill.

B.2 Consultation output summary

B.2.1 Online questionnaire

An online questionnaire was circulated to CIRIA's contacts on urban drainage. We received sixty responses, with nearly a third (29%) of responses coming from local

authorities and just over a quarter (26%) being provided by consultants and practitioners.

B.2.2 Problems to tackle

At the start of the project, we identified seven main areas important for achieving IUD. These were policy and regulation, funding, planning, design, construction and implementation, operation and maintenance. When asked about the problems that should be addressed through research, guidance, pilots and other initiatives nearly 60 per cent of all respondents thought that policy and regulation was the most important problem to tackle. Around 40 per cent stated that that funding was the biggest challenge. Respondents' views are shown in Figure B-1.

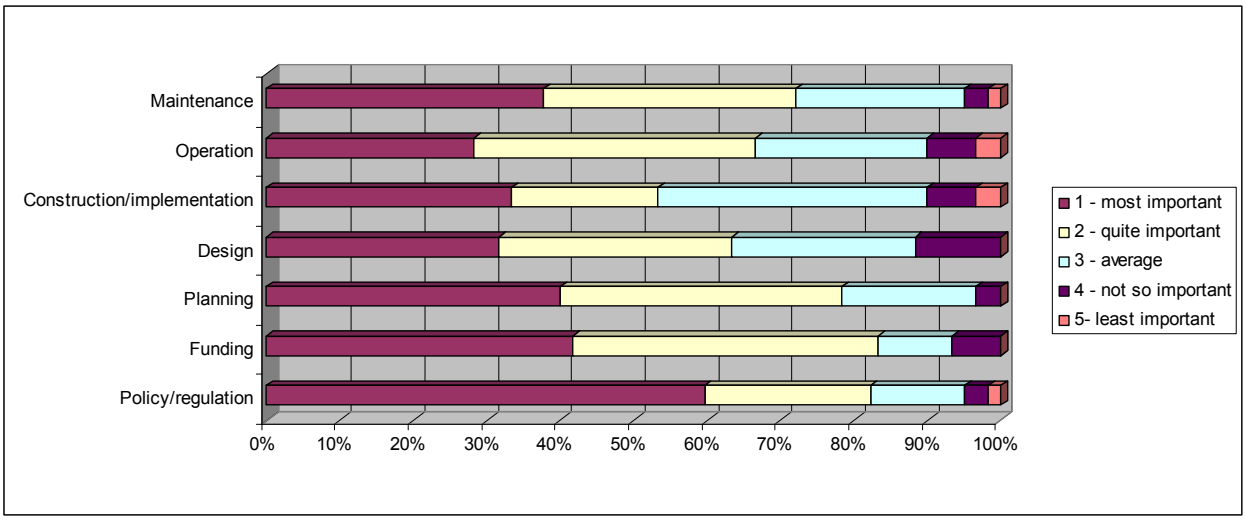

Figure B-1 Problem areas that should be addressed on IUD.

Participants were also asked who was likely to have the greatest problems. Many thought that sewage undertakers, local authorities and regulators would face the greatest challenges.

When asked about the most important processes for implementing integrated urban drainage in existing developments, the majority of respondents believed that stakeholder engagement and understanding of flooding mechanisms was the most important process, closely followed by identifying data and information requirements and managing flood risk. In new developments, participants stated that spatial planning and flood risk assessments were also important.

Participants were also asked to identify the problems under each theme. These are summarised in Table B-1.

A large number of gaps and barriers were identified in the questionnaire. We have summarised these along with gaps highlighted during other consultation methods.

Table B-1 Ideas to improve each area of IUD.

Setting policy and regulation	Identifying funding
Obtaining social equity in policy and funding options.	Simplified funding arrangements need to be developed.
Addressing challenges of existing surface water management infrastructure.	Capital and operational expenditure needs to be adequately balanced.
Clarifying existing regulatory approaches.	Funding approaches should address challenges with existing infrastructure.
Policy approaches to address diffuse water pollution as well as flood risk management.	Need to demonstrate equitable solutions.
Better interpretation of policy by regulators.	Identification of approaches to fund schemes that enable partners to participate.
Partners to be involved in policy and regulation development.	An approach needs to be developed to allocate costs related to different components and maintenance options.
Cooperation between partners is required.	
Planning schemes	**Designing schemes**
Overcoming lack of local knowledge to determine opportunities and constraints.	Greater awareness of performance of different SUDS components.
Planning for climate change.	Overcoming the challenge of capacity building.
Approaches to encourage effective and early liaison between clients and local authorities.	Designing for maintenance, health and safety and climate change.
Improving awareness of those involved in the planning and development control process about surface water management.	Building multi-functional systems.
Partner engagement needs to be developed.	Need to ensure guidance and research does not overcomplicate the process.
Design standards for different partners need to be clarified.	More demonstration projects should be developed.
Encouraging the setting of multiple objectives.	
Constructing schemes	**Operating schemes**
Challenge of reducing environmental impact of construction.	Difficulty in identifying most appropriate organisation to operate schemes.
Ensuring adequate supervision, inspection and final sign off of surface water management infrastructure.	Cost-effective operation of surface water management assets.
Potential development of an accreditation scheme.	How can maintenance be enforced and regulated.
	Assessment and inspection procedures should be finalised.
Maintaining schemes	**Other**
Commitments and approaches to maintenance need to be clear.	Need to be aware of research and guidance.
Approaches to facilitate joint maintenance of surface water management.	How to effectively manage the existing surface water management infrastructure.
Waste management from surface water management infrastructure needs to be investigated.	Insufficient research has been made into disconnection and retrofitting surface water management.
Guidance on determining commuted sums would be useful (links with adoption issues).	Insufficient monitoring has been carried out within the UK of installed schemes.

B.2.3 Workshop results

A consultation workshop was held on 9 June 2008, by invitation only. Views were collected on the problems faced in implementing good practice and knowledge gaps. We discussed the development of a decision-making framework and identified a number of research priorities. The aims of the consultation workshop were to:

- outline the existing position of integrated urban drainage good practice;
- understand research gaps;
- develop the decision-making framework;
- understand priorities.

This section briefly highlights the key findings from the workshop.

B.2.4 What people want to achieve within IUD

Delegates were asked to consider practices they wanted to achieve that would help IUD. Six key themes to IUD were identified (and another category), similar to those in the questionnaire.

- setting policy and regulation;
- identifying funding;
- planning surface water management schemes;
- designing surface water management schemes;
- construction and implementation of surface water management;
- operation and maintenance.

Delegates stated the need for a coordinated approach to setting policy and regulation. Integration was an important element for policy and regulation, rather than the current institutional arrangements that delegates felt did not foster collaboration.

For funding, the delegates identified the need for funding streams and a system for charging. Some felt that a risk-based funding scheme should be developed, whilst others wanted to retain the current funding process.

When planning schemes, delegates strongly advocated the integration of surface water management and urban design. Better stakeholder engagement with inclusive consultation was also seen to be important.

For designing schemes, a similar link between surface water management and urban design was highlighted. Adaptation was important here, as was the management of flow on the surface.

For construction and implementation, delegates felt that more sustainable solutions were needed. Partners should be more aware and landscape architects had an important role to play. The term ‘self-help’ was used to summarise what homeowners could do to manage flows through source control if guidance was available.

For operation and maintenance, good maintenance regimes and understanding the impact of limited or poor maintenance was highlighted.

Building on the above, delegates then prioritised what would most influence the success of IUD.

The highest priorities were:

- achieving multiple benefits with integrated water management;
- coordinated approach between all local authorities;
- developing a risk-based approach to funding;
- developing a polluter pays principle for surface water charging;
- funding of training for local authorities;
- smarter construction for implementing IUD;
- clarity in maintenance responsibilities and regime.

B.2.5 Policy context

In June 2008, Sir Michael Pitt and his team produced *Learning lessons from the 2007 floods* (Cabinet Office, 2008). This review collated a vast evidence base on the consequences of the 2007 floods and investigated approaches to improving flood risk management in the UK.

The review produced a comprehensive report with 92 recommendations for stakeholders within the urban flood risk community, the key organisations being Government, the Environment Agency, local authorities, flood risk management practitioners and the wider community.

Recommendations focussed on the need to assess and reduce the risks from flooding, reduce its impacts as well as ensure that communities are better prepared for floods and cared for during an emergency. With regard to IUD the review addressed:

- **Coordination** – Pitt suggested the Environment Agency should have a strategic overview for all forms of flooding and the local delivery should be led by local authorities.
- **Local flood risk management** – The review recommended that local authorities should tackle local flood risk challenges and develop partnerships, asset registers and surface water management plans.
- **Sustainable drainage** – Recommendations included removing the automatic right to connect surface water drainage of new developments to sewerage systems. Allocating responsibilities for SUDS should also be addressed.
- **Cooperation** – Pitt suggested that partnerships should be used to assess and manage flood risk. This was strengthened by a recommendation that all responsible organisations have a duty to share information and cooperate with local authorities and the Environment Agency.

The Pitt review strongly supported the Environment Agency having a strategic overview for all forms of flooding, as it already has this role for coastal flooding, but should be extended to inland flooding. At the national level, the Environment Agency would provide advice, regulation and information, but might have to augment existing relationships to develop partnerships where necessary.

The challenges and research suggested in this consultation is likely to be influenced by these activities and some of the research may consequently support the delivery of some of the Pitt recommendations and potential changes in flood risk governance and delivery.

B.2.6 Identifying solutions

During the workshop, participants were asked to set out projects that would benefit IUD. During the consultation phase it was clear that many of the consultees did not have a full appreciation of the existing science, research, guidance and tools available. Some of the projects identified in Table B-2 may reflect the need for an outcome from R&D to support decision and policy-making. These project suggestions may help overcome problems of basic understanding, communication, dissemination and implementation of good practice.

Table B-2 Summary of projects identified in consultation workshop.

Project Name	Project Summary
Develop a coordinated framework for integrated urban drainage	Identify different organisations, systems and processes. Define stakeholders and their roles and responsibilities. Recognise existing processes that operate at different spatial and organisational scales.
Design guidance for retrofitting SUDS	Need for industry guidance covering choice, (optioneering) implementation and construction of retrofit.
Facilitate data exchange between stakeholders	Identify and resolve issues that would facilitatesharing data between stakeholders
Integrate maintenance of IUD assets	Need for all stakeholders to understand each other's assets, responsibilities and maintenance regimes.
Flood mapping in urban areas	Integrate sources of flooding in urban areas and represent them visually.
Multifunctional design	Realise wider benefits, building on wider sustainability policies/agenda.
Improve urban flood forecasting	Develop methods to improve forecasting of urban floods, to improve responses from rescue services and local authorities.
Integrate water management with planning & urban design	Education, integration and stakeholder engagement to achieve integration of multifunctional areas at development stage.
Polluter pays approach to surface water charging	How do we ensure owners of source of run-off are held accountable? What incentives can be put in place?
Raise awareness of smart solutions/designs	Whilst the technology and guidance exist for smart solutions for integrated flooding issues, designs are often based on single needs, truncated due to timescales or to achieve the minimum necessary. Raise awareness and encourage update of technology and guidance for construction of solutions.
Risk-based realisation of asset maintenance	Clarification of wider impacts to partner responsible for maintenance.
Risk-based approach to funding	Integrate funding for flood schemes across flood sources and responsibility.

Self-help (stage 1): retrofit/new source control technology	Identify source control for new and existing properties. Then trial different technologies on a catchment and quality impact from long-term monitoring.
Self-help (stage 2): education of public to implement/retrofit SUDS in homes	Launch publicity/education campaign to raise awareness of benefits for homeowners of source control and encourage implementation.
Construction implementation - smart construction	Identify best practice in construction and facilitate implementation. Identify and encourage innovations that can provide reductions in short term.
Provide training for local authorities	Develop an awareness of the role of local authorities in shaping space and building resilience.
Understand drainage	Guidance to promote understanding of existing drainage mechanisms, their capacity and the development of agreed design standards.

Once project ideas had been set out, voting was used to identify the top five most popular solutions. These were:

- Integrating water management with planning and urban design.
- Understanding drainage.
- Facilitating data exchange between stakeholders
- Integrated maintenance of IUD assets.
- Flood mapping in urban areas.

B.2.7 One-to-one interviews

We interviewed experts and professionals from various organisations. These included policy and decision makers, practitioners, sewerage undertakers and local authorities. A number of areas were explored:

- problems that prevent IUD being implemented in new developments;
- problems that prevent IUD being implemented in existing developments;
- gaps in knowledge;
- suggested gaps in research;
- achieving successful initiatives.

Those interviewed were from the following organisations:

- Pennine Water Group
- Wessex Regional Flood Defence Committee
- Monash University
- Seven Trent Water
- Local Government Association

- DCLG
- Pitt flooding review (Cabinet Office)
- Association of British Insurers
- Home Builders Federation
- National Flood Forum

B.2.8 Problems that prevent IUD being implemented in new developments

There was broad agreement between those interviewed, that early stakeholder engagement is essential in the development control and planning process. This enables opportunities and constraints to be understood and can generate strategic benefits based on a shared vision. If good quality flood risk assessment and outline drainage schemes are prepared, this enables the design to be appropriately challenged.

The potential tension between land take and high density developments can be managed to build a multifunctional surface water infrastructure. The lack of planning policies, clarity of roles and approaches to adoption reduce the chances of establishing a sustainable funding regime for the long-term adoption of SUDS.

B.2.9 Problems that prevent IUD being implemented in existing developments

Those consulted felt that tackling the legacy problems of existing drainage was the greatest challenge faced. Good interaction between partners and with the public is required to share information and realise other benefits (such as better water quality).

Management of drainage exceedance was thought to be essential, along with the need to understand how other changes to the built environment, like urban creep, can affect flood risk.

A better understanding of the contribution of surface water management is needed, particularly in business models and regulatory approaches. Technically, practitioners need to explore the opportunities afforded by source control (flow reduction), designing for exceedance and building resilience.

B.2.10 Gaps in knowledge

Many of those interviewed thought it was difficult to identify the research and information available. Research and guidance outputs needed to be more accessible, easily understood and appropriately presented for the target audience. Those organisations commissioning research need to understand where the gaps are. There was considerable support for networks to promote dissemination to practitioners, similar to LANDF♦RM.

Research and guidance needs to be presented with simple outcomes and understandable benefits. Examples of good practice and demonstration projects need to be disseminated with an appreciation of how they can be applied to the problems that practitioners face.

Suggested gaps in research include:

- improving modelling, overland flow could be better understood;
- development of 'low tech' easy-to-use flood routing tool;
- synchronisation of different design standards;
- understanding the impact of rural/agricultural land use on urban flood risk;
- additional guidance on source control, permeable surfaces and so on ;
- more guidance on maintenance of surface water management assets to reduce uncertainty about practicalities and costs, and a procedure for determining commuted sums;
- improving the collation of information following floods, particularly by insurers;
- better understanding of the combination of probabilities from different flooding sources;
- additional guidance and pilot studies on engaging with the community (decision-making, planning, design and implementation).

There was consensus that non-technical overviews often help with understanding across a wide range of stakeholders and those networks, case studies and demonstration projects are essential to encourage wider uptake of good practice.

Sound science and a robust evidence base should be used as a foundation for applied research. Many stakeholders require a common understanding of the challenges and language so that guidance and tools can deliver changes in practice. Specific stakeholder requirements suggested include:

- **Spatial planners** may require a better understanding of the drivers, requirements and opportunities to set multiple objectives and act as intelligent clients when asking for SFRAs.
- **Highway engineers** may require further information and examples of opportunities for using roads and other areas for water conveyance and storage during extreme flood and weather events. Researchers need to understand engineers' concerns and provide guidance to overcome problems.
- **Emergency planners** need to be involved early in the process and need to be part of a multi-disciplinary approach so that consequences of plans and actions can be better understood.
- **Environmental regulators** play a role in understanding general requirements for the built environment and coordinating multifunctional developments and surface water management assets.

B.2.11 Delivering successful initiatives

Successful projects are those that link well to the drivers and are well planned, executed and disseminated to the right target audience. Organisations that commission and fund research need to understand the difference between long-term strategic research and shorter term tactical research and development.

There was consensus that effective dissemination of outputs will directly influence their impact. Demonstration projects and pilots generate enthusiasm and explain what works well. They often deliver a vision backed up by science, research and implementation.

They also provide a mechanism for engagement. Initiatives need to reinforce simple messages with examples of good practice.

B.2.12 Stakeholder consultation summary

Many of the responses from the consultation focused on the need for engagement in the implementation of the framework and the delivery of initiatives. Engagement is required at the outset to understand requirements, risks and benefits. Engagement through dissemination and implementation is also vital for benefits to be realised.

It was recognised that the Defra IUD pilots provided engagement, but this needs further development. There is growing acknowledgement of the contribution that multidisciplinary teams can make to IUD. Initiatives that are well-connected with scientists, engineers and practitioners should be prioritised.

C Appendix C – Research and policy summary

C.1.1 Introduction

This section covers recent research and policy developments related to integrated urban drainage, summarising government policy developments relevant to IUD, and current and proposed research as well as ongoing best practice.

C.1.2 Assessment of policy

C.1.2.1 Current IUD management

In England and Wales, legislation governing the drainage of urban areas can be traced back hundreds of years. It gives statutory and permissive powers to organisations and the general public. It is complicated by the intertwined regulatory process where responsible organisations can be public, private and regulated or private and unregulated. The regulatory framework may be rationalised by the Floods and Water Bill that will be consulted on in 2009. The key organisations and groups are:

- Department for Environment, Food and Rural Affairs (Defra)
- Environment Agency
- Sewerage Undertakers
- Local authorities (drainage, planning and highway)
- Internal Drainage Boards
- Landowners
- Riparian owners
- Insurers
- Navigation authorities

Drainage responsibilities have been documented on many occasions and are summarised in the *IUD Scoping Study Report* (Balmforth *et al.* 2006).

Currently in England and Wales there is no strategic approach to urban flood risk that brings all the stakeholders together. No one body has the overall responsibility for IUD. This is unlikely to change, although the Environment Agency's strategic overview for inland waters may go some way to providing a strategic framework for assessing and managing flood risk with local delivery provided by local authorities.

More recent success in IUD has been a result of *Making Space for Water* IUD pilot studies and public concern that has driven the responsible agencies to work together.

Reasons for the current ineffective delivery of IUD are outlined by Balmforth *et al.* (2006). First is the lack of framework to support IUD, although the publication of SWMP guidance is expected to address this. Other barriers include responsibilities being unclear, different funding arrangements, and different aims and targets. A

particular constraint on sewerage Undertakers is the five-year AMP cycle which inhibits long-term thinking.

For new development, Planning Policy Statement 25: Development and Flood Risk (PPS25) (DCLG 2006) sets out government policy on development and flood risk. Its aim is to ensure that flood risk is considered during the planning process and that inappropriate development is avoided. A sequential test is applied to allocate land for development and where possible avoid flood risk. PPS25 is supported by a Practice Guide (DCLG 2007) which provides guidance of how to implement development and flood risk policies and supports an integrated approach to drainage management as well as the implementation of sustainable drainage.

However, there is currently no duty on local authorities to enforce SUDS to be used to manage flood risk. Management of surface water flows is often below-ground and managed by sewerage undertakers. To compound this, developers currently have a legal 'right to connect' surface water connections to combined drainage systems. Implementation of SUDS is confused further by a lack of guidance on ownership and long-term responsibilities for adoption. However, such challenges may be addressed following Defra's (2008a) publication, *Future Water*.

C.1.2.2 Making Space for Water

In 2004 the Government undertook a consultation exercise on *Making Space for Water*. The response in 2005 set the agenda for how the new water strategy would be implemented, over a 20-year (or beyond) timeframe. Following this, a programme of work was developed covering a number of themes:

- holistic approach to managing flooding and costal erosion risk;
- achieving sustainable development;
- increase resilience to flooding;
- funding.

A number of projects were started under these themes. One of these *HA2, Urban Flood Risk and Integrated Drainage* is particularly relevant to IUD. This started with a scoping study and was followed by fifteen pilot studies covering different issues related to integrated urban drainage. Generally, the pilots investigated potential solutions to known flooding problems.

The final report of HA2 highlights a number of issues (Gill 2008a). Availability of data is sometimes poor, which can produce misleading results when assessing flood risk. A hierarchal risk-based approach to flood risk assessment is considered appropriate to target detailed modelling, however guidance is required to establish the best approach. Resolving flooding in urban areas may only be achievable over many years through regeneration. The necessary skills to carry IUD management are in short supply. Current institutional arrangements make it difficult to coordinate IUD management.

Complementing HA2, another project *HA1 Environment Agency Strategic Overview: Inland Flood Risk Management* was initiated. This explored what the strategic role of the Environment Agency should be. Implementation of the wider strategic overview is expected to take place progressively, but will require legislative backing from the Floods and Water Bill, the draft of which will open for consultation in 2009 (Defra 2008b).

C.1.2.3 Future Water

In February 2008, the Government launched its *Future Water* vision looking ahead to 2030. *Future Water* in particular considers how surface water can be managed more sustainably. It also considers integrated planning for new development. The vision is to use surface water management plans (SWMP) as a tool to improve the assessment and management of urban surface water, together with coordination between stakeholders (this has been developed and follows on from the HA2 project). The strategy also seeks to promote sustainable drainage by clarifying responsibilities and providing incentives for developers and property owners. A key aspect is the surface water management consultation (February to April 2008). The consultation was broken down into three parts in line with Sir Michael Pitt's review into the flooding in summer 2007. These were (Defra 2008c):

- using SWMP to improve coordination between agencies involved in drainage and local management of flood risk;
- increasing uptake of sustainable drainage systems (SUDS) by clarifying responsibilities for adoption and management;
- reviewing the ability for premises to connect surface water drainage automatically into the public sewer system (Section 106 of Water Industry Act 1991).

Defra (2008c) published a summary of responses. For SWMP this indicated that:

- plans should be mandatory in critical drainage areas;
- skills and resources are an issue;
- spatial planning plays a key role in resolving surface water flooding for new and existing development;
- the complexity and cost of modelling surface water risk may be significant.

For SUDS it indicated that:

- subject to funding availability, local authorities should take on the responsibility for adopting and maintaining above-ground SUDS;
- many sewerage undertakers wish to be responsible for below-ground SUDS that drain to surface water sewers;
- legislative changes are required to improve the uptake of SUDS.

For reviewing the right to connect:

- the automatic right to connect should be amended to a conditional right;
- Government will not meet its aim without legislative change.

The consultation indicates that major change is required in surface water management.

C.1.2.4 Surface water management plans

Following the consultation and conclusion of the HA2 project, Defra developed guidance for surface water management planning. The first edition of the guidance for SWMP (Defra 2009) is to be tested in pilot projects in 2009. The guidance released as a living draft will be updated and developed following a period of consultation and as a result of the learning gained from the pilot projects.

C.1.2.5 Floods and Water Bill

The recent flooding in summer 2007 has highlighted the need for change in how flood risk is managed. Currently, a draft Floods and Water Bill is being prepared and should be consulted on in 2009 (www.defra.gov.uk/environ/fcd/floodsandwaterbill.htm).

C.1.2.6 Government's response to the Pitt Review

The Government's response to the Pitt Review was published in December 2008 (Defra 2008c). This responded to the 92 recommendations set out in the Pitt Review, including those linked to IUD. This highlights the work already been completed in the interim between the Pitt Review and the Government's response, as well as the Government's future actions plan.

C.1.2.7 Permitted development rights

To reduce the increase of hard surfaces, from October 2008 the Government amended the General Permitted Development Order to prevent the paving of front gardens with an impermeable surface (DCLG 2008), for areas greater than five metres squared. Permitted development is only considered where the surface remains permeable.

C.1.2.8 Property level flood protection and resilience

A current theme under the *Making Space for Water* programme is increasing resilience to flooding with four defined projects. The most recent consultation considers options to increase the use of property measures to reduce the impact of flooding on properties that have a high chance of flooding every year. There is a cost-benefit to improving the resistance or resilience of properties with a one in 50-year chance of flooding or higher (Thurston *et al.* 2008). The consultation builds on the pilot grant scheme that Defra completed in the summer of 2008. It asks stakeholders for their views on whether offering households a free home flood survey would be sufficient to boost take-up or whether a government grant to subsidise the costs of measures themselves would be required (http://www.defra.gov.uk/corporate/consult/flood%2Dprotection/letter.htm 2008).

C.1.2.9 Cave Review: Competition and innovation in water markets

This review covers the whole of the water industry, but its implications could have a significant impact on integrated urban drainage. The review aims to (http://www.defra.gov.uk/environment/water/industry/cavereview/index.htm 2008):

- benefit business and household customers through lower bills, better service and more responsive products;
- increase the efficiency and sustainability of water use.

C.1.3 Assessment of research and good practice

C.1.3.1 Introduction

The aim of this work was to identify areas currently receiving most attention and hence discern gaps and topics requiring additional refinement. Almost 100 projects have been identified and reviewed. An outline of each project is included in Appendix A,

listed in terms of project title, description, aim/objectives, relevance to IUD, key deliverables, contacts and web link. IUD is a fast moving and developing subject area.

During the review, it was necessary to focus on projects/output most closely aligned with IUD, as many minor elements of projects are linked to IUD. Therefore the summary below included those considered most relevant at the time of the review, completed in June 2008.

This review is structured around the project type, based on classifications from the Frascati Manual (OECD 2002). For example, basic research is defined as 'experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view' and applied research is defined as 'original investigation undertaken in order to acquire new knowledge' but 'directed primarily towards a specific practical aim or objective'. The report references individual reviews [using a number] summarised in further detail in Appendix D.

C.1.3.2 Overview

Table C-1 summarises by number, each of those projects classified under topic areas and 'type' of research. The latter headings are used here to provide structure to the discussion. They are: basic research, applied research, guidance, dissemination, education and training, capacity building, software and tools demonstration/pilots and reports/reviews. A review of this table, without going into detail of the projects themselves, indicates a lack of comprehensive output in the following areas: data, incident management, funding and basic research, education and training.

C.1.3.3 Applied research

IUD is built on a firm foundation of basic research made up from its component parts which provides the knowledge and understanding for it to be progressed. Perhaps not surprisingly, no basic research (without particular application as defined by Frascati (OECD 2002)) was identified for IUD, it being a relatively new topic. The first and most common research type considered is applied research.

There is and has been significant research effort currently devoted to modelling of various types. This includes risk modelling of infrastructure such as a river reach or stretches of coastline [3] or urban drainage systems [29], extreme flood processes [10], land use and planning [12], above-ground exceedance flows [19, 84, 92], integrated wastewater system [25, 28], time series rainfall [29], urban water cycle [35], extreme weather events [46], uncertainty [48] and optimisation [50]. Underlying themes of this work are risk and uncertainty, extremes (especially impact of climate change on weather), exceedance flows and asset management. An important gap is method and procedures for collection, handling and sharing of computed and historical data [40].

Some of the modelling research underpins on-going mapping work [41, 84]. Other mapping work is associated with weather extremes [46] and land-use planning [12]. Further work is needed to improve accuracy and resolution of mapping, especially in urban areas, given the complexity and ever-changing conditions encountered.

Applied research work is being carried out in the area of forecasting. This includes theoretical work on 'futures' and their implication for sewerage and urban areas [9,16], short-term rainfall forecasts in urban areas [88, 89], pluvial flooding [90], fluvial flooding [48] and public understanding of forecasts [80]. Significant challenges remain in terms of the veracity of weather radar information, validating such data with gauged data, the complexity and impact of large urban areas and the link between rainfall extremes and flooding. A gap appears to be research on the ability of urban drainage systems to react to extreme events, for example through real-time control.

Table C-1 Table of output assessed matched to IUD themes and project types (numbers are related to projects in Appendix D).

	Frascati classification	R&D	R&D	R&D / Non R&D	Non R&D	Non R&D	Non R&D	Non R&D	Non R&D	Non R&D
	Project Types	Basic research	Applied Research	Guidance	Dissemination	Education and Training	Capacity Building	Software and Tools	Demonstration / Pilots	Reports and Reviews
IUD Theme	Data		40							59,61,74
	Modelling		3,10,12,19,25, 28,29,35,44, 46,48,50,84,92	41,42,78						58,59,70
	Mapping		12,41,46,48,84		40			41,46,84		57,59,61,62
	Forecasting		16,80,88,89,90	1	1			48	1	57
	Risk Assessment		3,6,9,15,20,23 ,29,41,75,78,8 6,87	5,21,22,27, 47	20,21,22,80		4	3,10,29,48, 50	4,24,78,86, 87	37,56,57,71
	Spatial Planning		7,8,47	5,8,13,26,3 0,32,34,51, 72				12	8	11,33,72,82
	Design and Construction		2,16,31,75	13,14,18,49 ,52,93	14,20	14		35	18,31	62,63,64,65,6 6,67,68,69,78 ,83
	Operation and Maintenance		16,28,43,45,48	14	14,20	14		25,28,35	10	61,63,65,69
	Performance Monitoring		17,38					3	38	70
	Incident Management		77							60,61,73,74,8 3
	Resistance & Resilience		55,76	53,81						11,57,73
	Stakeholder Management		7,19,31,54,55, 79,80	30			23,55,75,76 ,79		31	59
	Funding									11,59,82
	Policy / Legislation /Regulation		9,26,48		9,11				11,39	33,56,58,59,6 0,61,62,82
	Other		85							

Arguably the area with the greatest concentration of research is that of risk assessment and management. Work completed or underway includes: drivers and responses [9], flood risk management methodologies [3, 20, 23], pluvial flooding [29, 78, 86], flooding from small urban rivers [75], urban/rural integration [41], whole-life costing [87], risk of serious harm or death [6], multi-institution, multi-stakeholder integration [23] and the Thames estuary case [15]. Clearly, flood risk has now reached central stage in IUD, but much needs to be clarified and developed to make it an operational reality in urban areas. Further work is needed on the link between rainfall extremes, flood probability, flood risk and cost-effective adaptation strategies.

The role of spatial planning in flood risk management has been widely agreed. However, so far little work has been carried out to understand the impact of spatial planning on flood risk, at strategic or local level. There are projects demonstrating the link between flood risk and planning [7, 8, 47], but little that qualifies as applied research. Academic planners need to be engaged in further research in this area to develop the theoretical base that underpins practice.

The next topic is design and construction. Projects in this area are related to drainage design under extremes [2, 16], urban areas in flood plains [31] and non-structural methods [75]. A significant gap here concerns design and construction for flow exceedance in urban areas including protected flood pathway and highways for flood conveyance. Several applied research projects have looked at aspects of operation and maintenance, including sewer operation [16, 43, 45, 48] and system sustainability [28]. However, there is missing research on the potential link between flood risk management and system maintenance strategies. Additionally, there is a long-term gap in our knowledge of active urban drainage operation in addition to traditional passive approaches.

Performance monitoring is rarely carried out and IUD-related research is no exception. Only two projects were identified in this area: locating and mapping underground infrastructure [17] and a long-term sewer monitoring study [38]. Data is the lifeblood of all research and performance assessment. Research is needed on how, where and when monitoring is required. Especially important and lacking are data on drainage exceedance episodes.

Another important area that does not seem to have been researched is incident management. Only one project has been identified in this area and covers understanding, modelling and assessment of failures of flood incident management [77]. This area requires at least further social science work to identify underlying causes of failure, and how and why key stakeholders behave in emergency situations.

Building and other infrastructure resistance and resilience work is reviewed next. Again, relatively little research has been carried out in this area, but new projects on limiting flood damage and easing recovery [55] and building an evidence base of flood resilience will at least start the process. There is a lack of laboratory and field research on the performance of non-structural methods in this area.

An area of emerging importance in IUD is how, why, and when to engage the many relevant stakeholders. These include the public, emergency services, local authorities, utility companies and government agencies. Progress is already being made with projects identified covering: (changing) public perceptions [7], identification of key actors [19], interactions [19, 31], use of communication support tools [54, 87], awareness raising [55], perceptions and behaviours [79], understanding and use of probabilistic flood warnings [80]. Key areas for further work are the impediments to joint working at institutional level, particularly in emergencies, and public awareness and preparedness.

At the policy level, we could identify no research on the impact, costs and benefits of targeted funding for IUD or flood risk management, although there are many unsubstantiated calls for funding. Some research supports policy, legislation and regulation development. This includes future foresight [9], flood risk management for new developments [26] and urban and rural flood risk policy issues [48]. In general, science-led policy is the Government's preferred approach.

C.1.3.4 Guidance

A reasonable amount of guidance is already available to help progress the technical aspects of IUD. However, this guidance often fails to properly account for the context in which IUD has to take place.

The first area considered is modelling, and guidance is currently being produced on use of the RASP (Risk Assessment for Strategic Planning) tool for mapping flooding from all sources [41], pluvial flooding [78] and the use of 2D surface flooding models. The latter includes a review of commercial models and should include 1D models, in terms of their advantages and disadvantages. Other useful modelling guidance has been produced by WaPUG (www.wapug.org.uk) which is currently developing an IUD modelling guide.

Guidance on best European practice on flood forecasting is being produced [1], but little other guidance in this area has been reported so far. The same is true of independent guidance on mapping, which is a gap that should be filled.

Guidance on flood risk assessment and/or management has been developed in terms of: flood plain management [5], urban flood management [21], best European practice [22], non-specialist users of joint probability methods [27] and linking land use planning with strategic flood risk assessments [47].

Spatial planners now have a number of guides to help them deal with aspects of IUD. This includes development in flood plains [5], flood risk [8, 13], new developments [26], sustainable flood and coastal management [30], PPS25 [51], surface water management plans [72] and sustainable water management [32 34]. Closer engagement with spatial planners will be needed to ensure guidance is produced that meets the needs of practice.

Design and/or construction guidance has been produced for SUDS [14, 49, 52], sewers [18] and exceedance flows [93]. Further guidance on design for exceedance flow drainage components such as car parks and highways is needed. Less guidance is available on operation and maintenance although there is some on SUDS [14], indicating a large gap. Design and operation is covered in UK textbooks such as *Urban Drainage* (Butler & Davies, 2004) and *Sewers* (Read, 2004).

In this review, no guidance for IUD was found on performance monitoring or incident management, indicating a clear gap. Two guidance documents cover resistance and resilience: temporary and demountable flood protection [53] and new buildings [81]. Further targeted guidance is needed.

Although stakeholder engagement research is now in evidence, rather less guidance is available to support it, although one project has addressed it to some extent [30]. Advice on how to conduct studies and the benefit and impact of different approaches is needed.

C.1.3.5 Dissemination

A key aim of all research is disseminating the findings. This tends to be done through peer-reviewed papers and conferences for other researchers in similar fields. This often fails to pass on knowledge to practitioners in a form that can be readily used. In some cases, research projects are aimed specifically at dissemination and there will be overlap with projects providing guidance.

Only a handful of projects were found with the sole or main aim of dissemination. These were on the following topics: forecasting [1], flood risk management [4, 20, 21, 22], future flood risk [9], flood policy [11], SUDS design and operation [14] and probabilistic flood warning [80].

The key issue here is appropriate dissemination, particularly for academic projects. Whilst published journal papers and international conference papers must be produced, extra effort is needed to publish in more accessible places in more digestible forms. In turn, there is a need for forums that will accept such work and make it more accessible. Web-based 'intelligent' portals are an emerging method of achieving this.

C.1.3.6 Education and training

The review carried out for this study did not extend to searching for in-house training, short courses, continued professional development, higher degrees and the like. Only CIRIA [14] emerged as industry-recognised providers. The principles emerging from IUD will need to be disseminated widely to have the required impact and a wide variety of training and education providers will need to develop training material in this area.

Capacity building is linked to education and training. Several projects tackled this area as part of their remit, including work on risk management [4, 23, 75], flood resilience [55, 76] and institutions [79]. This is another area that requires further attention. Large-scale change will only come about by strengthening existing capacity associated in IUD. This is particularly so in organisations and professions with increasing responsibilities in this area but little prior knowledge (such as local authority drainage engineers and planners).

C.1.3.7 Software and tools

Some research projects have software or tools as their main outputs. Many of these will not find their way directly into practice, but may underpin developments in commercial software. The transition from research tools to practitioner tools is neither efficient nor effective and more works needs to be done to improve the process.

Software is being produced for mapping of extreme weather events [46], flood risk [41] and exceedance flows [48, 84] and for forecasting extreme events [48, 89, 90]. Tools are also being developed for condition monitoring and asset management [3], uncertainty reduction in extreme event prediction [10, 48], spatially varying time-series rainfall [29] and optimisation [50]. Just one tool seems to be linked to spatial planning [12], and none are associated with incident management, resistance and resilience, stakeholder engagement, funding or policy. Design and construction is included in terms of drainage components [35] and operation in terms of wastewater system optimisation [25, 28, 34]. No outputs relate specifically to maintenance.

No work has been reported on usability of software or on software design and development.

C.1.3.8 Demonstration pilots

A number of demonstration or pilot studies were identified in this review. These focus on the following areas: flood forecasting [1], flood risk management [4], climate change adaptation [24], pluvial flood risk assessment [78, 87], risk attribution [86], flood risk and planning [8], flood reduction [18], river corridors [31], dam break [10], sewer monitoring [38], stakeholder interactions [31] and integrated urban drainage [11, 39]. The latter projects refer to IUD pilot studies completed in the course of this project.

Unfortunately, most recent demonstration projects have focused on the formation of stakeholder groups and the assessment of stakeholder needs and flood risk rather than the delivery of flood risk management measures. It is in this delivery area that best practice demonstration projects are most needed.

C.1.3.9 Reports and reviews

This final section covers most of reports and reviews recently published, particularly in terms of the 2007 flooding. Chief among these is the Pitt Review. Lessons learnt have been gathered and recommendations made. These are discussed under the project areas used throughout the review.

There is a need to better share data between stakeholders [59, 61, 74], with better sharing of models [59] and the need to predict and map the probability of flooding from all sources in extreme conditions [57, 58, 59, 61, 62, 70]. Flood forecasting is another area that requires attention [57].

Better risk assessment and management approaches are widely called for [37, 56, 57, 71], including what the Environment Agency strategic overview might consist of. The importance of and interaction with the spatial planning process is also identified [11, 82], including the role of SWMP [33, 72].

Water company strategic direction statements make reference to their plans to improve or upgrade their systems, particularly in terms of providing flood protection for homes by design and operational means [62, 63, 64, 65, 66, 67, 68, 69, 70, 83]. Interestingly, many [64, 65, 68, 70] refer to SUDS as potential means to mitigate increased flood risk. One aims to monitor its entire network remotely [70].

The management of flooding incidents is widely covered in the reviews including the need for emergency planning for pluvial flooding [60], the role of utilities in emergency response [73, 74] and improving the speed and quality of emergency response [83]. Increasing the resilience of buildings and infrastructure to flooding is also called for [11, 57, 73]. Stakeholder engagement is also raised in terms of the need for the public to understand the changing nature of flood risk due to climate change [59]. Funding needs are stressed from a variety of perspectives [11, 59, 82]. A number of reviews make cases for policy change [33, 56, 58, 60, 61, 62, 82].

D Appendix D – Individual summaries of projects and reports reviewed

D.1 Project 1: ACTIF (Europe): Achieving Technological Innovation in Flood Forecasting

D.1.1 Project description

The flooding that occurred in central Europe in August 2002 demonstrated the value of providing flood warnings to mitigate the social and economic impacts of flooding. The increasing vulnerability of communities to extreme meteorological events requires established mitigation measures to be re-evaluated and improved. ACTIF explores how floods can be mitigated via improvements in forecasting and how uncertainties in flood forecasting may be quantified in a meaningful way to the end users. The cluster of research projects in FP5 demonstrates the importance of flood-forecasting research. The purpose of ACTIF is to derive and disseminate additional benefits from these projects to help implement technological innovations achieved in research.

D.1.2 Aims/Objectives

The focus of ACTIF is to actively consolidate and disseminate Fifth Framework research advances in flood forecasting through the following mechanisms: convening of workshops; promotion of an international conference; preparation of guidelines of best European Practice in three aspects of flood forecasting technology; preparation of guidelines on access to high quality, site-specific data for further research and analysis.

D.1.3 Relevance to IUD

ACTIF contributes to the promotion of sustainable development through the reduction of economic losses from flooding and the improvement of public safety by non-structural methods.

D.1.4 Key deliverables

ACTIF formed a bridge between academic researchers, applied researchers, public authorities and industry in the area of hydro-meteorological risks to:

- advance knowledge and understanding between European research groups;
- build awareness of the outputs of EC and other research;
- develop an appreciation of its relevance to mitigation of public risks;
- make the research outputs accessible to the scientific and user communities;
- gather experiences of pilot sites to demonstrate application of the research.

The main outputs were best practice papers and conference papers downloadable from: http://www.actif-ec.net/conference2005/proceedings/index.html. The papers are mostly related to flood forecasting.

D.1.5 Contacts: Project Coordinator**:** actif@hrwallingford.co.uk

D.1.6 Link: http://www.actif-ec.net/

D.1.7 Year of completion: 2006

D.2 Project 2: Climate Change and the Hydraulic Design of Sewerage Systems

D.2.1 Project description

The UKWIR Climate Change Research Project was undertaken by HR Wallingford-led consortium which included the Met Office, MWH and Imperial College. The task involved the use of the Hadley Centre Regional Climate Model (RCM). The output from the RCM was used to produce climate change maps for return periods up to 100 years. This information provides the basis for developing industry tools to design sewers for the 21st century. The additional task was to evaluate the impact of climate change on the performance of sewerage systems and to estimate cost implications for the water industry. The work also involved looking at a whole range of issues directly or indirectly affected by changes in hydrology.

D.2.2 Aims/Objectives

The project addressed the following subject areas:

- Evaluate climate change impact on rainfall for whole of UK over next 80 years.
- Provide the water industry with the tools for drainage design for the 21st century.
- Evaluate performance implications of climate change on drainage systems and potential cost implications of continuing to provide current target service levels.
- Consider rainfall issues that relate to drainage design and operation.
- Evaluate possible changes in *standards* and alternative solutions to sewerage upgrading.

D.2.3 Relevance to IUD

The project provided the basis for developing industry tools to design sewers for the 21st century, and for the sustainable design of sewer systems in future.

D.2.4 Key finding

The impact of climate change on sewerage hydraulic design and the performance of sewerage systems to future (year 2080) rainfall and the changes that might be needed in the hydraulic design of sewerage systems to address any problems that climate change might pose.

D.2.5 Key deliverables

Reports on: international drainage practices; changes in river levels and flows around the UK; changes in sewage run-off and water quality; changes in the performance of sewage networks.

D.2.6 Contacts: UKWIR Office

D.2.7 Link: http://www.ukwir.org/content/default.asp?PageId=38194 or http://www.ukwir.org/site/web/content/reports/reports&SubFolders=90275&FolderId=90265&SubFolderId=90275

D.2.8 Year of completion: 2004

D.3 Project 3: CMAM: Condition Monitoring and Asset Management (CMAM) for complex infrastructure systems

D.3.1 Project description

The CMAM project addressed the science underlying the management and modelling of complex systems such as a coastal cell or reach of a river. It was motivated by the recognition that basic research on the representation of complex infrastructure systems for issues such as multi-attribute decision-making, process modelling, condition characterisation, reliability analysis and uncertainty handling was not easily used by flood and coastal defence practitioners, or even modellers. In particular, new thinking in systems management had failed to have a significant impact on industry practice in flood and coastal defence and the related river and coastal management activities. The research was steered by a group of seven industrial partners, including a major UK dam owner (Scottish and Southern Energy) and the Environment Agency as the lead authority for flood defence.

D.3.2 Aims/Objectives

To produce a more applicable method to flood and coastal management; and to explore the use of decision support techniques applied to CMAM to improve the safety and economic performance of complex infrastructure systems.

D.3.3 Relevance to IUD

The research developed a new method for modelling the performance of complex infrastructure systems. This not only addresses specific technical issues but considers how these collectively contribute to overall organisational and business performance. The method merges hierarchical modelling of processes, multi-attribute measurement of performance and uncertainty handling with interval probabilities.

D.3.4 Key finding

The new decision support tools integrate new methods of condition characterisation with asset management process for complex infrastructures including dams, flood defences and engineered and natural slopes.

D.3.5 Key deliverables

The principal outputs are a summary report, a PhD thesis and the PERIMETA software. There is also the intellectual knowledge that has been developed, synthesised and disseminated by the research team. This is probably the biggest contribution of the CMAM project, as the systems-based, hierarchical approach to the management of flood and coastal defences is now well embedded in Defra and Environment Agency strategy (e.g. the Agency's new Flood Risk Management Strategy) and into emerging practice (e.g. flood management plans). Some of the detailed knowledge about how best to represent a complex system and to deal with uncertainty and incomplete information on the state of the component assets will feed into the work on Performance-Based Asset Management System (PAMS). This is a major "step change" project that will draw together a range of new techniques to enable management decisions on has been identified through the O&M Concerted. The concepts that were developed in this research informed the ICE Presidential Commission on Flooding and are embedded into its report on *Learning to Live with Rivers*. They also feed into Defra's new *Flood & Coastal Defence Project Appraisal Guidance Note 6 on Performance Evaluation.*

D.3.6 Key publications

PhD Thesis on *Performance-based management of flood defence systems.* Submitted by Richard Dawson to the University of Bristol in May 2003.

D.3.7 Contacts

Professor Jim Hall (Jim.Hall@ncl.ac.uk), Dr Richard Dawson (Richard.Dawson@ncl.ac.uk)

D.3.8 Link: http://www.ceg.ncl.ac.uk/research/

D.3.9 Year of completion: 2003

D.4 Project 4: COMRISK (Interreg): COMmon strategies to reduce the RISK of storm floods in coastal lowlands (COMRISK)

D.4.1 Project description

COMRISK was a common project of North Sea Region coastal defence authorities. It aimed to improve risk management for coastal flood prone areas. The project ran from 2002 to 2005 and was co-financed by the Community Initiative Programme Interreg III B North Sea Region of the European Union.

D.4.2 Aims/Objectives

COMRISK aimed to improve coastal flood risk management through a transfer and evaluation of knowledge and methods as well as pilot studies. The project was divided into two main parts: the umbrella project and the subprojects. The umbrella project focused on an exchange of experience and on the coordination and integration of the subprojects. It had the following aims:

- to bring together coastal defence experts from administration, science and private companies from around the North Sea and beyond;
- to exchange experiences and studies of good practice on coastal risk management;
- to evaluate and further develop innovative integrated risk management strategies, considering national regulations and responsibilities;
- to initiate and support transnational cooperation on integrated coastal risk management (networking);
- to integrate coastal risk management into strategies for a sustainable management of the coastal zones in the North Sea Region.

D.4.3 Relevance to IUD

COMRISK brings together scientists and private companies to exchange experiences and study for good practice on risk management, and develop the integrated risk management strategies for sustainable management of coastal zones.

D.4.4 Key deliverables

The outcome of the project is an enhanced network between the partners. Each of them, being the highest coastal defence authority in its state/region, established a policy paper with recommendations to improve coastal risk management.

D.4.5 Contacts

Daniel Witzki (daniel.witzki@im.landsh.de), Dr Jacobus Hofstede (jacobus.hofstede@im.landsh.de)

D.4.6 Link: http://www.comrisk.org/

D.4.7 Year of completion: 2005

D.5 Project 5: FD2013: Flood Plain Management Manual (Stage 1)

D.5.1 Project description

Floodplains are areas of special concern because they are often highly developed but are at risk of suffering from a severe natural hazard (flooding). However, the management of floodplains and the associated flood risks is fragmented and not carried out as a single coordinated activity. There are intense and conflicting pressures on floodplains. These include conservation, restoration, amenity and development in addition to providing for the passage and storage of floods. Guidance, in a similar form

to that already prepared for Australian floodplains, is needed to inform all stakeholders of floodplain management issues and provide a basis for managing flood plains taking into account these conflicting pressures. The Stage 1 Report provides preliminary guidance to local authorities and others involved in floodplain management and includes proposals for Stage 2 of the project; it is primarily intended to set the scene for the Stage 2 research.

D.5.2 Aims/Objectives

The purpose of the project is to provide guidance on how to reduce flood risks on floodplains. This includes raising awareness of floodplain management issues, providing guidance on how to manage floodplains within the present legislative context for land use planning, and providing guidance on flood emergency planning.

D.5.3 Relevance to IUD

The project promotes the IUD approach which includes:

- Raising the awareness and involvement of the public and other stakeholders in flood risks and floodplain management.
- Guidance on how to take account of flood risks on floodplains within the statutory land use planning system.
- Guidance on the outputs required from shoreline management plans, catchment management plans and associated strategy plans for floodplain planning purposes.
- Guidance on how to prepare flood emergency plans within the overall emergency planning framework.

D.5.4 Key deliverables

The following outputs contained in the Stage 1 Report provide preliminary guidance to local authorities and others involved in floodplain management: a summary of best practice principles for the management of floodplains to reduce flood risks, based on present knowledge; guidance on information on flood risk that should be included in statutory land use plans; guidance of the outputs required from CFMPs, SMPs and strategy plans for planning of land use in the floodplain; guidance to local authorities on flood emergency planning; and Stakeholder sheets that provide specific information about flooding for particular stakeholders.

D.5.5 Key publications

The project produced an R&D Technical Report, a Final Project Report (CSG15), and an R&D Technical Summary.

D.5.6 Contacts

Matt Crossman (matthew.crossman@defra.gsi.gov.uk)

D.5.7 Link:http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=10468

D.5.8 Year of completion: 2002

D.6 Project 6: Flood Risks to People (Phases 1 and 2)

D.6.1 Project description

The project covers direct impacts of flooding, both during and up to one week after the event, including: death (usually drowning) as a direct and immediate consequence of deep and/or fast flowing floodwaters; physical injuries as a direct and immediate consequence of deep and/or fast flowing floodwaters; and deaths/physical injuries associated with the flood event (but occurring in the immediate aftermath). The project is divided into two phases. Phase 1 is concerned with evaluating existing knowledge, identifying main risk factors, and developing a preliminary methodology for assessing risks to people. Phase 1 also identifies research needed for further development and testing in Phase 2.

D.6.2 Aims/Objectives

The overall objective of the project is to develop a method for estimating the risk of death or serious harm to people from flooding.

D.6.3 Relevance to IUD

The project focused on development of a method to estimate the risk of death or injury to people caused by floods, and to minimise the risk to people. This is another essential part of total risks from floods that should be integrated into IUD management.

D.6.4 Key finding

The main factors that cause death/injury to people during or immediately after floods include flow velocity, flow depth, and the degree to which people are exposed to the flood (the exposure potential). The exposure potential is related to such factors as speed of onset of flooding, availability and quality of flood warning, size of floodplain, location on floodplain, type of accommodation, etc.

D.6.5 Contacts

Dr Suresh Surendran, Risk Analyst, Environmental Policy Risk and Forecasting, Environment Agency

D.6.6 Link: http://www.rpaltd.co.uk/reports-by-sector.shtml#FloodRiskAssessment

D.6.7 Year of completion: 2006

D.7 Project 7: Creating New Floodplain Landscapes (Floodscape) - Interreg

D.7.1 Project description

In the past, flood water has been controlled by building walls, embankments, gates and barriers. As the climate changes and becomes more unpredictable new solutions need to be found, since it is not always safe to build flood defences higher and assume they will never fail. This practice is also expensive and has major impact on the landscape, wildlife and people's enjoyment of river spaces. A new approach is needed to manage flooding. FloodScape is a four-year project to develop innovative solutions to Flood Risk Management (FRM). Led by the Environment Agency in the United Kingdom, with partners in Belgium, the Netherlands and Germany, it is part-funded by the EU Interreg IIIB North West Europe programme and the Office of the Deputy Prime Minister. It is demonstrating, through *seven pilot actions*, that flood risk management can accommodate present and future requirements relating to spatial planning, public acceptance and conservation of the natural environment. New floodplain landscapes can also be used for recreation, agriculture, homes and businesses. A central aspect of the FloodScape pilots has been the engagement of local communities and stakeholders in developing these new landscapes. Tools and methods have been developed and tested and a practical toolkit developed.

D.7.2 Aims/Objectives

- Develop common and transparent principles for flood risk management decision-making at the European level.
- Test communications methods for changing public perceptions about flooding.
- Help create new landscapes combining flood risk management with nature conservation, agriculture, recreation and cultural heritage.
- Help create new landscapes combining flood risk management with flood resilience, infrastructure and hard landscape features.

D.7.3 Relevance to IUD

Development of common and transparent principles for flood risk management decision-making.

D.7.4 Key finding

Integrating spatial planning with flood risk management planning is essential in order to facilitate understanding and awareness of the spatial implications of accommodating flood risk management solutions in the landscape. Communication and engagement with stakeholders and communities, as early as possible in the flood risk management process, results in decisions which are more likely to be sustainable because local people are prepared to take ownership and responsibility for them. Encouraging the active participation of stakeholders and communities in flood risk management will support and help to develop national policy moves towards making space for water

D.7.5 Contacts: Floodscape, Environment Agency (floodscape@environment-agency.gov.uk)

D.7.6 Link: n/a

D.7.7 Year of completion: 2006

D.8 Project 8: FLOWS: Floodplain Land use Optimising Workable Sustainability (Interreg)

D.8.1 Project description

FLOWS is a transnational project with participants from Germany, the Netherlands, Norway, Sweden and the United Kingdom. Government agencies from each country act as lead partner in the respective participant countries. FLOWS has a total budget of €9,847,575 and is being funded by the European Regional Development Fund (ERDF)/Norwegian ERDF through the Interreg IIIB North Sea Region programme and the partner countries. A project team, based at Cambridgeshire County Council, has been set up to support the FLOWS sub-projects. The team is responsible for ensuring that FLOWS runs according to its timetable and that the budget is spent according to plan. The team will also ensure that the results of the project are communicated to decision-makers and planners across Europe.

D.8.2 Aims/Objectives

The goal of FLOWS is to improve the sustainability of development in areas at risk of fluvial flooding. The partner organisations are making the most of their transnational partnership to ensure that the final strategy, planned for publication at the close of the project, is based upon a broad scope of experience and comparative analysis. It is planned to be an authoritative and reliable guide to spatial planners in their decisions on flood risk. As a consequence of its work, FLOWS expects flooding of new developments to be minimised and existing properties to be more resistant to flooding, so that it is harder for flood water to enter, and resilient, making it easier to clean up after a property has been flooded. For that purpose, the project partners will work together to set good examples of infrastructure improvements. This is to be achieved through demonstration show cases on how to safeguard and minimise the damage and disturbance on properties caused by floodwaters in low-lying urban conditions.

D.8.3 Relevance to IUD

The project seeks to improve the sustainability of development in flood risk areas by working with technical and social aspects of flood risk information and its integration into decision support systems for spatial planning. The project also considers transferable strategies for improved water management.

D.8.4 Key findings

A survey of how the different partner countries integrate technical flood-related information into decision-making processes. An inventory of the mapping and

modelling techniques and knowledge available to manage flood risk. A report on the public perception of flooding and flood risk, and a series of best practice guidance on retrofitting buildings against flood risk.

D.8.5 Contacts

Julia Barrett (Julia.barrett@cambridgeshire.gov.uk); Per Einar Faugli (pef@nve.no); Udo Reincke (Udo.Reincke@bsu.hamburg.de); Sture Hermansson (sture.hemansson@s.lst.se); Bert Kappe (Bert.Kappe@flevoland.nl)

D.8.6 Link: http://www.flows.nu/

D.8.7 Year of completion: 2006

D.9 Project 9: *Foresight Future Flooding*

D.9.1 Project description

Future Flooding is a government *Foresight* initiative. It looked far into the future at drivers that were problem- rather than technology-based. The project involved a wide spectrum of stakeholders and was run by Defra. The overall aim of the project was to produce a long-term (30 to 100 years) vision for flood and coastal defence in the whole of the UK that takes account of the many uncertainties, and can be used as a basis for policy. In common with other *Foresight* projects, the vision produced should be challenging and independent. The project's structure has three phases: drivers, scenarios and work plans; impacts; and responses.

D.9.2 Aims/Objectives

The aims of the project were to:

- identify and assess the relative importance of drivers which will affect future flood risk;
- construct a set of risk-based scenarios 30 to 100 years ahead;
- provide an overview of responses and when best to use those responses;
- inform policy and its delivery;
- consider implications for the future skills base;
- identify possibilities for knowledge transfer from other areas of science and technology;
- inform public understanding;
- promote dialogue between science researchers and professional partners.

D.9.3 Relevance to IUD

The project has given stakeholders a better understanding of the potential scale of future flood risks and has helped to inform strategic planning and investment in managing these risks. It also considered a wide range of responses to these risks, the choice of which will depend on how the future unfolds.

D.9.4 Key finding

The project highlighted the need for a coordinated response to tackling flood risk and integration of policy and implementation at a national, regional and local level. Workshops on Flood and Coastal Defence helped to further this integration, with involvement from Defra, Environment Agency, Office of the Deputy Prime Minister (ODPM), the LGA (Local Government Association) and the Department for Transport (DfT).

D.9.5 Key deliverables

Making Space for Water (MSFW) is a consultation exercise to develop a new strategy for flood and coastal erosion risk management for the next 20 years. It was launched by Defra in July 2004 and FCD was identified as a key driver for this new strategy. FCD informed the development of MSFW by demonstrating the value of a scenario-based approach for considering future flood risk and providing the information on the nature of these risks.

D.9.6 Key publications

The bedrock of the project was two volumes of peer-reviewed scientific summaries, the results of the work of over eighty science experts. They covered the future risks, drivers and means of managing those risks. A further volume covering Scotland was also published. The executive summary provided a broad view of the project's key messages and findings. All reports were published under the title *Future Flooding*. The report included maps demonstrating possible changes in flood risk according to various metrics by area of the country (England and Wales). These proved to be an excellent way of communicating the key messages from the project.

D.9.7 Contacts: Foresight Web Site Service Desk (ForesightWeb@dti.gsi.gov.uk)

D.9.8 Link: http://www.foresight.gov.uk/OurWork/CompletedProjects/Flood/index.asp

D.9.9 Year of completion: 2004

D.10 Project 10: IMPACT: Investigation of Extreme Flood Processes and Uncertainty

D.10.1 Project description

The IMPACT project addresses the assessment and reduction of risks from extreme flooding caused by natural events or the failure of dams and flood defence structures. To manage and minimise these risks, it is necessary to identify hazards and vulnerability, to have good knowledge of structure behaviour in emergency situations, and to understand the potential consequences of failure to allow contingency planning for public safety.

Research will be undertaken through a combination of fieldwork (controlled testing and analysis of six-metre high embankment failures), laboratory physical modelling and combined desk study and numerical simulation. A key aim of the IMPACT project is to

advance the understanding of uncertainty associated with the above processes. This knowledge will be combined through a single system (case study) to demonstrate the magnitude of uncertainty associated with the end data and implications for its application within industry (i.e. for asset management, emergency planning etc.).

D.10.2 Aims/Objectives

Research for this project has been structured to have the greatest impact on reducing uncertainty in predicting extreme flood conditions. Aims are to advance scientific knowledge and understanding, and develop predictive modelling tools in four key areas:

- Movement of sediment (and potentially with pollutants) generated by a failure.
- Mechanisms for the breaching of embankments (dams or flood control dykes) and factors determining breach location.
- The simulation of catastrophic inundation of valleys and urban areas.
- Use of geophysical techniques for the rapid integrity assessment of flood defence embankments.

D.10.3 Relevance to IUD

The IMPACT project has generated advances in the understanding and modelling of a range of extreme flood processes including breach formation, flood propagation, sediment movement, modelling uncertainty and embankment integrity assessment. This has placed EU researchers, and subsequently European flood modellers, at the forefront of capabilities in this field.

D.10.4 Key finding

The IMPACT project provides greater scientific knowledge and understanding of extreme and aggressive flood flows following the catastrophic failure of a water control structure. More specifically, the work provides scientific knowledge and understanding of breach formation through dams and flood defence structures, the movement of sediment under extreme flood conditions and the simulation of flooding in urban areas. It will improve understanding of the risks associated with the potential failure of dams and flood defence structures and also understanding of the uncertainty associated with the prediction of extreme flood conditions and processes. Application of this knowledge within industry should lead to a reduced risk of failure (and hence reduction in long-term costs) and greater public safety through emergency planning and community disaster preparedness.

D.10.5 Key deliverables

Results from the five technical work package areas have been structured according to the following deliverables: field and laboratory data; benchmark tests of current models; new approaches to breach formation modelling; new approaches to flood propagation modelling; new approaches to modelling sediment movement under extreme flood conditions; development of a geophysics-based approach for the rapid assessment of embankment integrity; assessing modelling uncertainty; and site-specific case studies.

D.10.6 Link: http://www.impact-project.net/

D.10.7 Year of completion: 2004

D.11 Project 11: MSFW: *Making Space For Water*

D.11.1 Project description

Making Space For Water is composed of four key themes: holistic approach, achieving sustainable development, increasing resilience to flooding, and funding.

In particular, Work Package 2 under the holistic approach theme focuses on urban flood risk and integrated drainage. Defra published an impact assessment on policy options for integrated urban drainage in June 2007 as part of early consultation on the scope of the Environment Agency Strategic Overview project. Ministers launched 15 integrated urban drainage pilot studies on 15 January 2007. The projects will test new approaches to reduce the impact of urban drainage flooding, so that towns and cities across the country are better prepared for the impacts of climate change.

D.11.2 Aims/Objectives

In summary, to allow space for water so that we can manage the adverse consequences for people and the economy from flooding and coastal erosion while achieving environmental and social benefits in line with wider government objectives.

D.11.3 Relevance to IUD

Making Space for Water has identified a strong need for a holistic, joined-up and integrated approach to deal with the problems of flooding. This is especially the case in urban areas where there is currently a complex interaction of drainage systems, and widespread difficulty in identifying ownership of the problem.

D.11.4 Key publications

A series of deliverables to date are summarised in:
http://www.defra.gov.uk/environ/fcd/policy/strategy/update2.pdf

D.11.5 Contacts: Defra

D.11.6 Link: http://www.defra.gov.uk/environment/flooding/policy/strategy/index.htm

D.11.7 Year of completion: 2007

D.12 Project 12: SMURF: Sustainable Management of Urban Rivers and Floodplains

D.12.1 Project description

SMURF was a three-year project that started in August 2002, supported financially by the EU LIFE-Environment Programme. The project was based on the River Tame in the West Midlands - specifically the urban area of the river catchment that includes Birmingham and a large part of the Black Country. The River Tame is a typical example of an urban river - polluted, heavily modified by culverting, straightening, re-routing and with concrete banks and few natural features. SMURF aims to tackle these environmental problems on the Tame by integrating the planning and management of land use, water quality, ecology and flooding. The methods developed by the SMURF project will be used as a model for work on similar rivers throughout the UK and the European Community.

D.12.2 Aims/Objectives

To demonstrate how the principles of urban river basin management planning can be applied to highly modified and degraded catchments by implementing sustainable land-use planning and water management techniques. The SMURF project aimed to:

- Improve the amenity, ecology and sustainability of the river catchment.
- Involve local communities in the planning of the river basin.
- Establish ecological objectives for the river system and a transferable sustainable indicators set.
- Develop a detailed land-use planning model to help with redevelopment in the floodplain and protect the community from future impacts of climate change.
- Demonstrate how small-scale changes can improve a heavily modified river.

D.12.3 Relevance to IUD

The Sustainable Management of Urban Rivers and Floodplains (SMURF) project has been investigating how implementing sustainable land-use planning and water management techniques could tackle the problems associated with urban rivers.

D.12.4 Key deliverables

The desktop SMURF system, the WebSMURF system.

D.12.5 Key publications

A report on Environmental Sustainability Indicators for Urban River Management (http://www.smurf-project.info/indicators_report.pdf)

D.12.6 Contacts

Environment Agency Midlands Region

D.12.7 Link: http://www.smurf-project.info/

D.12.8 Year of completion: 2006

D.13 Project 13: Strategic planning for flood risk in the growth areas

D.13.1 Project description

The Government's Sustainable Communities Plan sets out a strategy for 200,000 new homes in the South-East by 2016. Many of these homes will be built in flood risk locations. The Association of British Insurers (ABI) is committed to working with the Government, local authorities, and property developers to ensure that this development occurs sustainably.

D.13.2 Aims/Objectives

This guidance, produced by the ABI, sets out the key considerations that should be addressed to minimise flood risk for developments in the growth areas, so that insurance may remain readily available for new properties. Key considerations outlined in the guidance include: standard of defence over time; design of flood defences; location of new developments; flood resilient construction; and drainage considerations.

D.13.3 Relevance to IUD

These issues can be addressed by undertaking flood risk assessments for all new development, to understand flood risk at an early stage of development, and the options for managing the risk in a sustainable and cost-effective manner. By taking on board these considerations, planners and developers can ensure that flood risks for new developments in the growth areas are managed sustainably, so that financial protection may continue to be offered in the long term.

D.13.4 Key deliverables

Guidance which sets out considerations to be addressed to minimise flood risk for developments in growth areas, so that insurance remains available for new properties.

D.13.5 Contacts

Dr Sebastian Catovsky (sebastian.catovsky@abi.org.uk)

D.13.6 Link: n/a

D.13.7 Year of completion: 2004

D.14 Project 14: SUDS (CIRIA Initiative)

D.14.1 Project description

Sustainable drainage is a concept that includes long-term environmental and social factors in decisions about drainage. It takes account of the quantity and quality of run-off, and the amenity value of surface water in the urban environment. Many urban drainage systems can cause problems of flooding, pollution or damage to the environment and are not proving to be sustainable. Drainage systems can be developed in line with the ideals of sustainable development, by balancing the different issues that should be influencing the design. Surface water drainage methods that take account of quantity, quality and amenity issues are collectively referred to as Sustainable Drainage Systems (SUDS). These systems are more sustainable than conventional drainage methods because they:

- manage run-off flow rates, reducing the impact of urbanisation on flooding;
- protect or enhance water quality;
- are sympathetic to the environmental setting and needs of the local community;
- provide a habitat for wildlife in urban watercourses;
- encourage natural groundwater recharge (where appropriate);
- deal with run-off close to where the rain falls;
- manage potential pollution at its source;
- protect water resources from point and diffuse pollution.

They may also allow new development in areas where existing sewerage systems are close to full capacity, thereby enabling development within existing urban areas.

D.14.2 Aims/Objectives

To disseminate and promote good practice in the implementation of sustainable drainage in the built environment.

D.14.3 Relevance to IUD

SUDS promotes an IUD approach for sustainable development, where urban drainage is moving away from the conventional thinking of designing for flooding to balancing the impact of urban drainage on flood control, quality management and amenity.

D.14.4 Key deliverables

Website consists of techniques, reports, issues, cases, training, publications, etc to implement sustainable drainage concept.

D.14.5 Key publications

Interim Code of Practice for SUDS; Model agreements for sustainable drainage systems (C625); *Sustainable drainage systems. Hydraulic, structural and water quality advice* (C609); *Sustainable urban drainage systems - design manual for England and Wales* (C522).

D.14.6 Contacts: suds@ciria.org

D.14.7 Link: http://www.ciria.org.uk/suds/

D.15 Project 15: Thames Estuary 2100 (Initiative)

D.15.1 Project description

Thames Estuary 2100 (formerly *Planning for Flood Risk Management in the Thames Estuary*) is a joint initiative between the Anglian, Southern and Thames regions of the Environment Agency, which aims to determine the appropriate level of flood protection needed for London and the Thames Estuary for the next 100 years. The effects of climate change, such as sea level rise, increased rainfall and storm frequency, mean that London and the Thames Estuary will be at greater risk from flooding in future years. Furthermore, many flood risk areas are undergoing development and regeneration, meaning that more people, buildings and infrastructure are likely to be exposed to the risk of flooding in the future. Although London's existing tidal defences offer a high level of protection from today's flood risks, they were only designed to provide protection up until 2030. While slight modifications to these defences could extend their useful life by a few more years, the need for a long-term, strategic look at London's flood defences is becoming increasingly apparent. Thames Estuary 2100 is the first step of the process and will help shape the way in which future flood defence schemes are designed and managed. Taking action now will allow time for research, design and the physical construction of the defences.

D.15.2 Aims/Objectives

Thames Estuary 2100 aims to:

- look at tidal defences for the wider Thames Estuary setting;
- assess the useful life of existing defences and understand the 'drivers' (climate change, urban development, social pressures and the environment);
- inform and gain support of political and funding partners and stakeholders;
- prepare and manage a programme of studies (linked with consultation) that will lead to a strategy for flood risk management in the Thames Estuary for the next 100 years.

D.15.3 Relevance to IUD

The project focuses on the effects of climate change, such as sea level rise, increased rainfall and storm frequency, where London and the Thames Estuary will be at greater risk from flooding in future years and more people, buildings and infrastructure are likely to be exposed to the risk of flooding. Thames Estuary 2100 is the first step of the process and will help shape the way in which future flood defence schemes are designed and managed.

D.15.4 Contacts: TE2100@environment-agency.co.uk

D.15.5 Link: http://te2100.dialoguebydesign.net/dbyd.asp

D.16 Project 16: UKWIR Project 21st Century Sewerage Design

D.16.1 Project description

Currently, 96% of the UK's population is connected to public sewers. Sewerage systems are the largest and arguably the most valuable single group of assets owned by UK water companies. In the next 75 years, major socio-economic and climatic changes are likely to impact significantly on these systems. These impacts may adversely affect sewer system performance and the levels of service customers receive. This project contains a review of research studies that have examined the most significant of these diverse changes and impacts. It is structured to follow the driver-pressure-state-impact-response framework, which has been developed to aid long-term planning especially when examining infrastructure with a design and operational life on a similar timescale to major climatic and socio-economic changes.

D.16.2 Aims/Objectives

The aim of this project is to promote innovative thinking and ideas within the UK water industry about the future of UK sewerage systems by examining existing knowledge on sewerage system design and operation and to forecast the potential development of these systems in the UK over a 20- and 75-year timescale. The project is intended also to inform key stakeholders, particularly Government, Regional Development Agencies, Water UK, OFWAT and the Environment Agency and to engender debate between these stakeholders and those responsible for sewers in the UK.

D.16.3 Relevance to IUD

The project assessed the future state of UK sewer systems by driver-pressure-state-impact-response framework and recommended research and development activities to implement these responses for sustainable drainage.

D.16.4 Key finding

The potential changes that UK sewer systems may experience, at two timescales: one up to 2020 and the other up to 2080; a wide range of drivers and pressures, considers what are appropriate measures to describe the state/performance of UK sewer systems and their impact on the environment and society.

D.16.5 Key deliverables

Potential responses to address the future impacts on sewer systems or to exploit new opportunities and their effectiveness; the impact of drivers and pressures on the UK sewer network (climate change, urbanisation and socio-economic changes).

21st Century Sewerage Design: Summary Report (06/WM/07/6) available from http://www.ukwir.org/ukwirlibrary/91271

Tait, S, Ashley, RM, Cashman, A, Blanksby, J, Saul, AJ (2008) Sewer system operation into the 21st century, study of selected responses from a UK perspective. *Urban Water Journal*, 5(1),79-88.

D.16.6 Contacts: Pennine Water Group

D.16.7 Link: http://www.sheffield.ac.uk/penninewatergroup/

D.16.8 Year of completion: 2005

D.17 Project 17: Mapping the Underworld

D.17.1 Project description

A four-year EPSRC funded initiative, originally instigated by UK Water Industry Research (UKWIR) on behalf of the utilities, aims to solve the problems associated with the difficulty in finding buried infrastructure. Five integrated research projects have been funded to lay the foundation for the programme of work that will ultimately need direct stakeholder involvement in developing and proving the system. Areas covered: sensors, mapping technologies, knowledge integration, condition assessment, novel technologies for future utility provision.

D.17.2 Aims/Objectives: Solve problems with finding buried infrastructure.

D.17.3 Relevance to IUD: Addresses major issue of infrastructure used in IUD.

D.17.4 Key findings: Ongoing

D.17.5 Contacts: a.c.royal@bham.ac.uk

D.17.6 Link: http://www.mappingtheunderworld.ac.uk/

D.17.7 Year of completion: 2013

D.18 Project 18: NORIS: NO Rainwater In Sewers

D.18.1 Project description

Combined sewers carry wastewater (domestic sewage, wastewater from commercial and industrial establishments and groundwater infiltration) along with surface run-off. Overload of these systems can occur as a result of heavy rain, infiltration, snowmelt. As a result, combined sewers overflow and untreated sanitary sewerage enters receiving waters.

D.18.2 Aims/Objectives:

NORIS works on identifying measures to prevent pollution events caused by combined sewers.

D.18.3 Relevance to IUD

The function of sewers in the conveyance of rainfall run-off, which is the focus of this work, is essential to IUD.

D.18.4 Key findings

In five different pilot projects, work has been carried out to develop new technologies and methods to improve water quality and reduce risks and consequences of flooding. These facilities will last a long time after the project has ended and will be available for study visits and future follow-up. New methods and technologies are now developed, tested and available for use, not only in the North Sea Region but everywhere where such problems occur. NORIS has also improved our knowledge of how urban water management is organised in the different countries in the North Sea Region.

D.18.5 Key deliverables

The Inspiration Book: It sums up the outcomes and activities of the partners and work packages in the NORIS project (http://www.noris-interreg.eu/daten/documents/Inspiration%20Book.pdf)

D.18.6 Link: http://www.noris-interreg.eu

D.19 Project 19: AUDACIOUS

D.19.1 Project description

Climate change is more often than not seen as a threat. However, the need to manage extreme rainfall events in urban areas provides an opportunity to integrate the activities of highway authorities, land drainage authorities, planning authorities, water service providers and regulators to improve our urban environment. the management of climate change impacts can contribute to the integrative activities required to develop "Sustainable Communities" in an ever changing world and improving the environment

for their people. In order to generate optimum solutions involving contributions from key stakeholders, we need enhanced urban drainage models that can be adapted to meet the need of changing environmental factors such as groundwater levels, vegetation, changing design standards and rainfall. These models need to simulate interactions between surface and pipe flows and be used in conjunction with whole-life cost assessment of solutions within a risk-based approach.

D.19.2 Aims/Objectives

- To set out a clear picture for a range of stakeholders of the scope and interactions between the likely problems and their effect on the performance of drainage systems. To provide new procedures, computer models and (targeted) guidance (toolbox) to assess climate change impacts and develop mitigating responses for building and local drainage systems.
- To enable the integration of models and procedures with the behaviour of, and within the wider context of, drainage and urban systems.
- To establish the baseline procedures for evaluation and mitigation of the effects of climate change on existing urban drainage and to disseminate these widely.

D.19.3 Relevance to IUD

Provision of modelling tools for the design of IUD schemes. Identification of stakeholders and interactions.

D.19.4 Key findings

The key finding of the project is that capacity building, both in the infrastructure and other systems to better manage local flood risk and also in the way in which this is delivered through key stakeholder communities, is the single most important response to flood risk management.

D.19.5 Key deliverables

A series of guidance, models and case studies (http://www.eng.brad.ac.uk/audacious/deliverables.html).

D.19.6 Link: http://www.eng.brad.ac.uk/audacious/

D.19.7 Year of completion: 2005

D.20 Project 20: FLOODsite

D.20.1 Project description:

FLOODsite is an integrated project in the Global Change and Ecosystems priority of the Sixth Framework Programme of the European Commission. It started in 2004 and runs to 2009. The FLOODsite consortium includes 37 of Europe's leading institutes and universities and the project involves managers, researchers and practitioners from

a range of government, commercial and research organisations, specialising in aspects of flood risk management. FLOODsite covers the physical, environmental, ecological and socio-economic aspects of floods from rivers, estuaries and the sea. It considers flood risk as a combination of hazard sources, pathways and the consequences of flooding on the receptors – people, property and the environment.

D.20.2 Aims/Objectives

FLOODsite will deliver:

- An integrated European method for flood risk analysis and management for rivers, estuaries and the coast.
- A consistent approach to flood risk management process and practice.
- Techniques and knowledge to support integrated flood risk management:
  - Sustainable pre-flood measures (spatial planning, flood mitigation infrastructure and measures to reduce vulnerability).
  - Flood event management (early warning, evacuation and emergency response).
  - Post-event activities (review and regeneration).
  - Frameworks for decision support for long-term and flood event risk management.

D.20.3 Relevance to IUD

FLOODsite develops tools, methods and frameworks that are central to IUD, and considers the system and the stakeholders before, during and after the flood event.

D.20.4 Key deliverables

More than 400 publications to date; most available from the website. Modelling tools and a flood risk management knowledge map (available at: http://www2.ioer.de/floods/html/floodsite_mit.php). A conference: http://www.floodrisk2008.net/

D.20.5 Contacts: Professor Paul Samuels (HRW)

D.20.6 Link: http://www.floodsite.net

D.20.7 Year of completion: 2009

D.21 Project 21: COST C22

D.21.1 Project description

This action is based on a multi- and interdisciplinary approach and brings together scientists involved in water management, hydrology, urban planning and design, civil engineering, social sciences, construction engineering and ecology. The action mostly includes applied and pragmatic research methods.

The programme had three phases:

- Phase 1: *inventory* of the state of the art of urban flood management.
- Phase 2: *analysis and integration* of common approaches and distillation of best practices and identification of gaps in knowledge.
- Phase 3: *dissemination and consolidation* of the research findings.

D.21.2 Aims/Objectives

- Greater knowledge required for prevention and mitigation of flood impacts on urban areas by exchanging experiences, developing integrated approaches, promoting best practices in urban flood management (UFM).
- Gather and share information on the subject across Europe with respect to theory, methods, and practical experiences.
- Process and present the information in a form that others can learn from.
- Initiate R&D projects for the EU's seventh framework programme.
- Stimulate national R&D initiatives, increase awareness of the importance of UFM in general.
- Disseminate results using seminars, proceedings, papers and a website.

D.21.3 Relevance to IUD

A research consolidation activity at the EU level on IUD.

D.21.4 Key deliverables.

Publication of *Advances in Urban Flood Management* in 2007. This book addresses a broad spectrum of issues in the emerging field of urban flood management.

D.21.5 Contacts: c.zevenbergen@duravermeerdiensten.nl

D.21.6 Link: http://www.cost22.org/

D.21.7 Year of completion: 2009

D.22 Project 22: CRUE: Coordination of research financed in the European Union on Flood risk management (ERA-NET)

D.22.1 Project description

The CRUE network was set up to consolidate European flood research programmes, promote best practice and identify gaps and opportunities for collaboration.

The network's 13 partners come from most European countries that have been badly affected by flooding. By supporting best practice and the spread of knowledge, they expect to improve flood management in their own countries and the rest of Europe.

D.22.2 Aims/Objectives

The CRUE ERA-NET will introduce structure within this area of European research through an inter-comparison of the process of research programme formulation, implementation and management. This will lead to the consolidation and promotion of best practice and identification of gaps and opportunities for international collaboration. CRUE will also address the need to improve dissemination of research results to derive public benefit from past investment in the generation of knowledge and understanding.

Relevance to IUD

Consolidation of European flood research programmes, promotion of best practice and identification of gaps and opportunities for collaboration on future programme content.

D.22.3 Key deliverables (expected)

- Improved standards of FRM, linking policy and research and contributing to international activities and policy development.
- Contribution to national and regional policies.
- Better exploitation and dissemination of FRM research.
- Positive economic impact – better decisions and savings.
- Improvements to national and regional research programmes.

D.22.4 Contacts: sebastian.catovsky@defra.gsi.gov.uk

D.22.5 Link: http://www.crue-eranet.net/

D.23 Project 23: RIMAX: Risk Management of Extreme Flood Events

D.23.1 Project description:

The national research programme *Risk management of extreme flood events*, funded by the German Federal Ministry of Education and Research (BMBF), was initiated as a consequence of the floods in August 2002 when intensive and lasting rainfall hit Germany, Austria, the Czech Republic and Slovakia in the catchments of the river Elbe and the river Danube. The aim of the research programme is to develop better instruments of flood risk management by integrating different disciplines and stakeholders. It focuses on flood events with a return period greater than 100 years and with high damage potential. The programme consists of three major subjects: integrated concepts of flood risk management; technical flood defence; cross-sectional tasks.

D.23.2 Aims/Objectives

The aim of the research programme RIMAX is to integrate different disciplines and participants to develop better instruments of flood risk management. RIMAX concentrates on extreme flood events which occur once in a hundred years or less often with a highly destructive potential. The programme is funded by the German Federal Ministry of Education and Research.

D.23.3 Relevance to IUD

Research into multi-institutional/multi-stakeholder approaches to flood risk management.

D.23.4 Key deliverables (expected)

Improved instruments of flood risk management by the integration of different disciplines and participants. Interim results in: http://www.rimax-hochwasser.de/download.html?&L=1

D.23.5 Contacts

http://www.gfz-potsdam.de/pb5/pb54/staff/merz/index.html

D.23.6 Link: http://www.rimax-hochwasser.de

D.23.7 Year of completion: 2008

D.24 Project 24: BKCC - Adaptation Strategies for Climate Change in the Urban Environment

D.24.1 Project description

The ASCCUE project aimed to better understand the impacts of climate change on towns and cities through three 'exposure units' of human comfort, urban green space and the built environment. The work was carried out in two contrasting case study locations, a representative conurbation (Greater Manchester) and an extreme case (Lewes, Sussex). ASCCUE was part of the £3.2 million EPSRC Building Knowledge for a Changing Climate (BKCC), a consortium now continued through network and workshop activities under Sustaining Knowledge for a Changing Climate (SKCC).

D.24.2 Aims/Objectives

1. Make a city-wide assessment of climate-related risks to, and constraints on, development in two contrasting urban areas.
2. Investigate climate change impacts on building integrity, human comfort and urban greenspace at the neighbourhood level.
3. Explore the scope for climate change adaptation through strategic planning and urban design.
4. Examine the interaction between adaptive strategies and measures to reduce greenhouse gas emissions.
5. Involve local and national stakeholders in impact assessment, solution testing and dissemination of findings.

D.24.3 Relevance to IUD

Assessment of flood risk due to increasing urbanisation and climate change.

D.24.4 Key deliverables

A risk assessment method was developed using a set of urban morphology units as its spatial framework. Other findings from the work have been written up in a special edition of the *Journal of Built Environment* (Lindley *et al.* 2007) and *Municipal Engineer* (Gwilliam *et al.* 2006 and McEvoy *et al.* 2006).

D.24.5 Link:

http://www.sed.manchester.ac.uk/research/cure/research/asccue/

D.24.6 Year of completion: 2005

D.25 Project 25: CD4WC

D.25.1 Project description

The project CD4WC deals with optimising the efficiency of the urban wastewater system with regard to ecological consequences in natural water bodies and with regard to investment and operation costs. The variety of possible systems approaches, operation strategies and management options will increase thanks to the implementation of the European Water Framework Directive. The project will give guidance and support for this optimisation. The acronym CD4WC implies how the knowledge gained in the project will be disseminated: a CD will be produced that is publicly available.

D.25.2 Aims/Objectives

In CD4WC, the benefits of development of the urban wastewater system resulting from the Water Framework Directive (WFD) will be identified and quantified in terms of ecological and economic consequences. Criteria to assess ecological consequences are - besides water quality - secondary resource inputs such as energy, materials and chemicals. Various options and strategies to develop the wastewater system will be evaluated. Main emphasis is on dynamic interactions between the sewer system, wastewater plants and receiving water as well as on the possibilities of measures in the receiving water and at sources. The methods applied are analysis of river basin managers' data to gain insight in experience, performance of measurement campaigns to close information gaps, numerical modelling to assess system changes and extensions, and economic balancing to evaluate alternative pollution control instruments, such as permits, fees and pollution trading.

D.25.3 Relevance to IUD

WP5 is dealing with the use and infiltration of storm water into the waste water system.

D.25.4 Key deliverables

The project outcomes are disseminated with the help of a dedicated wiki site (ISIWiki). The deliverables are available in a CD.

D.25.5 Link

http://www.tu-dresden.de/CD4WC/src/index.php?id=1&session_id=none

D.25.6 Year of completion: 2006

D.26 Project 26: Flood risk assessment guidance for new development

D.26.1 Project description

This project has developed a science and risk-based framework for a nationally consistent approach to assessing and managing flood risk for new development across England and Wales. This has been achieved by integrating and simplifying guidance (including CIRIA's *Development and flood risk – guidance for the construction industry* (C624)) and the latest findings from a range of research projects.

D.26.2 Aims/Objectives

Define an appropriate assessment of flood risk for use at all scales of development planning (from national-scale planning policy decisions to individual planning applications) and for all types of development. A consistent approach for flood risk management of new development is also included.

D.26.3 Relevance to IUD

Provides a framework, guidance and tools to assess and manage flood risk to assist with the regulation and planning of new developments in England and Wales.

D.26.4 Key deliverables

All deliverables included in a web site: http://www.hydres.co.uk/index.html

D.26.5 Contacts

Helen Udale-Clarke, Contract Project Manager, HR Wallingford, +44 (0)1491 822 325
Suresh Surendran, Client Project Manager, Environment Agency, +44 (0)1925 653 999

D.26.6 Link

http://www.ciria.org/SERVICE/search_bookshop/core/orders/product.aspx?catid=3&prodid=113

D.26.7 Year of completion: 2005

D.27 Project 27: Joint probability - dependence mapping and best practice

D.27.1 Project description

The project focuses on: a best practice guide for non-specialist users of joint probability methods, to encourage them to adopt and use the methods without the need for specialist advice; a detailed report containing more information and descriptions for experienced users; a third report containing more detailed results from a river flow, surge and daily precipitation analysis, including some time-lagged and spatially separated dependence analyses, with interpretation relevant to hydrologists. Work builds on dependence mapping and development of test practice guidelines.

D.27.2 Aims/Objectives

Continue the process of dissemination and take-up of joint probability research which assesses environmental variables including waves, tides, surges, rainfall and wind. Enable engineers and other direct users to better use joint probability methods, leading to more effectively designed defences.

D.27.3 Relevance to IUD

The results of this project are relevant to most flood risk and defence design calculations. They would be used primarily by practitioners such as flood defence designers, but would also be of interest to policy-makers, regulators and researchers.

D.27.4 Key deliverables

TR2, best practice guide; TR1, the detailed report; TR3 more detailed results from the river flow analysis.

D.27.5 Link

http://randd.defra.gov.uk/Document.aspx?Document=FD2308_3427_TSM.pdf

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D.28 Project 28: MISTRA: Sustainable urban water management

D.28.1 Project description

The water supply and sewage treatment systems of Swedish towns and cities provide drinking water in sufficient amounts, dispose of sewage in a hygienically acceptable manner, and take care of storm water to prevent flooding. They fulfil these three basic requirements without damaging the environment, but they do not satisfy the requirement for being ecologically sustainable. Future water supply and sewage treatment systems must be able to recirculate plant nutrients and function to a greater extent with the help of the active participation of the users (the general public). The systems are to be easy to understand, so that users can take greater responsibility to prevent the input of harmful substances, and they are to function well, be robust and adapted to local conditions.

D.28.2 Aims/Objectives

Provide answers to the following questions:

1. How should water supply and sewage treatment systems in urban areas be designed and run in the "sustainable Sweden" of the future?
2. Do the present systems contain such basic shortfalls that we must change over to other systems?
3. Under what circumstances must the systems be changed?
4. What criteria should be used?
5. In those cases where existing systems are kept - how should they be developed to become sustainable?
6. When existing systems must be replaced by new ones - how should the latter be designed and run in order to be sustainable?

D.28.3 Relevance to IUD

MISTRA objectives focus on wastewater but the issues investigated apply also to drainage systems.

D.28.4 Key deliverables

Scientific deliverables (articles, books, models). User deliverables (scientific data for use in international environmental negotiations, accessible synthesis of current knowledge about how natural resources can be managed, prototype or a test programmes for assessing toxicity).

D.28.5 Contacts

Marie Uhrwing, marie.uhrwing@mistra.org.

D.28.6 Link

http://www.stockholmresilience.org/mistra/english/researchresults/researchprogrammes/completedprogrammes/sustainableurbanwatermanagement.4.1eeb37210182cfc0d680007302.html

D.28.7 Year of completion: 2006

D.29 Project 29: SAM - System-based Analysis and Management of urban flood risks

D.29.1 Project description

The DTi SAM project (System-based Analysis and Management of urban flood risks) is developing a new generation of models and procedures for assessing and predicting the performance of urban drainage assets. This is being achieved by extending RASP-based methods into the urban drainage environment. It has the potential to provide step change in the way that urban drainage is managed both above and below-ground. The project will also investigate the issues involved in applying spatially varied rainfall and provide guidance in its application.

D.29.2 Aims/Objectives

The aim of the project is to develop a risk-based procedure and tools to support integrated urban drainage design and management, for use by drainage practitioners, including tools and guidance on the application of spatially varied rainfall.

D.29.3 Relevance to IUD

The tools and the methodologies of this project are directly related to IUD.

D.29.4 Key deliverables

The project will make significant advances in the following areas:

- generation and application of spatially varying time-series rainfall and a comparison with standard techniques;
- development of a risk-based procedure for the analysis of urban flooding;
- development of tools and a software design statement to support the application of IUD management;
- experience of applying a systems-based approach to urban flooding and investigation of the issues involved in IUD management and future research and development needs.

D.29.5 Contacts

Richard Kellagher HR Wallingford (r.kellagher@hrwallingford.co.uk).

D.29.6 Links: www.dti-sam.co.uk

D.29.7 Year of completion: 2009

D.30 Project 30: Sustainable flood and coastal management (SFCM)

D.30.1 Project description

Sustainable flood and coastal management is a research project that aims to develop practical guidance and tools for policy-makers and practitioners to improve the sustainability of flood and coastal management strategies and schemes.

D.30.2 Aims/Objectives

Within the context of flood and coastal management, discuss issues of:

- climate change;
- the impacts and role of planning guidance;
- opportunities to meet environmental targets;
- stakeholder partner engagement;
- adaptation of defences;
- materials and recycling;
- development of alternatives to flood defence.

D.30.3 Relevance to IUD

Cross-cutting approach to flooding (technical and institutional).

D.30.4 Key deliverables

The following documents can be downloaded as the latest project outputs:

- FD 2015 SFCM Consultation
- FD 2015 SFCM Scoping Report Volume 1
- FD 2015 SFCM Scoping Report Volume 2

D.30.5 Contacts

Steven Wade or Jonathan Simm at HR Wallingford, Howbery Park, Wallingford, OX10 0BA. Tel: +44 (0)1491 835381.

D.30.6 Link: http://www.sfcm.org.uk

D.31 Project 31: URSULA - Urban River Corridors and Sustainable Living Agendas

D.31.1 Project description

URSULA is an interdisciplinary collaboration between seven departments in Sheffield, Bradford and Durham Universities, and a wide range of external partners. The hypothesis is that there are significant social, economic and environmental gains to be made from integrated and innovative interventions in urban river corridors. URSULA tests this by providing a portfolio of interventions, tools and supporting evidence for the redevelopment of urban river corridors to create 'places where people want to live and work, now and in the future' The project draws on case studies in Sheffield, the UK and beyond, and test outcomes with local stakeholders in Sheffield on the corridor of the Don and its tributaries.

D.31.2 Aims/Objectives

Aims are to: (1) understand current and potential future values of the benefits of urban development, to gather the evidence; (2) propose how we can move from current to future values by innovation in urban design; (3) identify how stakeholder interactions (associated with market, governance or research processes) impact on river redevelopment.

D.31.3 Relevance to IUD

IUD is a part of sustainable and integrated urban design.

D.31.4 Contacts: http://www.ursula.ac.uk/team/

D.31.5 Link: http://www.ursula.ac.uk/

D.31.6 Year of completion: 2008

D.32 Project 32: Sustainable water management in land-use planning

D.32.1 Project description

The project (and subsequent CIRIA report) provides guidance on how water-related issues could be considered within the land-use planning process. It details the wide range of stakeholders, policies, processes and guidance that exist to foster sustainable water management.

D.32.2 Aims/Objectives

The report covers:

- key stakeholders in water management and land-use planning;
- the land-use/spatial planning process;
- interactions between the planning process and other key stakeholders;
- barriers to integration of sustainable water management in new development;
- guidance and decision support;
- recommendations.

D.32.3 Relevance to IUD

The report addresses issues of integration (in its various facets) of the built environment and the water environment. This includes sustainable flood risk management. Recommendations are made to further integrate sustainable water management within the land-use/spatial planning process.

D.32.4 Key deliverable

CIRIA Report on *Sustainable water management in land-use planning* (C630).

D.32.5 Contacts

Paul Shaffer, paul.shaffer@ciria.org.

D.32.6 Link: www.ciria.org

D.32.7 Year of completion: 2005

D.33 Project 33: Improving surface water drainage

D.33.1 Project description

This is a (Defra) consultation document to accompany proposals set out in the Government's water strategy: *Future Water*. Flooding in the summer of 2007 showed that significant damage can be caused by surface water flooding. The interim report from the Pitt review urged early action to improve the way surface water is managed, particularly in high-risk areas. Three policy proposals are provided for consultation. Two impact assessments review the costs and benefits of each policy option.

D.33.2 Aims/Objectives

The aim of the consultation is to improve the way that surface water drainage is managed. The three proposals are:

- Establishing SWMP as a way of improving the coordination of activities between stakeholders
- Clarifying responsibilities for adoption and management of SUDS.
- Reviewing the automatic right to connect (Section106 of Water Industry Act).

D.33.3 Relevance to IUD

The consultation is at the heart of the debate over how organisational and technical barriers can be overcome to improve IUD and reduce the impact of flooding.

D.33.4 Key deliverable

The deadline for responses was 30 April 2008.

D.33.5 Contacts: surfacewaterdrainage@defra.gsi.gov.uk

D.33.6 Link: www.defra.gov.uk

D.34 Project 34: Water Cycle Studies

D.34.1 Project description

Water cycle studies are a new approach to support the provision of drinking water, disposal of storm and wastewater and impacts on downstream rivers. They adopt an integrated approach to water infrastructure planning which helps stakeholders meet the challenges of urban growth, climate change and tightening water quality standards through the Water Framework Directive.

D.34.2 Aims/Objectives

The aim of a water cycle study is to overcome two key constraints to development:

- Environmental capacity: water abstraction, wastewater discharge.
- Infrastructure: flood defences, water supply, sewerage.

D.34.3 Relevance to IUD

Water cycle studies are relevant in two ways. Firstly, they are an attempt to foster an integrated approach between multiple stakeholders , albeit in the narrower context of new developments. Secondly, they incorporate issues concerning urban drainage and flood risk management.

D.34.4 Key deliverable

Environment Agency report on *Water Cycle Planning. Guidance on carrying out water cycle studies.*

D.34.5 Contacts

Gerard Stewart, Water Services Infrastructure group, gerard.stewart@environment-agency.gov.uk

D.34.6 Link

http://www.environment-agency.gov.uk/research/planning/33368.aspx

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D.35 Project 35: WaND: Water Cycle Management for New Developments

D.35.1 Project description

The WaND project is a multi-institution EPSRC-collaborator funded research project within EPSRC's Sustainable Urban Environment Programme. Work packages focus on technical aspects of the water cycle (water supply, wastewater collection, storm drainage and SUDS) In addition, there are work packages dealing with social, planning and health issues. The project concentrates on the management of the water cycle at the local level in new developments. This includes work on demand management, recycling, sustainable drainage, wastewater collection and flood modelling. A number of case study sites are included.

D.35.2 Aims/Objectives

The project aimed to support integrated, sustainable water management for new developments by providing tools and guidelines for project design, implementation and management.

D.35.3 Relevance to IUD

WaND is relevant in the sense that it acknowledges the 'joined-up' nature of the water cycle and explores technical solutions and multi-partner decision-making. More specifically, an above-ground urban flood modelling approach is demonstrated in use

for new development planning. Also, WP2, 6 and 10 deal with drainage issues, and in particular the performance, modelling and optimal siting of SUDS.

D.35.4 Key deliverables

- An overview of drainage systems, particularly SUDS, and selection criteria (WP2).
- A prototype toolbox for the integrated design of sustainable urban water management systems in new developments and the quantification of the uncertainty and risk of this design. The toolbox supports drainage option selection for new developments through a multi-criteria framework, and drainage siting at a development level through GIS suitability map generation (WP6).
- Tools for evaluating and designing stormwater drainage components (SEATS-SWDS, InfoWorks modules) (WP2).
- Guidance on the inclusion of water quality parameters in commercial models. Modifications to MUSIC software for UK hydrological conditions (WP10).

D.35.5 Key publications

The project has produced many publications. Most of these are delivered through an intelligent portal. This is currently available on CD-ROM.

D.35.6 Contacts

Professor David Butler, d.butler@exeter.ac.uk

D.35.7 Link: www.wand.uk.net

D.35.8 Year of completion: 2008

D.36 Project 36: WaND Good Practice Guide

D.36.1 Project description

The multi-disciplinary, multi-institution WaND project has produced many outputs in a wide range of areas associated with sustainable urban water management. This project attempts to capture these outputs into a form useful to practitioners.

D.36.2 Aims/Objectives

To provide guidance on water cycle management for new developments based on the key messages, methods and technologies produced by the WaND research project.

D.36.3 Relevance to IUD

The WaND Good Practice Guide is relevant because it acknowledges the 'joined-up' nature of the water cycle and explores technical solutions and multi-partner decision-making. The guide places good practice within the drivers for change and the current legislative framework.

D.36.4 Key deliverable

CIRIA WaND Good Practice Guide

D.36.5 Contacts

Professor David Butler, d.butler@exeter.ac.uk; Paul Shaffer, paul.shaffer@ciria.org

D.36.6 Link: www.ciria.org

D.36.7 Year of completion: 2008

D.37 Project 37: Future Water – The Government's Water Strategy for England

D.37.1 Project description

Future Water sets out the Government's vision for the water sector in the next 20 or so years. It includes some of the steps needed to achieve the vision. The vision is for the sustainable delivery of secure water supplies and an improved water environment.

D.37.2 Aims/Objectives

Government's vision for water is that by 2030 at the latest:

- Environmental water quality and ecology is improved and high drinking water quality is maintained.
- Risks from flooding and coastal erosion are sustainably managed, with greater understanding and better managed surface water.
- Water resources are sustainably used and fair, affordable and cost-reflective charges are in place.
- Greenhouse gas emissions are cut.
- Adaptation to climate change is continuously embedded in the water industry and water users.

D.37.3 Relevance to IUD

IUD will need to be set within Government's vision. The vision includes surface water management in general, and addresses the issue of integrated planning for new development and better management of surface drainage.

D.37.4 Key deliverable:

Future Water – The Government's Water Strategy for England, Defra, Cm 7319.

D.37.5 Link:

http://www.defra.gov.uk/environment/quality/water/strategy/pdf/future-water.pdf

D.37.6 Year of completion: 2008

D.38 Project 38: Urban Water Cycle (Interreg iiib):

D.38.1 Project description:

The Urban Water Cycle (UWC) project ran from 2004 to 2007 under the Community Initiative Programme Interreg III B North Sea Region of the European Union. The project showed how the performance of the urban water cycle can be optimised with respect to the built environment. For that purpose five themes were identified, two of which, flows and purification, deal with the efficiency of water cycles, while the rest of the themes (water system, water management and society) focus on how efficiency can be increased by achieving a balance between the UWC and the environment. During the project each partner carried out studies and pilot projects where new purification and source control technologies as well as innovative uses for existing technologies were tested.

D.38.2 Aims/Objectives

The project aimed to optimise the overall performance of the urban water cycle in the built environment in which it is embedded. Specific attention was paid to the organisational, legal and financial aspects of urban water cycle management in the North Sea region.

D.38.3 Relevance to IUD

The countries around the North Sea face similar problems, so an integrated approach is needed. UWC identifies five themes and several case studies looking at local solutions to stormwater management.

D.38.4 Key deliverables

The work of the project partners focused on optimisation of the urban water cycle in the different pilot regions. For example, after identifying the pilot test site, the city of Bradford identified different treatment processes and a flood impact assessment was carried out. In 2006, Yorkshire Water decided to establish a long-term strategic monitoring study of the sewer system within the pilot study.

D.38.5 Contacts:

Ted de Jong (t.j.dejong@wrd.nl)

D.38.6 Link: www.urbanwatercycle.org

D.38.7 Year of completion: 2007

D.39 Project 39: Integrated Urban Drainage Scoping Study

D.39.1 Project description:

The development and implementation of integrated urban drainage management (IUDM) was strongly supported by respondents to the consultation exercise for *Making Space for Water* (Defra 2004). It was believed that enabling partnerships and adopting a joined-up approach to planning of improvements would bring integrated catchment benefits for urban areas (reducing flood risk, improving water quality and water resources management). To assess the practical benefits of this 'joined-up' approach a number of pilot projects were established in which important lessons would be learned on how best to deliver integrated solutions, what barriers there might be, and how these might best be managed. The scoping project aimed to inform these pilots.

D.39.2 Aims/Objectives

The aim of the project was to review research and industry practice related to IUDM. Specific objectives were to:

- Identify research and development project outputs related to IUD.
- Review tools to assess flooding including mathematical models related to IUD.
- Review constraints and barriers to IUD planning.
- Review current and possible future best practice of IUD, as well as current and emerging good practice.
- Investigate, review and summarise current best practice in partnerships providing IUDM.
- Prepare a questionnaire to help select pilot sites with integrated flooding problems.

D.39.3 Relevance to IUD

This is a key document setting out the context for integrated urban drainage and has been used by the 15 integrated urban drainage pilots.

D.39.4 Key findings

- The main elements that stimulate collaborative working were identified. These were analysed and set alongside the current legislative/regulatory framework to develop a simple step-by-step approach for IUD strategies and solutions.
- Legislation that governs urban drainage has resulted in an overcomplex system with diverse responsible bodies. With cooperation, however, it is possible for these bodies to work together on urban drainage management.
- The new planning process in England, that requires consistency between regional spatial strategies, local development frameworks and local surface water management plans, provides a sensible umbrella under which integrated urban drainage planning can take place.
- Data management and the sharing of data presents a particular challenge, and the necessary data management, decision-making and flood modelling tools are not yet fully available in a user friendly form.
- Government needs to consider the necessary legislative and regulatory change to foster such an integrated approach.

D.39.5 Key deliverable

Defra Integrated Urban Drainage Scoping Study Report, 2006.

D.39.6 Contacts

Dr Chris Digman (Christopher.J.Digman@mwpm.mwhglobal.com)

D.39.7 Link

http://www.defra.gov.uk/environment/flooding/documents/manage/surfacewater/scoperev.pdf

D.39.8 Year of completion: 2006

D.40 Project 40: Surface and groundwater flood risk

D.40.1 Project description

The Government's *Making Space for Water* strategy includes three projects closely linked to the Environment Agency's mapping strategy. In addition, a recommendation in the interim Pitt review is that "*the Environment Agency, supported by local authorities and water companies, should urgently identify areas at highest risk from surface water flooding where known, inform Local Resilience Forums and take steps to identify remaining high risk areas over the coming months*". The Environment Agency committed, as a result of these reports, to provide information on surface water flooding and to make the initial results available to Local Resilience Forums (LRFs) in August 2008.

The information should enable LRFs to better plan for flooding emergencies and provide information to support future flood risk management in England and Wales.

D.40.2 Aims/Objectives

To produce a set of data highlighting areas naturally vulnerable to surface water flooding by 1 August 2008 and collect data relating to historic surface and historic groundwater flooding by 2010.

D.40.3 Relevance to IUD

A key issue in IUD is addressing vulnerability to surface water flooding.

D.40.4 Key deliverables

- Assessment of the best method of data production for the short and long term.
- Data specification.
- Contract documents.
- Legal agreements associated with use of Environment Agency data and data from other sources.

- Specification of data required to produce historic information.
- Process and training for gathering historic data and working with external organisations.
- Method/system for storing the historic data.
- Process and training for validating, revising and updating the datasets.
- Rules and guidance for using the products and their release.
- Communications plan,
- Risk register.

D.40.5 Contacts: Environment Agency

D.40.6 Year of completion: 2010

D.41 Project 41: RASP compatible approach to mapping flooding from all sources

D.41.1 Project description:

The RASP (Risk Assessment for Strategic Planning) approach has been widely used for assessing flood probability. However, the basic approach in RASP is limited to flooding from main rivers and the sea and is also limited to certain (simple) flooding systems. New approaches are now needed to model flood risk and it usage, considering different systems and components of the systems and connections between these. This includes the need to assess the joint probability of flood risk within urban and/or rural areas at any scale and assess the combined effects of flooding from all sources (fluvial, pluvial, groundwater, sewers and the sea).

D.41.2 Aims/Objectives

The aim is to support a more integrated approach to flood risk management by providing tools that enable us to model, predict and map the probabilities of flooding from multiple sources via urban and rural pathways, using information on depth and velocity.

D.41.3 Relevance to IUD

The project responds to the challenge of *Making Space for Water* which seeks a more integrated approach to managing all sources of flooding and managing a wider range of flooding systems. The Pitt review recommends the requirement for mapping surface water and producing surface water management plans considering all sources of flooding.

D.41.4 Key deliverables

- Review of available data, knowledge and methods relating to joint probability assessment, probabilistic modelling and mapping of flooding from sources other than rivers and the sea.
- Concepts and algorithms for calculating the joint probability of flooding from a range of sources, including flood extent, depth and velocity for different spatial and temporal scales.

- Conceptual models and mock-up demonstrations to show how data could be used, analysed and presented in the form of maps.
- Schedule of data requirements and quality standards needed to assess the probability of flooding from other sources.
- Report on the uncertainties inherent in the approach.
- Improved JOINTSEA (version x) software to handle joint probability of all source of flooding.
- Tool for operational staff to incorporate all sources of flooding in our national (NaFRA), catchment (MDSF2) and local (SFRM) strategic flood risk mapping.
- Report on system architecture and other details about the software tools, lesson learnt from piloting the tool, actions taken and recommendations.
- Process and best practice guidance on usage of tool and implementation plan.

D.41.5 Contacts:

Suresh Surendran, Environment Agency (suresh.surendran@environment-agency.gov.uk)

D.42 Project 42: 2D modelling review

D.42.1 Aims/Objectives

- Carry out a comprehensive desk-based review of commercially available two-dimensional models.
- Provide the Environment Agency with procurement recommendations with detailed selection criteria.
- Provide an outline method for a full benchmarking study of 2D models or some similar rigorous process as an alternative to traditional benchmarking.
- Develop guidance for Environment Agency staff on the different 2D modelling software packages and on building and evaluating 2D models.

D.42.2 Relevance to IUD

Two-dimensional modelling is a key technical component of IUD.

D.42.3 Contacts: Environment Agency

D.42.4 Year of completion: 2009

D.43 Project 43: APUSS (Assessing infiltration and exfiltration on the Performance of Urban Sewer Systems)

D.43.1 Project description

Infiltration of groundwater into sewer pipes can be particularly detrimental to treatment plant efficiency (hydraulic overloading due to the infiltrated volume of water can reach up to 100 per cent of the wastewater volume in some cities, dilution of pollutant concentrations leads to a lower pollutant removal efficiency), while exfiltration of wastewater can lead to groundwater contamination (especially where groundwater is a water resource for drinking water production). The APUSS project has been part of the Fifth R&D Framework Programme European cluster CityNet (http://citynet.unife.it/) including six individual projects dealing with integrated urban water systems.

D.43.2 Aims/Objectives

- Elaborate a set of new measurement methods to directly estimate exfiltration and infiltration rates in sewers by means of tracers.
- Develop and test volumetric measurement methods for house connections, with a matrix approach to extrapolate house measurements to wider catchments.
- Test and validate the above new measurement methods in various contexts with associated end-users.
- Develop and validate modelling approaches at various timescales.

D.43.3 Relevance to IUD

Information about infiltration and exfiltration from sewer systems is relatively poor and investments are frequently based on weak information, limited datasets with rather high uncertainties. This project improved the techniques for modelling of mechanisms through which water is exchanged between groundwater and sewer systems.

D.43.4 Key deliverables

Complete list of deliverables is available on http://www.insa-lyon.fr/Laboratoires/URGC-HU/apuss/deliverables.html:

- Unified software tool, including experimental data storage, automatic model calibration, graphical display of results, and links with performance indicators.
- Fully documented large scale example of application of the methods and software.
- Set of performance indicators accounting for infiltration and exfiltration.
- A multi-criteria approach to compare and rank investment strategies to solve I/E problems and to analyse the economic value of sewer systems and to evaluate the cost of applying the new methods.

D.43.5 Contacts

Jean-Luc Bertrand-Krajewski, jean-luc.bertrand-krajewski@insa-lyon.fr

D.43.6 Link

http://www.insa-lyon.fr/Laboratoires/URGC-HU/apuss

D.43.7 Year of completion: 2006

D.44 Project 44: FD2118 Broad Scale Modelling Scoping

D.44.1 Project description

This project presents the vision for broad scale modelling within a DPSIR (Drivers-Pressures-States-Impacts-Responses) framework, a summary of technical developments and future vision for component areas, and an outline programme of integrating research.

D.44.2 Aims/Objectives

To address:

- The extent to which an integrated modelling system of the physical environment is feasible and desirable, given individual requirements of fluvial, estuarial and coastal flood management.
- How current developments such as continuous rainfall and run-off simulation and risk-based flood impact modelling may be assembled into a coherent set of tools, useable by the FRM community.
- How such a set of catchment tools would interface with similar sets of tools currently being developed for the estuarial and coastal areas.
- The extent to which broader issues of environmental management such as socio-economic aspects can be integrated with the physical systems model(s).

D.44.3 Relevance to IUD

Urban Flooding Section of this document outlines the need for integrated modelling of flooding.

D.44.4 Key deliverables

Key aspects of the DPSIR-BSM framework are:

- Quantitative scenario modelling of drivers and pressures that impact on flood risk.
- Whole-catchment and shoreline modelling of flood and erosion risks under uncertain future climatic and socioeconomic conditions, and under a wide range of response options.
- Integrated assessment of portfolios of responses based on economic, social and environmental criteria, including measures of vulnerability, resilience, adaptability and reversibility.
- Integration of technical and socioeconomic modelling through agent-based modelling approaches.
- Quantification of sources of uncertainty and their propagation through the modelling/decision-making process.
- Supporting a multi-level participatory approach to decision-making.

Summaries of visions of the five- and ten-year future developments are provided for:

- Socio-economic aspects.
- Computing, data systems, data assimilation and uncertainty,
- Modelling for catchments, estuaries and coasts.
- Urban flooding and infrastructure.

D.44.5 Contacts:

Professor Howard Wheater, h.wheater@imperial.ac.uk

D.44.6 Link: n/a

D.44.7 Year of completion: 2007

D.45 Project 45: CARE-S (Computer Aided Rehabilitation of Sewer Networks)

D.45.1 Project description:

This project deals with public sewer and storm water networks of any dimension. It includes problems caused by ageing, structural failures, inflow/infiltration, exfiltration (leaking) and insufficient capacity which can cause floods, pollution of receiving waters, pollution of groundwater and soil, treatment plant impacts and maintenance costs.

D.45.2 Aims/Objectives

The project aim is to establish a rational framework for sewer network rehabilitation decision-making. CARE-S aims to analyse the structural and functional reliability of wastewater networks at minimum cost and disturbance, that is, how to rehabilitate the right sewer at the right time by using the right rehabilitation technique at a minimum total cost, and before serious failures occur (pro-active approach). The specific aims of the project are to improve the analytical tools to assess the technical or functional state of sewers or the needs for rehabilitation, link them and to make them usable for the formulation of a rehabilitation strategy.

D.45.3 Relevance to IUD

The project provided a set of indicators directed to gauge the weight of socio-economic costs of wastewater system malfunction. This implies the development of analysis and methodologies, directed to an exhaustive identification of the variety of social and economic social costs, according to different local situations.

D.45.4 Key deliverables

All project reports are available on http://care-s.unife.it/index.html. The final product of the project will be a decision support system for sewer network rehabilitation, including:

- A control panel of performance indicators (PI) for rehabilitation decisions.
- Analytical and statistical tools to assess and forecast some of the PIs.
- A procedure to define the socio-economic and environmental risks of malfunctioning sewer systems.

- A procedure for choosing the right rehabilitation technology.
- A procedure for defining the best planning strategy for rehabilitation investments.
- A software package called Sewer Rehab Manager that will enable consultants and wastewater service providers to use the above products according to their needs.

D.45.5 Contacts

Dr Sveinung Sægrov sveinung.sagrov@sintef.no

D.45.6 Link

http://www.eugris.info/displayProject.asp?ProjectID=4502&Aw=CARE-S&Cat=Project

D.45.7 Year of completion: 2005

D.46 Project 46: Community Resilience to Extreme Weather (CREW)

D.46.1 Project description

The project has six inter-linked work programme packages: PP1 Coping Technologies (People and Buildings), PP2 Community Coping (Resilience Capacity and Coping Strategies), PP3 Impacts - Socio-Economic Simulators (EWESEM), PP4 Hazards - Extreme Weather Event Simulators (SWERVE), PP5 Dissemination - Web-Display and Interface for Programme Outputs (WISP), PP6 Management - Project Coordination and Management.

D.46.2 Aims/Objectives

The project aims to gain a better understanding of the effects of extreme weather events and to develop tools to improve the resilience of local communities. A set of computer models will be developed to determine current and future extreme weather event probabilities. These events will include flooding, heat waves, water drought, wind, lightning and subsidence. These models will be based on the development of ‘weather generator' models for providing time series of potential temperature, evaporation and precipitation. A mapping framework will be developed to identify the probability of local extreme weather events and risk ‘hotspots' as well as the probability of combined weather events occurring in any one place. By combining existing and emerging technologies to provide local-scale estimates of extreme weather event probabilities, the work should improve our ability to assess risk and explore the current and future impacts of climate change. The Extreme Weather Events Socio-Economic Model will be the first attempt to develop a community-level impact model that integrates the health, employment, housing, crime, emergency services sectors with long-term predictions of climate change and extreme weather event scenarios, and will do so in a way that captures both the immediate and lagged effects.

D.46.3 Relevance to IUD

This project does not focus on urban drainage but on a range of extreme weather events, of which only some are related to urban drainage. Relevance to IUD is in integration of community response to flooding (and other extreme weather events).

D.46.4 Key deliverables

- A working prototype GIS-based web portal for mapping all extreme weather events.
- An integrated socio-economic and health impact modelling tool, within the GIS framework, for facilitating and evaluating 'what if' scenarios.
- An end-user-based design specification for a GIS web-mapping portal for mapping extreme weather events and impacts.

D.46.5 Contacts: Dr Gavin Wood, g.a.wood@cranfield.ac.uk

D.46.6 Link: http://www.extreme-weather-impacts.net

D.46.7 Year of completion: 2011

D.47 Project 47: Land Use Planning Quality and Influence of SFRAs in the Planning Process. FD2610.

D.47.1 Project description

Provide an evidence base of the quality and effectiveness of strategic flood risk assessments (SFRAs) and their influence and use in the planning process, specifically; and help inform how preparation of the SFRA interfaces with other flood risk management planning and operation activities.

D.47.2 Aims/Objectives

The project considers:

- the quality and consistency of approach of SFRAs prepared to date;
- how SFRAs are used during the sustainability appraisal process;
- the influence of SFRAs on policies and land allocations and the interaction with other plans;
- application of the sequential test;
- application of climate change allowances;
- how surface water flood risk issues are taken into account;

D.47.3 Relevance to IUD

Will influence PPS25 and help inform how preparation of the SFRA interfaces with other flood risk management planning and operation activities.

D.47.4 Key deliverables

Part 1 – Collation of information related to completed SFRAs including:

- Specification and budget.
- Sources and pathways for flooding shown and modelled in each SFRA.
- Which parties provide data, and the agreements set in place.
- How they link to other plans.
- How they are being used by local planning authorities.

Part 2

- Look in more detail at a small range of SFRAs and examine their development, coverage, influence on land allocations, flood risk and surface water management policies, and outputs.

Part 3

- The third part of the project will draw together information from Parts 1 and 2 and consider the implications for, and recommendations for changes to, the PPS25 and the Practice Guide.

D.47.5 Link: n/a

D.48 Project 48: Flood Risk Management Research Consortium (FRMRC)

D.48.1 Project description

FRMRC is an interdisciplinary research consortium investigating the prediction, prevention and mitigation of flooding. It involves over thirty organisations - academic institutions and research centres. Work is divided into the following Research Priority Areas (RPAs): land use management; real-time flood forecasting; infrastructure management; whole-systems modelling; urban flood management; stakeholder and policy geomorphology; sediments and habitats; and risk and uncertainty. Following the conclusion of FRMRC in 2008, Phase Two has recently started, with the aim to build on the results of FRMRC1 and further increase the understanding of flooding processes and improve flood risk management.

D.48.2 Aims/Objectives

In broad terms, the aim of the FRMRC is to undertake an integrated programme of research to support flood risk management practice worldwide; short-term delivery of tools and techniques to improve flood risk management in the UK; and development and training of the next generation of flood risk management professionals through their involvement in and exposure to the consortium's research.

D.48.3 Relevance to IUD

FRMRC is addressing key issues in IUD and as such is highly relevant.

D.48.4 Key deliverables

The project has delivered a number of UFMOs (user-focused measurable outcomes):

- Measures and serviceability indicators linked to a drainage system asset performance and deterioration model.
- Implementation plan for library of tools for uncertainty evaluation.
- Exploitation of new data types to create digital surface models for flood inundation modelling.
- Integrated surface and sub-surface interactive flooding and inundation model.
- Updating algorithms in flood forecasting.
- Flood Risk Management Policy Issues - Volume 1 – Rural.
- Flood Risk Management Policy Issues - Volume 2 – Urban.
- Accounting for sediment in rivers - A tool box of sediment transport and transfer analysis methods and models to support hydromorphologically-sustainable flood risk management in the UK.
- Improved approaches to condition assessment - Volume 1: Performance-based visual inspection of flood defence assets.
- Improved approaches to condition assessment - Volume 2: Detailed technical report.
- The influence of desiccation fine fissuring on the stability of flood embankments.
- A user guide to the risk and uncertainty decision tree Wiki site.

These are all available on http://www.floodrisk.org.uk/content/view/13/31/. A long list of deliverables is envisaged in FRMRC2.

D.48.5 Contacts

Professor Ian Cluckie, I.D.Cluckie@bristol.ac.uk

D.48.6 Link

FRMRC web site is http://www.floodrisk.org.uk/.

D.48.7 Year of completion: 2008

D.49 Project 49: Living roofs and walls-technical report supporting London's planning policy

D.49.1 Project description

Living roofs is a broad term defined by the GLA (Greater London Authority) and Design for London to include green roofs, roof terraces and roof gardens. Green roofs can form part of a sustainable drainage (SUDS) solution by reducing the amounts of storm water run-off and attenuating peak flow rates. Consequently, this proven source control technique reduces the downstream need for expensive underground drainage infrastructure and also cuts the risk of localised flooding events.

D.49.2 Aims/Objectives

- Helping London to adapt to climate change.
- Improving building energy balance and reducing CO_2 emissions.
- Reducing urban heat island effect.
- Enhancing amenities.
- Improving storm water attenuation.

D.49.3 Relevance to IUD

In the summer, a green roof can typically retain 70-80 per cent of rainfall run-off.

D.49.4 Key deliverables

The 60-page report, which elaborated benefits of living roofs and walls, presented case studies, analyzed barriers to implementation and looked at supportive policy and standards. Also policy approaches in other cities, whole-life costing and wider partner involvement issues were presented. The report can be downloaded from the link below.

D.49.5 Contacts: jamie.dean@designforlondon.gov.uk

D.49.6 Link: http://www.london.gov.uk/mayor/strategies/sds/docs/living-roofs.pdf

D.49.7 Year of completion: 2008

D.50 Project 50: Incorporation of state-of-the-art optimisation techniques into HR Wallingford's risk modelling framework

D.50.1 Project description:

This project is a KTP (Knowledge Transfer Partnership) between HR Wallingford and the Centre for Water Systems at the University of Exeter. The project incorporates state-of-the-art optimisation techniques developed at Exeter University into HR Wallingford's risk modelling framework with a view to producing improved better decision support tools (DST) for flood management.

D.50.2 Aims/Objectives

- Creation of framework for new DST
- Incorporation of real options to DST
- Incorporation of evolutionary algorithms to DST
- Incorporation of multi-objective optimisation
- Incorporation of optimisation under uncertainty
- Embedding of knowledge

D.50.3 Relevance to IUD

Flooding is a key issue in IUD. Complex methods implemented in this project will enable a higher level of IUD modelling.

D.50.4 Key deliverables

Improved decision support tool for flood management, with the potential for applications in other areas.

D.50.5 Contacts:

Dr Soon-Thiam Khu S.T.Khu@exeter.ac.uk

D.50.6 Year of completion: 2011

D.51 Project 51: PPS25 - Practice Guide

D.51.1 Project description

Planning Policy Statements (PPS) set out the Government's national policies on different aspects of land use planning in England**.** *Development and Flood Risk: A Practice Guide Companion to PPS25* is a consultation paper that sought views and comments on the 'Living Draft' of the Draft Practice Guide Companion to PPS25.

D.51.2 Aims/Objectives

PPS25 aims to specify:

- the key planning and decision-making principles;
- risk-based approach through flood risks assessments, incorporating so-called sequential approach, the sequential test and the exception test;
- responsibilities of all parties.

D.51.3 Relevance to IUD

PPS25 emphasises the importance of IUD management and puts it in context of land use planning.

D.51.4 Key deliverables

Policy documents.

D.51.5 Link:

http://www.communities.gov.uk/archived/publications/planningandbuilding/developmentflood

D.51.6 Year of completion: 2006

D.52 Project 52: Preliminary rainfall run-off management for developments

D.52.1 Project description

Defra/Environment Agency *Preliminary rainfall run-off management for developments* is a guide aimed at regulators, developers and local authorities to advise on the management of stormwater drainage for developments and in particular to assist in sizing of storage elements for the control and treatment of stormwater run-off.

D.52.2 Aims/Objectives

The objectives of this document are to:

- Provide an easy-to-use method for assessing initial storage volumes for stormwater control and provide simple guidance on the stormwater design process.
- State the Environment Agency's policy on stormwater treatment and discharge.
- Provide supporting information on the assumptions used and briefly cover other important technical issues.

D.52.3 Relevance to IUD

Though this guide does not cover all IUD issues in a comprehensive manner, it does promote various IUD concepts, such as SUDS.

D.52.4 Key deliverables

The interim Environment Agency procedure, along with a number of useful graphs, images and look-up tables from different sources that are needed for the design of urban drainage systems.

D.52.5 Link: http://www.specify-it.com/CIS/Doc.aspx?AuthCode=&DocNum=283194

D.52.6 Year of completion: 2007

D.53 Project 53: Temporary and Demountable Flood Protection

D.53.1 Project description

This document reviews a number of demountable flood protection systems.

D.53.2 Aims/Objectives

Categorise and review temporary and demountable flood protection systems; and develop a systematic method for choosing defences for different scenarios and using them in a safe manner.

D.53.3 Key deliverables

For a number of products available on the market, the following is provided: product name and manufacturer details, diagram and general description, available sizes/dimensions, structural, operational and financial aspects.

D.53.4 Contacts

Fola Ogunyoye, f.ogunyoye@royalhaskoning.com

D.53.5 Link n/a

D.54 Project 54: Participatory Flood Risk Communication Support System (Pafrics)

D.54.1 Project description

Pafrics is research project in Japan, developed to help flood risk governance based on an integrated framework. It boosts users' understanding of a new approach to flood risk management and flood control strategies by learning about flood risk or having a simulated experience of a combination of measures to reduce flood risks. The system is designed mainly for small-member workshops administered by facilitators, but can also be used for self-study. The system is designed for use with mobile personal computers. Some of the system functions are already publicly available and the system is accessible via the Web.

D.54.2 Aims/Objectives

Pafrics, a flood risk communication support tool, basically aims to popularize a new concept of flood risk management based on theory of risk analysis. The basic premise is that a concept of integrated flood risk management through the combination of physical and procedural disaster control measures taken by administrative authorities, regional communities, and residents would be widely applicable.

D.54.3 Relevance to IUD

The project adopts an integrated approach to urban drainage and flooding and provides an example of a communication and learning forum for a wide range of stakeholders. The web approach is innovative and potentially transferable.

D.54.4 Key deliverables

The Pafrics website (in Japanese). The site includes: 1) flood risk reduction measures and the role of local residents; (2) concept of integrated participatory flood risk management; (3) local flood risks and hazard maps; (4) flood risk awareness and flood control measures taken by residents; (5) characteristics of flood risks and damage; (6) probable precipitation and flood risk. The content is developed in the form of scenarios that can be also presented in workshops.

D.54.5 Contacts: sato.sun@bosai.go.jp

D.54.6 Link: http://www.bosai.go.jp/sougou/shakai/shakaigijutu/pafrics.htm

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D.55 Project 55: FloodResilienCity

D.55.1 Project description

This is an Interreg IVB proposal that intends to change the mindset of the politicians, professionals and public in Brussels, Leuven, Mainz, Paris, Orléans, Dublin, Nijmegen and Bradford to embrace the concepts of sustainable flood risk management and facilitate new urban development plans.

D.55.2 Aims/Objectives

The aim of the project is to integrate the increasing demand for more houses and other buildings with the increasing need for flood risk management measures in North West European cities along rivers. Objectives are to:

- Enhance awareness and engagement in flood risk management at the policy level, among professionals and the public.
- Limit flood damage and ease recovery by planning and adapting buildings, infrastructure, surfaces and economic activities and building capacity in individuals and institutions to become more resilient.
- Reduce flood risk by implementing physical, technical, non-structural and procedural measures for the management of water systems.
- Provide support to recovery processes and engage and build capacity in communities during and after flood events.
- Develop the capacity to engage in the processes above to adapt to and manage flood risk by integrating the activities above.

D.55.3 Relevance to IUD

The agenda of this project is to engage cities in the issues associated with flood risk management, particularly with respect to new urban development, and cover many of the practical issues of IUD, albeit at the transnational level.

D.55.4 Key deliverables

The main output of is intense cooperation between the 11 partners on concrete actions in eight cities in North West Europe. The actions should bring tangible results and prepare the ground for each partner city to implement the FloodResilienCity strategy in their plans and policies.

D.55.5 Contacts: r.Ashley@sheffield.ac.uk

D.55.6 Year of completion: 2012

D.56 Project 56: Ofwat – Water and sewerage services during the summer 2007 floods

D.56.1 Project description

Ofwat investigation into water companies' performance.

D.56.2 Aims/Objectives

- The impact on service to the water and sewerage consumers.
- How companies and their assets performed in managing these events.
- Possible implications for the future planning and regulatory policy.

D.56.3 Relevance to IUD

Ofwat stated a need to look again at the arrangement for draining rainwater from urban areas and responsibilities for that drainage as they affect the sewerage system.

Ofwat will work with Defra, Environment Agency and water industry in developing policies to improve arrangements for urban drainage.

D.56.4 Key deliverables: RECOMMENDATIONS

- Ofwat will challenge companies to demonstrate understanding of flood risks to services.
- Ofwat will work with the industry and other relevant stakeholders to develop a framework for assessing flooding risk and identifying cost-beneficial measures to improve resilience of critical assets.
- Ofwat will use the climate change scenarios to be published by UKCIP08 to identify key priorities for adaptation by the water industry in England and Wales and guide judgements made with the PR09 process.
- Ofwat recommends that Defra amend the legal right to connect to public sewers with a view to promoting integrated drainage solutions.

D.56.5 Link:http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/AttachmentsByTitle/flood07_review131207.pdf/$FILE/flood07_review131207.pdf

D.56.6 Year of completion: 2007

D.57 Project 57: Review of the Summer 2007 Floods (Environment Agency)

D.57.1 Project description

Environment Agency's review of the flooding in 2007, lessons learnt and recommendations

D.57.2 Summary/key issues

Acting on lessons from previous reviews

In June 2007, a consultation on inland strategic overview was issued at the same time.

The groundwater flooding project (programme board) considered how we might map the level of risk from all forms of flooding. A linked project looking at the feasibility of extending the Environment Agency's flood warning service for rivers and the sea to cover surface water, groundwater and sewer flooding produced an options report in April 2007.

Recommendations

R1: Review Environment Agency's flood forecasting development programme to make sure it reflects lessons from the summer floods and explore scope to improve accuracy, reliability and timeliness.

R2: Review ways of using rainfall forecasts in flood forecasting system to provide more timely warnings in fast-responding catchments.

R10: Environment Agency and its professional partners should review the way advice and information on all aspects of flooding to the public is coordinated.

R11: The government should consider the Environment Agency's proposals to develop surface water risk mapping and flood warning tools for professional partners with a view to later wide scale application.

R12: The government should act in line with its *Making Space For Water* programme, responses to its consultation on inland and urban flood risk management and the lessons learnt from the summer floods to give the Environment Agency a strategic overview role for inland flood risks.

R13: The government should review whether flood risk protection standards for inland, coastal and surface water flooding are still appropriate in view of climate change.

R14: The government should consider whether investment in flood risk management for all sources of flooding is adequate.

R19: The government should make sure that utilities and public services take responsibility for protecting their assets and facilities. We propose that all public authorities and private sector utilities that provide essential public services should have a duty under the forthcoming Climate Change Bill, in line with those for Category 1 and 2 responders under the Civil Contingencies Act, to take account of future climate change impacts when providing their services.

R23: Multi-agency emergency response plans should be reviewed to make sure that they are consistent with the Civil Contingencies Act, and that all professional partners have access to adequate resources for managing flood events.

D.57.3 Link: http://publications.environment-agency.gov.uk/pdf/GEHO1107BNMI-e-e.pdf?lang=_e

D.57.4 Year of completion: 2007

D.58 Project 58: Scrutiny Inquiry into the Summer Emergency 2007 (Gloucestershire County Council)

D.58.1 Project description

Inquiry to understand what, how, and when the floods happened, identify lessons learnt and improvements to reduce such an event's impact in the future.

D.58.2 Relevance to IUD:

Inquiry identified:

- Lack of a body to coordinate/assume overall responsibility for the maintenance of watercourses.
- Adequacy of highways drainage and associated maintenance regimes,
- Lack of knowledge of the overall capacity of the county's drainage system.
- Impact of new developments on existing drainage systems,

D.58.3 Key deliverables

Recommendation: The inquiry believes there should be a single agency with overall responsibility for the maintenance of watercourses, as the current system is not effective, and therefore recommends legislative change to create a single agency with overall responsibility for the maintenance of watercourses. The new system must include clear signposting for members of the public on how to report problems and who is responsible for addressing those problems.

Recommendation: Defra should investigate developing a flooding model capable of predicting the probability of significant surface water flooding in extreme conditions.

Recommendation: The county council and the district councils should ensure that the issue of flash flooding is addressed within their Strategic Flood Risk Appraisal.

Recommendation: The overview and Scrutiny Management Committee should establish a task group to look into the impact on flood risk of land use planning and new developments, including developments in the floodplain and consequent adoption techniques.

D.58.4 Link:

http://www.gloucestershire.gov.uk/utilities/action/act_download.cfm?mediaid=21100

D.58.5 Year of completion: 2007

D.59 Project 59: Environment Agency response to Interim Pitt Review

D.59.1 Project description

Letter to Sir Michael Pitt.

D.59.2 Relevance to IUD

Key points made the Environment Agency's letter:

- An urgent review and consolidation of flood risk management legislation will be needed if your recommendations are to be turned into action. Consideration by Government of a new Water Bill is, in our view, vital to rationalise outdated legislation and give full effect to your recommendations.
- The Environment Agency believes urgent action is required to:
  - Clarify the inland flooding strategic overview proposed by Government.
  - Review and update legislation urgently so that a strategic, integrated approach to flood risk management and 'opt-out' flood warning can be taken forward rapidly.
- Lack of resources and responsibility to deal with *Urgent Recommendation 2 – identifying areas of high risk of surface water flooding along with local authorities and water companies.*
- More emphasis required on:
  - The vital importance of sharing data and modelling between interested parties like ourselves, water companies, local authorities and highways authorities when tackling flood risk, particularly surface water flooding. The current aim of a holistic approach to flood risk assessment and management is being frustrated by our inability to obtain such data. We suggest that legislation may be needed if the current voluntary approach cannot be made to work far more effectively.
  - The need for the public and all other relevant parties to understand the changing nature of flood risk give the impact of climate change…….and continue to prepare the nation for the consequences of climate change and the decisions and costs that need to be addressed in climate change adaptation as move towards an uncertain future.

D.59.3 Year of completion: 2008

D.60 Project 60: The June 2007 floods in Hull

D.60.1 Project Title:

The June 2007 floods in Hull, Final Report by the Independent Review Body, 21st November 2007

D.60.2 Project description

Review of the flooding, investigation into how it happened, lessons learnt and how the response could be improved in the future.

D.60.3 Relevance to IUD

Summary of recommendations:

- Mandatory standards for flood protection in drainage systems must be set.
- Detailed information about the performance and operation of water utilities drainage systems should be in the public domain. Their operation and regulation must be transparent.
- Emergency planning for pluvial flooding should be undertaken by all regional and local authorities.

More detailed information on the recommendations:

- We were surprised by the lack of power the water regulator Ofwat has to control the design and performance of water utilities' drainage systems for flood conditions. We feel that mandatory standards for flood protection in drainage systems must be set. These must account for the possible impacts of climate change and be flexible enough to incorporate local vulnerabilities. We also feel that a Government level re-evaluation of the regulatory powers of Ofwat is required to enforce drainage standards and ensure adequate flood protection.
- Integral to this is a more transparent, less industry-based method of assessment of utility operation. Importantly, detailed information on the performance and operation of water utilities' drainage systems should be in the public domain. The utilities are private companies with commercial interests but they are also regulated monopolies that have a responsibility to serve the public and ensure adequate flood protection. It is vital that this role is transparent and transparently regulated.
- As pluvial flooding is not identified as a separate risk under the new Civil Contingencies Act 2004, we recommend that emergency planning for this eventuality should be undertaken as a matter of urgency by all regional and local authorities.
- We have found significant issues with the pumping and drainage infrastructure in Hull and recommend that urgent action is taken to provide permanent solutions. This includes upgrading Bransholme pumping station with the addition of extra capacity for added resilience and the redevelopment of West and East Hull pumping stations. Proactive pumping in preparedness for high rainfall events may improve the effectiveness of the current system's capacity. We also hope that added capacity is incorporated to account for possible climate change and development, rather than developing to the minimum standard. We recommend that Yorkshire Water, Hull City Council and the Environment Agency continue to work together (as they have begun to).
- We also recommend that a programme of further research is undertaken to address some of the scientific and academic questions that have arisen from this review. These questions include research into the complex groundwater movements in East Yorkshire and Hull, the impacts of altering land drainage systems on rivers, watercourses and the habitats within them.

D.60.4 Link

http://www.coulthard.org.uk/downloads/floodsinhull1.pdf

D.60.5 Year of completion: 2007

D.61 Project 61: Pitt Review – Learning lessons from the 2007 floods: An independent review by Sir Michael Pitt – Interim Report

D.61.1 Key issues/summary relevant to IUD

Urgent recommendations

REC 1 – The Review recommends that more frequent and systematic monitoring of groundwater levels at times of high risk should be undertaken by the Environment Agency, which should begin as soon as possible to predict and mitigate further serious ground water flooding from this winter onwards.

REC 2 – The review recommends that the Environment Agency, supported by local authorities and water companies, should urgently identify areas at highest risk from surface water flooding where known, inform Local Resilience Forums and take steps to identify remaining high risk areas over the coming months.

REC 10 – The Review recommends that Category 1 responders should be urgently provided with a detailed assessment of critical infrastructure in their areas to enable them to assess its vulnerability to flooding.

Relevant interim conclusions are highlighted below:

IC 7 The interim conclusion of the Review is that the Met Office and the Environment Agency produce an early assessment of costs, benefits and feasibility of techniques which can predict where rain will fall and where surface water flooding will occur.

IC 17 The interim conclusion of the Review is that local authorities should lead on the management of surface water flooding and drainage at the local level with the support of all responsible organisations including the Environment Agency, water companies and internal drainage boards, the Highways Agency and British Waterways.

IC 20 The interim conclusion of the Review is that local Surface Water Management Plans, as set out under PPS25, should provide the basis for managing surface water flood risk. These plans should be coordinated by the local authority and be risk-based, considering all sources of flooding.

IC 21 The interim conclusion of the Review is that a local register of all the main flood risk management and drainage assets (overland and underground) should be compiled by the relevant local authority, including an assessment of their condition and details of the responsible owners.

IC 22 The interim conclusion of the Review is that Defra should issue guidance on how all organisations can be brought together to work with local authorities on surface water flood risk management, sharing information, modelling and expertise on a consistent basis.

IC 23 The interim conclusion of the Review is that the Government, as part of its Water Strategy, should resolve the issue of which organisations should be responsible for the ownership and maintenance of sustainable drainage systems.

IC 24 The interim conclusion of the Review is that Defra should work with Ofwat and the water industry to explore how appropriate risk-based standards for drainage systems (including pumping stations) can be achieved.

IC 25 The interim conclusion of the Review is that, as part of the forthcoming water industry pricing review, the water companies, in conjunction with local authorities and other partners, should develop proposals for investment in the existing drainage network to deal with increasing flood risk.

IC 26 The interim conclusion of the Review is that local authority scrutiny committees review SWMPs and other linked plans, such as Local Development Frameworks and Community Risk Registers, to ensure that flood risk is adequately considered and to ensure greater transparency and progress in the management of that risk.

IC 33 The interim conclusion of the Review is that flooding legislation should be updated and streamlined under a single unifying Act that amongst other outcomes addresses all sources of flooding, clarifies responsibilities and facilitates flood risk management.

IC 38 The interim conclusion of the Review is that unless agreed otherwise locally, 'upper tier' local authorities should be the lead organisation in relation to multi-agency planning for severe weather emergencies at the local level, and for triggering multi-agency arrangements in response to severe weather warnings.

D.61.2 Link

http://www.cabinetoffice.gov.uk/thepittreview/interim_report.aspx

D.61.3 Year of completion: 2007

D.62 Project 62: Yorkshire Water Strategic Direction Statement

D.62.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.62.2 Priority 3: Service – Stopping our sewers flooding homes and businesses

- Aim to have no flooding of homes and businesses as a result of assets failing (25-year horizon).

- Take on the ownership of current private sewers.
- By 2035 – no home flooding from one in 30-year very intense rainfall (although climate change may force this to be reviewed).
- Aim to agree standards within a national framework for rainfall frequency which have to be managed.
- A major programme of "next generation" hydraulic modelling and investigations to ensure we target investment efficiently will be initiated early in the 25-year period.
- A strategic study to establish long-term flood protection approaches for acutely low lying areas, in particular Hull, is required.

D.62.3 Link

http://www.yorkshirewater.com/?OBH=4913

D.62.4 Year of completion: 2007

D.63 Project 63: Wessex Water Strategic Direction Statement

D.63.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.63.2 Relevance to IUD

- Collecting, treating and returning sewage to environment without damaging it.
- Ensuring customers are not affected by flooding from our networks.

Strategy
Allowing for the effects of climate change, the network should have sufficient capacity to ensure properties do not flood internally or externally more than once in a lifetime and storm overflows should operate to ensure no pollution is caused.

How would we like to do this?

- By proactive maintenance of all parts of the existing sewer network.
- By increasing the size of new and renewed sewers to deal with the likely effects of climate change.
- By immediately increasing the sewer capacity of any property that floods more than once to significantly reduce the chances of it happening again.
- By encouraging and participating in the creation and operation of sustainable urban drainage systems.
- By providing a comprehensive and competitive maintenance service for the drain between a customers' property and the public sewer.

Impacts and issues
While much depends on the effects of climate change, a progressive reduction in the instances of foul flooding and discharge should be possible. We will need to invest in larger sewers. However this would represent a very significant investment – to rebuild all our sewers would cost £8 billion or four times the current value of our company –

and would take time and cause significant disruption. Given this we believe there is a need for a national debate on the period over which we should seek to mitigate the effects of climate change on our sewerage system.

D.63.3 Link

http://www.wessexwater.co.uk/thewayahead/index.aspx?id=2531

D.63.4 Year of completion: 2007

D.64 Project 64: Severn Trent Water Strategic Direction Statement

D.64.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.64.2 Relevance to IUD

Prevent sewer flooding by:

- Ensuring that no customer community is subjected to internal sewer flooding.
- Improving the capacity of our network to cope with all but the most extreme forms of weather, through separation of foul and surface water drainage.
- Promotion of SUDS.

New problems continue to be discovered as a result of:

- New developments and paving over of previously permeable surfaces.
- Problems coming to light that had previously been unreported.
- Changing weather patterns – climate change may lead to increased storm frequency, with storms spread throughout the year rather than concentrated in the summer.

The implications of climate change are that the sizing of schemes to address sewer flooding, in terms of sewer size and storage capacity, will need to be reviewed.

Addressing new sewer flooding problems arising from overloaded sewers will continue to be a significant part of the capital programme. A key aspect of keeping down the growth in sewer flooding problems is dealing more effectively with surface water (rain water). Retaining surface water in the foul or combined sewerage system and passing it to sewage works for treatment is an inefficient use of the network and assets. This inefficient use of our system potentially leads to flooding, reduced sewer capacity and an increased carbon footprint. We will investigate the scope for separating foul and surface systems with the dual benefit of creating capacity and improving the efficiency of sewage works through treating stronger sewage. We will assess the scope and cost through examining some pilot areas – separating the whole network would be an extremely costly task.

There is also great potential for sustainable drainage systems (SUDS) to deal with surface water and reduce the growth in sewer flooding problems, keeping down costs and reducing costs of pumping sewage. SUDS are designed to deal with surface water as close to the point where the rain falls as possible, by local storage of the rain water or providing the ability for the water to soak away. They aim to mimic natural drainage methods and avoid passing large volumes of water quickly downstream reducing flooding from sewers and watercourses, which could also create opportunities for improved habitats for wildlife.

The development of SUDS has so far been slow. We will seek the necessary legislative backing, encourage the installation of SUDS, and install our own SUDS devices in response to problems on existing systems. We will commence this by installing some trial pilot projects.

We welcome the consideration currently being given to increasing the coordination between organisations responsible for inland flood risk management – Environment Agency, water companies, highways authorities, local authorities and internal drainage boards.

D.64.3 Link

http://www.stwater.co.uk/server.php?show=ConWebDoc.3295

D.64.4 Year of completion: 2007

D.65 Project 65: Welsh Water Strategic Direction Statement

D.65.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.65.2 Relevance to IUD

By 2035

- Contribute fully to the implementation of SUDS across all catchments to reduce surface water inputs.
- Protect key assets from all forms of flooding.
- Sewer flooding will only occur in all but the most extreme rainfall conditions.

By 2015

- Using SUDS reduce the amount of surface water entering sewers and drains, assessing 175 priority catchments and developing model schemes.
- Use the latest technology including real-time control to prevent service failures.

D.65.3 Link

http://www.dwrcymru.co.uk/English/Company/dwrcymru/SDS/index.asp

D.65.4 Year of completion: 2007

D.66 Project 66: United Utilities Strategic Direction Statement

D.66.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.66.2 Relevance to IUD

Following an integrated approach to drainage to reduce the threat of flooding against a backdrop where climate change makes severe storm events more frequent. We will promote a more joined-up approach between the parties responsible for the various urban drainage systems and encourage demand-side solutions to flooding risk.

Employing a range of approaches to solve environmental challenges – not just "end of pipe" engineering:

- Adopting a catchment-based planning framework.
- Managing programmes to recognise the contribution of other sectors.
- Promoting flexibility in regulation.
- Exploring and maximising opportunities for control at source.

A fully integrated approach to urban drainage to provide more effective flood protection to all our customers:

- A move away from piecemeal solutions.
- Promotion of a reduced number of organisations responsible for urban drainage systems with sewerage undertakers playing an expanded role in their management.
- Promotion of more sustainable housing development.
- Solutions which reduce peak run-off throughout the urban drainage system.
- Reducing the volume of storm water which enters the sewer system.
- Mitigating the consequences when the capacity of the urban drainage system is exceeded.

We have contributed to the reviews of flood management set up in the wake of the summer 2007 floods and are prepared to respond positively to proposals for changes in responsibility. Whatever the institutional and policy changes that may emerge, more sensitive development, taking full account of flood risk, will be a key ingredient for any new approach. We are also going to need to change how we manage the impact of rainfall by making greater use of sustainable drainage systems (SUDS).

Approaches include:

- local storage and re-use of rainwater;
- systems that slow down the flow of rainwater into the sewer and so reduce the peaks that can cause flooding;
- creation of more permeable surfaces for pavements and car parks.

We would also welcome statutory involvement in the planning process to support more sustainable housing development. We want our drainage system to be resilient and to see internal flooding of properties caused by foul sewage a thing of the past. New drainage systems are currently designed to provide protection against flooding from rainfall events that should happen no more than once in 30 years. We know that the level of protection we currently provide falls short of that standard in some locations. Achieving that standard across the region would be massively expensive without the wider changes we have outlined above.

D.66.3 Link:

http://www.unitedutilities.com/Documents/1711_3003_20SDS_20A4_20FINAL.pdf

D.66.4 Year of completion: 2007

D.67 Project 67: Southern Water Strategic Direction Statement

D.67.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.67.2 Relevance to IUD

We recognise that we cannot foresee all instances of sewer flooding in the future, but we will work to minimise these events. Our long-term aim is to ensure that no properties remain at risk of internal sewer flooding for more than one year. We do expect properties to be added to the register over time and the properties that remain will be the more difficult ones to produce cost-effective solutions for. As a result we expect some properties to be still at risk of flooding in 2015.

The responsibility for more general flooding is fragmented under legislation and is shared between the Highways Agency, the Environment Agency and the local authorities. We think this needs to be reviewed so there is clear accountability and we would be willing to expand our role in relation to managing flooding issues, for example, to include highway drainage which is currently under the remit of local authorities.

D.67.3 Link:

http://www.southernwater.co.uk/Aboutus/library/default.asp

D.67.4 Year of completion: 2007

D.68 Project 68: South West Water Strategic Direction Statement

D.68.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.68.2 Relevance to IUD

To help achieve our goal of zero pollution incidents we will need to separate road and highway drains from foul sewers in critical areas. We will be looking to put forward proposals for the highest priority areas in PR09 along with developing catchment plans during 2010-2015.

We have been actively engaged in Defra's national pilot project conducted in the Camborne and Torbay areas. We have worked with the Environment Agency, local authorities and other stakeholders with interests in seeking to develop sustainable solutions to urban drainage problems. Through this, we aim to reduce surface water inputs into combined systems, reduce flood risks from surface water systems, provide additional future capacity for foul sewers and protect the local environment. The adaptation required to accommodate the problems caused by climate change need to be included as the intensity of rainfall will increase. This will lead to short duration "flash" floods as a result of the topography of the region. We will also need to invest in our waste water treatment works so that they can cope with the change in the nature and volume of influent. The results of these pilots will inform our future investment plans for our sewerage networks and waste water treatment works.

In the long term, changes in legislation will be required to clarify drainage responsibilities; particularly where highway and surface water run-off is responsible for overloading sewers beyond their designed capacity. The alternative, particularly because of climate change, may be significant and expensive upgrades to the capacity of South West Water's assets. Clarifying ownership for Sustainable Urban Drainage Systems (SUDS) may well require specific legislation in the future. Such systems represent an essential adaptation strategy for coping with climate change.

D.68.3 Link:

http://www.southwestwater.co.uk/media/pdf/a/3/SWWSDS.pdf

D.68.4 Year of completion: 2007

D.69 Project 69: Northumbrian Water Strategic Direction Statement

D.69.1 Report description:

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.69.2 Relevance to IUD

It may not always be practical or cost-effective to build bigger sewers to take this storm water. We need to find solutions by bringing all the agencies concerned with drainage and flooding to work together, including local authorities, highways agencies, the Environment Agency and water companies.

By 2013 we aim to have completed a major study on Tyneside to explore sustainable drainage options that take into account regional development and the impact of climate change. This research will be done in conjunction with relevant agencies and will build on a recent similar, but smaller, study in Hartlepool that was led by Northumbrian Water.

This study will evaluate sustainable urban drainage techniques, the removal of highway drainage from sewers, increases in sewer capacity and the possible separation of combined sewage and surface water sewers.

In the study we will investigate how the sewerage system will cope with future patterns of surface water flows and whether sewers need to be designed to different standards in the future. Remote, real-time measurement technology will be used to understand how the system responds under different flow conditions.

Aim for integrated drainage planning in the long term

- **Produce a strategic, integrated drainage plan by 2013**

D.69.3 Contacts:

D.69.4 Link:

http://www.nwl.co.uk/NWL_-_Strategic_Report_v3.pdf

D.69.5 Year of completion: 2007

D.70 Project 70: Anglian Water Strategic Direction Statement

D.70.1 Report description

Strategic direction statement over 25-year period. Only flooding focused on in the statement.

D.70.2 Relevance to IUD:

Sustainable drainage

We will look to encourage the adoption of schemes that will provide a more sustainable solution to drainage problems. In the medium to long-term we will look for opportunities to implement strategic 'landscape-scale' sustainable drainage schemes as well as smaller schemes that service particular homes or developments. Such large-scale initiatives yield multiple benefits, are more robust, easier to maintain and yield greater biodiversity and amenity value.

Performance

Investment to improve the modelling and monitoring of our wastewater network will continue. The ability to monitor our entire wastewater network remotely and model it in real-time will help us:

- Achieve goals for compliance and pollution incidents.
- Reduce our carbon footprint.
- Anticipate and react to operational problems before they affect our customers.

Policy towards flood risk

We are assessing the impact of intense rainfall on the capacity of our wastewater network and the associated risk of sewer flooding. We are also looking for ways in which we can best manage the risks of flooding from rivers on our treatment plants and networks throughout the region. We are improving our understanding of the risks and impact of slow onset effects that may not become important until well after 2035. We are currently assessing the vulnerability of coastal water and wastewater treatment works and networks to sea level rise.

Some of these risks cannot be managed reasonably by us alone; designing the appropriate response will need the involvement of other stakeholders. For example, the response to sea level rise could range from managed retreat to full flood protection, with both scenarios likely at different points along our coastline.

The Government is reviewing its policy towards flood risk in the light of recent events. We will develop our own plans to reflect emerging policy. Some aspects are particularly important for our planning, for example, to what extent new house building will be permitted in floodplains.

We set out below some of the key actions that we will need to take to increase our resilience to climate change over the next 25 years.

- Identify which sites, processes, people and systems are most at risk from climate change, using the best available science and research.
- Identify critical weather-related thresholds affecting the business, beyond which impacts are intolerable or irreversible.
- Assess the indirect impacts of climate change on our business, for example, the impacts on other sectors on which we depend.
- Identify and implement cost-effective and sustainable adaptation actions to manage risks to our business, customers and the environment.
- Monitor the impacts of climate change and the success of our adaptation measures.
- Engage our customers in the climate change issue, communicating how it may affect our operations, the consequent impact on services and the part they can play in helping us adapt.
- Work closely with other members of the East of England Climate Change Partnership to develop an integrated response to climate change in our region.

D.70.3 Link:

http://www.anglianwater.co.uk/_assets/media/strategic-direction-statement.pdf

D.70.4 Year of completion: 2007

D.71 Project 71: Open Board Paper – Urban Flood Management and Warning – A Strategic Approach

D.71.1 Report description

This paper sets out a mechanism through which strategic overview of urban flooding and quality assurance of key processes supporting management of all inland flood risks could be achieved.

D.71.2 Relevance to IUD

Two key issues need to be addressed to reach a strategic overview of urban flooding. Firstly, there must be an assessment of risk posed by all forms of flooding that is shared by all operators. This is critical to identify where risks are greatest and intervention most urgent. Secondly, a common action-planning process that can coordinate responses and investments across the broad range of organisations involved, but which has sanctions to ensure compliance and standards of output, needs to be agreed.

D.71.3 Link: http://www.environment-agency.gov.uk/static/documents/Utility/3minutes211107_1958649.pdf

D.71.4 Year of completion: 2008

D.72 Project 72: Surface Water Management Plan Guidance

D.72.1 Project description

The SWMP guidance will provide advice and examples of good practice in:

- Building partnerships.
- Undertaking risk assessments.
- Choosing cost-beneficial solutions.
- Delivering solutions (who does what).

D.72.2 Relevance to IUD

A key component required to undertake surface water management which will become part of assessing strategically urban flood risk. The stakeholder management element delivered by this project will help bring partners together. Future guidance may be required to undertake the work technically.

D.72.3 Key issues

Two key issues need to be addressed to reach a strategic overview of urban flooding. Firstly, there must be an assessment of risk posed by all forms of flooding that is shared by all operators. This is critical to identify where risks are greatest and intervention most urgent. Secondly, a common action-planning process that can coordinate responses and investments across the broad range of organisations involved, but which has sanctions to ensure compliance and standards of output, needs to be agreed.

D.72.4 Contacts:

Elliott Gill, Halcrow

D.72.5 Link: http://www.defra.gov.uk/Environ/fcd/policy/firsteditionswmp.htm

D.72.6 Year of completion: 2009

D.73 Project 73: Report: EFRA – Flooding – Fifth Report of Session 2007-08 - Volume 1

D.73.1 Report description

Report of the Environment Flood and Rural Affairs' investigation into the flooding in summer 2007.

D.73.2 Relevance to IUD

Considers impact of summer floods from number of sources, and changes required.

D.73.3 Key conclusions

- Not enough consideration of pluvial flooding by Government and other partners.
- Government must deal with lack of ownership and responsibility for surface water flooding and provide clarity on organisation responsibility.
- EFRA believe that local authorities should have this responsibility, and should be responsible for the ownership and maintenance of SUDS.
- Presumption in favour of SUDS should be included in planning bill to back up PPPS25.
- EFRA rejected calls for a Flooding Agency.
- Government should review current statutory duties on utilities in relation to emergency planning. Utilities should improve the resilience of key assets, accounting for climate change and not paid for by the consumer.
- Lack of integrated water management approach – beyond IUD – within Government and *Making Space for Water.*
- Greater clarity and guidance required of SWMP. No clarity on how responsible organisations for surface water will act following the development of the plans. Government needs to set out how organisations

will fulfil their responsibilities and how the benefits of cooperation be turned into motion.
- Government must resolve responsibility of SUDS.

D.73.4 Year of completion: 2009

D.74 Project 74: Report: Lessons Learned from Summer Floods 2007

D.74.1 Project description

This describes the phase/report - emergency response by Water UK's Review Group on flooding in the summer of 2007.

D.74.2 Relevance to IUD

Identifies issues and conclusions linked to integrated approached to manage flooding in the future based upon the lessons from summer 2007 floods.

D.74.3 Key conclusions

- Water companies need to thoroughly review their emergency response and contingency plans.
- Water companies should be involved with the key agencies to be able to cope with critical incidents.
- Data sharing is required securely between responsible (flood risk) stakeholders
- Water companies should review the vulnerability of their critical infrastructure and key assets including how other utilities affect them and prepare short-term and long-term investments

D.74.4 Key conclusions

- Water companies should review their communication strategies with the public during emergencies.
- Work with Environment Agency and Met Office to develop systems to predict the potential severity of rainfall and potential large-scale flooding. This should include tools to better predict flood depth and extent.
- A review group governed by Water UK used to oversee the actions on the recommendations in the report.
- Consolidation, rationalisation and clarity of roles and responsibilities for draining and managing flows.
- Water industry keen to resolve issues and barriers preventing implementation of SUDS.

A phase II report is likely to consider longer term issues including:
- Climate change.
- Infrastructure and asset resilience.
- Allocation of responsibilities for flood prevention and remediation.
- Sewers – automatic right of connection, flooding, ownership, suitability of design standards in a changing climate.
- EU Flood Directive.
- Public expectations in the event of flooding.

D.74.5 Year of completion: 2009

D.75 Project 75: Risk Assessment and Risk Management in Small Urban Catchment Areas (FD2603)

D.75.1 Project description

The project will contribute to our understanding of the causes of, and solutions to, flooding from small, often hidden, urban rivers and streams. This will improve the evidence base for the best way to manage such small urban catchments. In heavily urbanised catchments the scope is potentially more limited for non-structural responses to manage flooding, but there may be some opportunities through good urban design and increased risk awareness. The project aims to develop a method for the use of non-structural solutions to flooding in urban environments. The results should be of value to urban planners, regulators and water companies. They will provide regulators with a planning framework and may influence the investment decision of local authorities and water companies with asset management responsibilities.

D.75.2 Aims/objectives:

The project addresses the following subject areas:

- Identify the efficiency of various methods of flood information in raising risk awareness and readiness for response in urban areas.
- Explore the opportunities and limitations of non-structural measures for flood mitigation in small urban catchments.
- Assess the effectiveness of physical and ecological modifications to drainage systems (from green roofs to channel changes) in managing the risk of flooding in urban areas.
- Assess the social, economical, and environmental effectiveness of non-structural measures in managing flood risk in developed urban areas.

D.75.3 Contact:

Project Manager: Sebastian Catovsky
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D.75.4 Year of completion: 2008

D.76 Project 76: Developing the Evidence Base for Flood Resilience (FD2607)

D.76.1 Project description

Alternative non-structural flood management responses (or measures) are required to further reduce the residual risk of flooding for both existing and new development and infrastructure, and these require evaluation for their suitability. This project aims to

assemble information on costs and benefits of measures to produce profiles for each of the individual packages of resilience/resistance measures relating to physical cost of purchase, maintenance cost, level of protection offered, level of benefit, environmental and social issues and technical feasibility. The project has a secondary aim to identify and research the social and attitudinal barriers to the uptake of these measures.

D.76.2 Aims/Objectives

The project aims to:

- Property level estimate of costs and benefits.
- Scale up to the national level under different policy assumptions.
- Identify issues, attitudes and beliefs to be researched.
- Design customer survey of households and businesses.
- Carry out and report customer survey.
- Provide a preliminary appraisal of policy options for flood resilience and resistance.

D.76.3 Contact:

John Goudie
john.r.goudie@defra.gsi.gov.uk

D.76.4 Year of completion: 2008

D.77 Project 77: Improved Approaches to Flood Incident Management Planning through Reliability Analysis and Decision Support (SC060063)

D.77.1 Project description

The main aim of this project is to create a tool for risk assessment in complex systems and supporting tools for decision-making in flood event management planning and wider FRM planning. The project aims to achieve this through improved understanding, modelling and assessment of failures of flood incident management, consequences and by providing a tool for assessing strategic options to manage the risk.

D.77.2 Aims/Objectives

To improve current approaches to risk assessment and develop a tool for decision-making in flood incident management planning consistent/compatible with existing RASP/MDSF frameworks. The project aims to build upon existing research and provide a method for reliability/uncertainty analysis of the full range of components and systems. The project will take a holistic view of flood event management and will be a step towards an integrated approach to flood risk management.

D.78 Project 78: Improving Institutional and Social Responses to Floods (SC060019)

D.78.1 Project description

The research incorporates five work packages focussing on:

- Evidence for targeted warnings and expected outcomes.
- Improving flood responsiveness and recovery.
- Capacity building framework for effective partnership working.
- Pathfinder examples.
- Research integration.

The work will benefit the Environment Agency's FRM policy and process (incident management) functions with a series of recommendations and guidance documents routed to key end users. The project will also help to define elements of the future Incident Management and Community Engagement theme research programme.

D.78.2 Aims/Objectives

The project has four key objectives.

I. Review knowledge and research to develop a programme of work to allow the production of more targeted warnings, matched to the perceptions and behaviours of different social groupings, including vulnerable communities.
II. Review knowledge and research on institutional and social responses during and after flooding, including work on institutional and community resilience, to recommend a programme of work to improve responses to flooding.
III. Review knowledge and research to develop institutional capacity, including through a learning framework and guidance manual, for effective partnership working at the local level throughout all stages of the flood risk cycle.
IV. Draw on knowledge and research to ensure that local institutional and social capacity is embedded within a wider, strategic framework of stakeholder engagement and risk communication.

D.78.3 Contact details

Project Manager: Doug Whitfield
doug.whitfield@environment-agency.gov.uk

D.78.4 Year of completion: 2007

D.79 Project 79: Communication and Dissemination of Probabilistic Flood Warning (SC070060)

D.79.1 Project description

A scoping study into probabilistic flood forecasting and warning identified a five to 10-year development programme for the introduction of probabilistic flood forecasting into operational use within the Environment Agency. The output of the study included six objectives for the long-term programme; those relevant to this project include:

- The routine operational use by those issuing warnings of probabilistic estimates of flood levels and inundation extents as an extra tool to help in deciding whether to issue flood warnings.
- Full sharing of information on uncertainty between forecasters, warners and key professional partners who wish to see this information (those who 'opt-in' to the service).
- Pilot-testing of the inclusion of uncertainty estimates in a selection of flood forecasting products available to the public.

D.79.2 Aims/Objectives

I. Determine how public and professional partners understand and use information about risk and uncertainty from literature and other sources of information.
II. Establish what socio-economic factors require consideration for the communication of risk and uncertainty using the output from parallel projects assessing the effectiveness of flood warnings.
III. Determine how information about risk and uncertainty is used and communicated internationally.
IV. Establish what professional partners and the public understand about risk and uncertainty and how they want to use information about risk and uncertainty if given with flood warnings.
V. Establish what flood risk management teams and incident response duty officers need and how they would use information about risk and uncertainty within flood warnings.

D.79.3 Contact

Project Manager: Jacqui Cotton, 07825 754 924
claire.sunshine@environment-agency.gov.uk

D.79.4 Year of completion: 2009

D.80 Project 80: Flood Resilience for New Buildings

D.80.1 Project description

CLG Sustainable Buildings Division and the Environment Agency sponsored a joint research project to develop guidance on improving the flood resilience of new buildings. The project was managed by CIRIA. A comprehensive literature search revealed that most existing guidance was based on assessments of building techniques rather than controlled tests in a hydraulics laboratory. The test process involved testing materials and then forms of construction such as walls or floors.

A risk assessment showed that resistance to flooding (measures to prevent or at least minimise the entry of floodwater into properties) to an excessive depth would not be safe. There was uncertainty about whether some forms of construction could resist a water depth greater than 60 cm – at greater depth there is risk of damage to the building, either from pressure of the water itself or from impacts from debris. This led to the project being steered towards resilience solutions (measures to reduce the consequences of water incursion) rather than resistance. Most of the testing involved walls, subjecting walls to wetting from one side to depths of one metre then immersion both sides for three days followed by a seven-day period of drying to show the rate of seepage and how readily the walls would dry out.

Technical guide *Improving the Flood Performance of New Buildings: Flood Resilient Construction* was published on 15 May 2007 by RIBA Publishing, ISBN 978 1 85946 287 4, as the final output of this part of the project. The guide is also available on the CLG website through the Planning Portal at http://www.planningportal.gov.uk/uploads/br/flood_performance.pdf. The guide covers the nature of flooding and the planning process; design strategies and the options of avoidance, resistance and resilience; building techniques; and a summary of the research done. A CLG press release gives further details.

D.80.2 Year of completion: 2009

D.81 Project 81: Summer Floods 2007: Learning the lessons. ABI.

D.81.1 Project description

This reports sets out the insurance industry's reflections on the 2007 summer floods in the UK. It calls for action from the Government in developing a long-term strategy to fight flooding.

D.81.2 Aims/objectives

The report identifies action needed in four key areas:

- National targets and leadership supporting local government.
- Identifying and reducing flood risk for today and tomorrow.
- Planning policy fit for the future.

- Preparing for floods and how to respond.

D.81.3 Relevance to IUD

Report argues for national strategic plan to fight flooding and an enhanced role the Environment Agency.

D.81.4 Key deliverable

Set of recommendations.

D.81.5 Link:

http://www.abi.org.uk/Publications/Summer_Floods_2007_Learning_the_Lessons1.aspx

D.81.6 Year of completion: 2007

D.82 Project 82: Flooding: Engineering resilience ICE

D.82.1 Project description

This reports sets outlines the strategic views of ICE on flood risk management and makes a number of recommendations on critical issues that must be addressed by central government and operating authorities, following the 2007 floods.

D.82.2 Aims/objectives

The report identifies action needed in several areas:

- Improve infrastructure to deal with future flood risks.
- Improve coordination of planning and funding for flood risk management activities
- Improve the speed and quality of emergency response to major events.

D.82.3 Relevance to IUD

Report covers key issues for IUD, especially in terms of clarifying responsibilities for flood risk management.

D.82.4 Key deliverable

Set of recommendations.

D.82.5 Link:

http://www.ice.org.uk/downloads/2008_flooding.pdf

D.82.6 Year of completion: 2008

D.83 Project 83: FRMRC Research Priority Area 6 Urban Flood Management, Work Package 6.1

D.83.1 Project description

This package focused on modelling and procedures for flood risk management in urban areas. New approaches for the integrated modelling of urban surfaces and drainage systems have been developed including: automatic GIS-based creation of surface flow paths and geometries; new models of surface/sub-surface linkages; development, application and objective comparison of 1D/1D and 1D/2D urban flood models; CSO performance evaluation using ANNs; application of fragility concepts to other causes of flooding; real-time monitoring of system failures; use of brownfields to reduce flood risk.

D.83.2 Aims/Objectives

Develop and test new methods in urban flood management in the above listed areas.

D.83.3 Relevance to IUD

FRMRC Work Package 6.1 is addressing key issues in IUD and as such is highly relevant.

D.83.4 Key deliverables

This work package has delivered:

- UFMO (report): Measures and serviceability indicators linked to a drainage system asset performance and deterioration model.
- UFMO (report): Integrated surface and sub-surface interactive flooding and inundation model.
- UFMO (report): Risk matrix and decision support tool to assess the risk and consequences of all types of urban flooding.
- New GIS-based model for creation of 1D surface network of flow paths and ponds.
- New 1D/2D coupled urban flooding model (SIPSON/UIM).
- New methodology for use of brownfield to reduce flood risk.
- UKWIR case studies (one completed, two underway).
- Publications: three book chapters, five journal papers, 20+ conference papers,

D.83.5 Contact

Professor Adrian Saul A.J.Saul@sheffield.ac.uk

D.83.6 Link

FRMRC web site is http://www.floodrisk.org.uk/.

D.83.7 Year of completion: 2008

D.84 Project 84: FRMRC Research Priority Area 6 Urban Flood Management, Work Package 6.2

D.84.1 Project description

This package focused on health impact assessment (HIA) for urban flooding. The model has been used to drive estimates of exposure of the population to a number of flooding scenarios within the case study area of the Ribble catchment.

D.84.2 Aims/Objectives

To move forward knowledge and understanding of the potential impact of urban floods on human health.

D.84.3 Relevance to IUD

Consideration of health impacts is relevant to IUD.

D.84.4 Key deliverables

- Comprehensive literature review on health impacts in urban flooding.
- Quantitative Microbial Risk Assessment tool (QMRA) to assess flood impact on human health.

D.84.5 Contact

Dr Lorna Fewtrell lorna@creh.demon.co.uk

D.84.6 Link

FRMRC web site is http://www.floodrisk.org.uk/.

D.84.7 Year of completion: 2008

D.85 Project 85: FRMRC Theme: Flood risk attribution in urban areas (collaborative work between Work Packages 4.5 and 6.1)

D.85.1 Project description

This research developed a sensitivity-based approach to attribute flood risk in urban areas and implemented it in a case study.

D.85.2 Aims/Objectives

The objective was to be able to disaggregate the total risk and attribute it to different components, both in terms of loading variables (e.g. rainfall) and the urban drainage

system parameters (e.g. pipe diameters). The ultimate aim was to guide targeting of management actions.

D.85.3 Relevance to IUD

Attribution of flood risk in urban areas by comparing risks from different sources is highly relevant for IUD.

D.85.4 Key deliverables

New method for flood risk attribution in urban areas.

D.85.5 Contact

Dr Richard Dawson richard.dawson@newcastle.ac.uk

D.85.6 Link

Paper available on: http://www.iwaponline.com/jh/010/jh0100275.htm

D.85.7 Year of completion: 2008

D.86 Project 86: FRMRC2 Work Package 3.2 Methodologies for Improved Urban Flood Risk Assessment

D.86.1 Project description

WP 3.2 proposes to assess the theoretical basis for the view that Integrated Urban Flood Risk Management (IUFRM) is cost-efficient and to trial methods of integrated physical and societal costing in sample urban areas.

D.86.2 Aims/Objectives

Two methods to improve local-scale flood risk assessments in urban areas will be developed: 1) Approaches to whole-life costing of non-structural responses in integrated urban flood risk management. The approach will review the feasibility of calculating the 'true overall cost' of different response strategies and interventions in urban flood risk assessments and subsequently propose a methodology for non-structural response strategies, with the potential application to a case study catchment. 2) Improved real-time risk models for Category 1 responders. The research proposes to evaluate the value and application of local-scale real-time urban flood risk animations at the scale suitable to Local Authority Category 1 responders. The research will explore the potential for improved real0time risk models to assist in flood incident management and will develop and undertake proof-of-concept implementation of inundation models to support uncertainty analysis.

D.86.3 Relevance to IUD

FRMRC2 Work Package 3.2 is addressing key issues in IUD and as such is highly relevant.

D.86.4 Key deliverables

- A literature review covering the feasibility of calculating the 'true overall cost' of different response strategies and interventions in UFR assessments.
- A literature review that addresses the challenges of identifying vulnerability-associated indicators applicable to social mapping.
- A 'proof of concept' report on the trial of a GIS-based vulnerability mapping tool at two contrasting data-rich sites in Yorkshire.

D.86.5 Contact

Dr Hazel Faulkner H.P.Faulkner@mdx.ac.uk

D.86.6 Year of completion: 2011

D.87 Project 87: FRMRC2 Work Package 3.3 Quantitative Precipitation Estimation during Extreme Storms

D.87.1 Project description

WP 3.3 proposes to improve the measurement of spatially distributed urban rainfall in near real-time under extreme conditions, to improve accuracy and reduce uncertainty.

D.87.2 Aims/Objectives

Met Office data from the Chenies and Thurnham radars, together with raingauge data, will be used to complete a multi-parameter study and to enhance understanding in near real-time of attenuation, including that due to melting snowflakes and heavy precipitation.

D.87.3 Relevance to IUD

This work is relevant for IUD.

D.87.4 Key deliverables

- A report on the inter-comparison study of multi-parameter radar and recommendations on the use of Dual-Polarisation Weather Radar Technology.
- A report on the application of polar-based dual-polarisation radar rainfall estimation to provide better estimates of precipitation with polar resolutions smaller than one km with online calibration using raingauge data.
- The development of an integrated calibration and processing system for multiple radar scans in the overlapping zone over the Thames Catchment.
- A report on the application of this system to short-term precipitation forecasting.

D.87.5 Contact: Professor Ian Cluckie I.D.Cluckie@bristol.ac.uk

D.87.6 Year of completion: 2011

D.88 Project 88: FRMRC2 Work Package 3.4 Short Term Forecasting of Storm Events over Urban Areas under Extreme Conditions

D.88.1 Project description

WP 3.4 seeks to extend the new state-of-the-art Short Term Ensemble Prediction System (STEPS) developed at the Met Office, to predict future (few hours forward) rainfall in urban areas.

D.88.2 Aims/Objectives

It is proposed that the nowcasting system will be enhanced by assimilating the wind fields from Doppler radar data and satellite data. The main focus will be on using the STEPS approach with high resolution radar data and convective scale runs of a high-resolution NWP model using ensemble forecasts rainfall data when appropriate to represent larger scale uncertainty.

D.88.3 Relevance to IUD

This work is relevant for IUD.

D.88.4 Key deliverables

- Extension of the Met Office's Short Term Ensemble Prediction System (STEPS) system by using high resolution dual-polarisation radar information in extreme rainfall conditions.
- A report on the inter-comparison study of multi-parameter radar and recommendations on the use of Dual-Polarisation Weather Radar Technology.

D.88.5 Contact

Professor Ian Cluckie I.D.Cluckie@bristol.ac.uk

D.88.6 Year of completion: 2011

D.89 Project 89: FRMRC2 Work Package 3.5 Real-Time Forecasting of Pluvial Flooding

D.89.1 Project description

WP 3.5 will evaluate the benefits of the forecasting model and sewer hydraulic models in forecasting pluvial flooding, by improvements in the resolution and accuracy of rainfall measurement and short-term forecasting of short duration high intensity storm events in urban areas. This WP links closely with WPs 3.4 and 3.6.

D.89.2 Aims/Objectives

The research will involve the development of new techniques for processing radar signals and their conditioning from ground data, the design and optimisation of a wireless data collection network for rainfall and operational data, and systems theory applications to rainfall data analysis. Storm forecasting will be integrated within advanced pluvial flooding models and real-time updating techniques. Using real data from monitored systems, the research will identify an appropriate scale of application and demonstrate the new short-term forecasting capability.

D.89.3 Relevance to IUD

This work is relevant for IUD.

D.89.4 Key deliverables

- A real-time high resolution and accuracy rainfall forecasting model based on the polar-based dual polarisation radar signal nowcasting enhanced with weather forecasting.
- The application of the forecasting model to historic radar data backed up by high density raingauge data and sewer flow measurements to identify the impacts of uncertainty in predictions.
- An assessment of the potential benefits of the forecasting model with appropriate sewer hydraulic models in predicting pluvial flooding with sufficient time to successfully trigger operational and non-structural responses, and hence establish the scale and detail at which modelling is required.

D.89.5 Contact

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D.89.6 Year of completion: 2011

D.90 Project 90: FRMRC2 Work Package 3.6 Online Sewer Flow and Quality Using Predictive Modelling

D.90.1 Project description

WP 3.6 will develop a method for predictive modelling of sewer flow and quality from rainfall measured in near real-time using radar and raingauge data. The method will be developed by the application of sophisticated mathematical algorithms using Artificial Intelligence (AI) techniques. These data driven models will use, for individual storm events, Met Office radar rainfall data at one-km resolution, raingauge, sewer flow and sewer flow quality data recorded at two case study catchments operated and managed by Yorkshire Water.

D.90.2 Aims/Objectives

The outputs will be used to predict the quantitative and qualitative performance of the system based only on near real-time radar data. The outputs will subsequently be trialled at additional case study catchments.

D.90.3 Relevance to IUD

This work is relevant for IUD.

D.90.4 Key deliverables

- A data management strategy to handle the real-time data of measured rainfall and sewer flow data.
- A method to derive a series of rule-based algorithms, based on AI techniques to describe system performance.
- Application of the new method to predict flood risk and pollution outputs for radar and other rainfall scenarios within the two case study catchments.
- Reporting of the method applied to three case study catchments, funded by UKWIR, if appropriate. Recommendations as to how the method should be transferred to other catchments.

D.90.5 Contact

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D.90.6 Year of completion: 2011

D.91 Project 91: FRMRC2 Work Package 3.7 Improved Understanding of the Performance of Local Controls Linking the Above- and Below-Ground Components of Urban Flood Flows

D.91.1 Project description

WP 3.7 proposes to better understand and model the hydraulic performance of individual types of gully system that are typical of those used in practice. Experimental and CFD studies will be completed.

D.91.2 Aims/Objectives

Experimental and CFD studies will establish the interactions between the above- and below-ground drainage network for a range of flow conditions and provide boundary conditions and coefficients for the input into 1D/1D and 1D/2D mathematical models to describe these interactions. The new methods will be applied to case studies using real drainage systems to determine the potential benefits of controlling the flows between the surface and sub-surface systems by means of gully design, frequency and maintenance.

D.91.3 Relevance to IUD

This work is relevant for IUD.

D.91.4 Key deliverables

- A laboratory system that mimics the real-time flood interactions between the above- and below-ground flood pathways and that represents a typical full scale inlet and associated pipe work.
- CFD models to simulate the flow performance into and from typical inlets/outlets.
- A series of algorithms to describe the governing parameters and coefficients for input into the interactive coupled surface/sub-surface model for a range of inlets/outlets, expressed in matrix format.
- Enhancements to the FRMRC1 interactive surface/sub-surface model and other commercial models that predict flood risk in the urban area.
- Application of the enhanced model to real case studies to identify the potential to manage flood risk by means of gully design, density, location and maintenance.

D.91.5 Contact

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D.91.6 Year of completion: 2011

D.92 Project 92: Designing for exceedance in urban drainage – good practice (Environment Agency R&D Report SC030219/TRI)

D.92.1 Project description

This technical guidance provides advice to drainage engineers, regulators, planners and the construction industry on the design and management of urban sewerage and drainage systems to reduce the impacts from drainage exceedance. It includes information on the design of underground systems and overland flood conveyance. It also provides advice on risk assessment procedures and planning to reduce the impacts that extreme events may have on people and property in the surrounding area.

D.92.2 Aims/Objectives

The broad objective is to improve the appreciation of the risks associated with urban drainage systems and understanding of how these risks may be mitigated. It provides guidance so that systems can be designed to accommodate periods when the design capacity of drainage systems are exceeded during extreme events. The specific objectives are to:

- address the issue of designing urban drainage systems that can cope with periods of exceedance;
- provide guidance on risk assessment procedures to determine the likelihood and impacts of drainage exceedance;
- provide guidance on planning and layout to reduce the impacts of exceedance in drainage systems;
- offer best practice guidance for the design of urban drainage systems that can sustainably accommodate periods of exceedance.

D.92.3 Relevance to IUD

This guidance is directly relevant for IUD**.**

D.92.4 Key deliverables

The principal output is CIRIA Publication C635. It provides:

- an overview of stakeholder roles in the management of exceedance;
- detailed design procedures including modelling hydrological processes, interactions between major and minor systems and developing exceedance flood risk assessment and designing for surface conveyance and storage;
- two illustrative case studies.

D.92.5 Link

http://www.ciria.org/service/AM/ContentManagerNet/Default.aspx?template=/TaggedPage/TaggedPageDisplay.cfm&TPLID=19&ContentID=10560&TPPID=3541&AspNetFlag=1&Section=Flood_risk_management_and_surface_water_drainage1

D.92.6 Year of completion: 2006

Appendix E – Initial categorisation of gaps

Gap No.	Gap
A1	Establish policies/system to enable IUD to be implemented (including regulation)
A2	Lack of good case studies/pilots
A3	Lack of training materials and capacity building
A4	Spatial planners, lack of understanding of flood risk management, need help
A5	Using roads as flood channels - the issues - and convincing highway engineers
A6	Educating emergency planners on flood risk and implications of actions
A7	Lack of uptake on SUDS - ADOPTION who and how funded if these techniques used as IUD
A8	Greater clarity of roles and responsibilities for flooding and to what standard and maintenance
A9	The impact of S106, right to connect
A10	Guidance to go with changes to permitted development
A11	General public flood awareness - home and wider context (for those at flood risk or not)
A12	Lack of data or knowledge on assets and existing surface water assets and systems or what is available
A13	Lack of planning policies around surface water management and watercourse corridors
A14	Lack of guidance on surface water management and SUDS
A15	Funding for traditional and SUDS engineering
A16	Planning policies to enable greater flood resilience and flood risk management
A17	Low tech/cost flood routing tool
A18	Dissemination of guidance/good practice
A19	Data, guidance on using permeable surfaces required
A20	CBA on IUD and drainage types
A21	Stakeholder interaction, what is required, best ways to do it, pitfalls to avoid
A22	Private sewer transfer
A23	Review of design standard levels of service
A24	Coordinated common approach between local authorities
A25	Integrate building regulations and urban drainage design standards
A26	Alternative funding options. Need to have a risk-based approach to funding and prioritisations. Funding IUD - how?
A27	Academia education required
A28	Integration of the whole water cycle and planning
A29	Need for consistent mapping/modelling approach of flood risk
A30	Lack of flood risk plans and maintenance plans
A31	Data sharing securely
A32	Stakeholders not being involved right from the start of a project
A33	Improved tools to asses water quality

Gap No.	Gap
A34	Improving the quality of construction through guidance/best practice
A35	Constructing IUD schemes for different elements at same time
A36	Poor quality of aesthetic SUDS design
A37	Local DIY - flood risk management guidance for builders and homeowners
A38	Lack of knowledge of maintenance costs for SUDS (WLC)
A39	If drainage assets are not maintained over time, what will the impact be on that drainage and other forms of drainage
A40	Need better building (regulations) control
A41	Need to educate developers of surface water management
A42	Inaccuracies/inconsistency of predicting surface water run-off and rainfall extremes
A43	Drainage not considered at the start of the project (new development)
A44	Creating and protecting above-ground flood routes in the future
A45	Being able to protect essential (critical) infrastructure in urban areas, when space in limited
A46	Lack of recorded data on surface water flooding and existing flood risk
A47	Commitment to retrofit IUD and funding it
A48	Lack of technical knowledge among policy-makers
A49	Enforcing legislation/regulation correctly
A50	Clearer guidance and standards for planning liaison offices in the Environment Agency and the need for consistency
A51	Allowance for climate change varies
A52	Allow/enable adoption of permeable pavements on roads
A53	Legal framework to allow retrofitting of IUD in existing areas
A54	Predicting the effect in downstream systems e.g. groundwater and how it behaves long term
A55	IUD having to be used rather than just conventional drainage by developers
A56	Local authority funding for surface water management (lack of money)
A57	Existing schemes gone wrong and the need for monitoring and feedback
A58	Lack of qualified staff in field
A59	Dissemination of information
A60	Lack of understanding of how different drainage systems interact and interface
A61	Ensuring construction quality is correct - could cover all forms of drainage but especially SUDS
A62	Lack of knowledge of construction costs for SUDS
A63	Lack of trained professionals to maintain non-conventional systems
A64	As - built information of poor quality
A65	Too much guidance and not integrated
A66	Not enough hydraulic design data for SUDS
A67	Need for flood warning of non-fluvial sources

Appendix F – Final gaps, grouped and aligned to stakeholders who may benefit and fund them

Gap No.	Gap	Stakeholders to benefit								Stakeholders who could fund									
		Local Authority	Developer	General Public	Environment Agency	Sewerage Undertaker	Internal Drainage Board	Defra	Utilities	Defra	Ofwat	Environment Agency	UKWIR	MET Office	DCLG	Research Council (Private)	Research Council - Public	Sewerage Undertaker	Utilities	Local Authorities
B1	Unclear (and could be improved) legislation on surface water management for planning and for the implementation of integrated urban flood risk management in existing and new developments	X	X	X	X	X				X	X	X								
B2	Need for accountable regulation that enforces legislation for all stakeholders, in particular covering environmental, flood risk and building control	X	X	X		X					X	X			X					
B3	Major lack of awareness of the roles and responsibilities of stakeholders and lack of understanding of who is responsible above certain standards and how stakeholders can work together to bridge the gaps	X		X	X	X				X	X	X	X							
B4	Allowance for climate change varies between different responsible organisations	X	X		X	X	X				X	X	X	X	X					
B5	Lack of planning policies to ensure surface water management is achieved with the appropriate drainage types	X	X		X	X	X			X					X					
B6	Need greater evidence to demonstrate the impacts, issues and benefits of using highways as flood channels and ensuring that all flood channels are protected in the future	X								X					X	X	X			
B7	Lack of quality in the design and construction of SUDS	X	X		X	X										X				
B8	Lack of suitable pilot/case studies to demonstrate effective urban flood risk management	X	X	X	X	X	X			X		X	X			X	X			
B9	Need to achieve good stakeholder interaction with the right stakeholders to achieve urban flood risk management, with the best ways to do it and what to avoid	X	X		X	X	X	X		X		X				X	X			
B10	Lack of date/knowledge/awareness of surface water assets and where surface water flooding occurs	X	X	X	X	X						X						X		X
B11	Lack of awareness of available research, guidance, tools, generally as a result of untargeted dissemination	X	X		X	X				X		X	X			X	X			

Gap No.	Gap	Stakeholders to benefit								Stakeholders who could fund									
		Local Authority	Developer	General Public	Environment Agency	Sewerage Undertaker	Internal Drainage Board	Defra	Utilities	Defra	Ofwat	Environment Agency	UKWIR	MET Office	DCLG	Research Council (Private)	Research Council - Public	Sewerage Undertaker	Utilities	Local Authorities
B12	Lack of understanding and knowledge of which critical infrastructure is at risk as a result of the drainage system performance and how that critical infrastructure should be protected, especially in dense urban areas	X			X	X			X	X		X						X	X	X
B13	Lack of leadership/legislation for the implementation and adoption of SUDS	X	X			X				X		X	X					X		X
B14	Lack of integrated maintenance plans (where one stakeholder impacts on another without knowing when carrying out maintenance)	X			X	X						X	X					X		X
B15	Lack of a flood warning system predicting impacts from non-fluvial sources	X		X	X	X	X		X			X		X					X	
B16	Lack of an agreed method/approach to share data between stakeholders	X			X	X	X			X			X							
B17	Need for a more common/consistent approach for dealing with planning submissions in local authorities	X	X		X							X			X					
B18	Need for clearer guidance, standards and consistency for planning liaison offices in the Environment Agency											X								
B19	Need for better tools to asses water quality from different sources and the impact on different receptors				X	X						X					X	X		
B20	Lack of integrated flood risk plans (covering all sources of flooding) and the need for a consistent approach to model/map overland flows and flood risk in urban areas	X			X		X			X		X				X				
B21	Lack of understanding of how rainfall run-off and subsequent flows in the urban drainage system impact further downstream in an integrated manner and how the systems interface and interact	X			X	X	X					X	X			X	X			

Gap No.	Gap	Stakeholders to benefit								Stakeholders who could fund									
		Local Authority	Developer	General Public	Environment Agency	Sewerage Undertaker	Internal Drainage Board	Defra	Utilities	Defra	Ofwat	Environment Agency	UKWIR	MET Office	DCLG	Research Council (Private)	Research Council - Public	Sewerage Undertaker	Utilities	Local Authorities
B22	Current funding mechanisms must be reviewed if money for urban flood risk management is to be available at the right time for the right stakeholders	X			X	X	X			X	X	X								
B23	Lack of knowledge of the costs of all drainage types against the benefits they bring (capital and operation costs)	X	X		X	X				X		X	X							
B24	Lack of capacity available (particularly in local authorities) to undertake integrated urban flood risk management	X														X	X			X
B25	Lack of knowledge (technical, implementation, stakeholder management and, capital and operational costs) generally in the industry of surface water management and particularly in local authorities for spatial planners and emergency planners	X	X		X	X						X				X	X	X		
B26	The lack of awareness and understanding in the general public of flood risk, what is sensibly achievable, and what measures they personally can take to reduce risk			X						X		X				X	X	X		X
B27	Not all stakeholders are involved in the development process (for drainage and flood risk) from the start of the project, often resulting in drainage being considered to later during the project life cycle	X	X		X	X									X					
B28	Missing guidance on surface water management in urban areas for all drainage types for all stakeholders	X	X	X	X	X	X			X		X	X			X	X			

Appendix G – Project details for prioritised 32 projects

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
1	Setting up an integrated urban drainage research, development and dissemination portal	D, ET	Develop a portal that is actively maintained by an organisation that is a one-stop shop for different practitioners to find and locate knowledge, as well as indicate ongoing work.	Enable end users to have access to the latest reports or where to get information from. Enable ongoing research activities to be easily mapped over a long period of time.	The project will use knowledge collated from this and other projects to build up links under different IUD themes. This will enable links or documents to be held on a website that all practitioners know they need to go to (including planning, drainage). The website, once set up, will be a growing and evolving site, with ever increasing data. The website should also have a rolling simple programme that indicates what research is being undertaken in the IUD and when it will be released. This could be expanded wider to cover other flood-related disciplines.	<£100,000	Under one year.	B11	8.9
2	Mapping Recorded Flood Incidents	G	To develop a common approach to mapping recorded flooding incidents that will allow incidents of a different type, spatial extent and resolution to be combined in a single map format.	A consistent approach to mapping flood probability/risk to help assess risk and develop management. It will foster data sharing and remove some of the contentious issues on data presentation.	The work will resolve how to combine the probability of flooding from different sources into an overall scoring. The mapping will include depicting flooding at individual property level that avoids identifying individual properties, that expresses flood probability/risk on an area basis.	<£100,000	Under one year.	B20	8.8
3	Designing for exceedance - Engagement and Dissemination	D, ET	To disseminate the concepts and guidance of designing for exceedance to a wider audience	Shares the knowledge of designing for exceedance to a wider audience. Enables	This project will through a number of suitable media look to share the knowledge captured in designing for exceedance. It is expected that a mixture of training, workshops and potentially an overarching DVD would	<£100,000	<1 yr	B11	8.7

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
				feedback from a wider audience of challenges faced in managing extreme events	be produced to help the designing for exceedance message. The project would also capture the key issues preventing implementation of the concepts, to understand how best to transfer the knowledge out.				
4	Designating and managing flood pathways - a practitioner's guide	G, D	To provide practitioners with guidance to enable them to identify, designate and protect flood pathways to manage flood risk	Practitioners understand the legal issues of designating flood pathways. Practitioners can designate flood pathways by understanding the legislation that can be used. Provide simple case studies of where flood pathways have been designated.	Development of guidance outlining the legal issues associated with designating flood pathways. This should be distributed to practitioners, and in particular local authorities to enable them to protect and design flood pathways.	<£100,000	Under one year.	B5,	8.7
5	The role of incentivisation in delivering integrated Urban Drainage	AR	To assess the potential of different business models and incentive models for encouraging various stakeholders to effectively engage in	Foster a more proactive approach to IUD and break down some of the existing barriers.	Assess the role of different funding regimes, regulation, incentives and business models on driving change to foster engagement of stakeholders. Evidence will be gained from other sectors and other countries in undertaking the work.	<£100k	<1 yr	B22	8.6

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
			integrated urban drainage.						
6	Training on stakeholder engagement for IUD	ET	To encourage the implementation of high quality stakeholder engagement	This will benefit those organisations that need to obtain engagement and participation by different stakeholders. This largely going to benefit local authorities and the Environment Agency.	There are a number of approaches to stakeholder engagement, some good examples have been used for Shoreline Mgt. There are also a number of organisations providing training on stakeholder engagement. This training will combine training on stakeholder engagement and guidance on IUD and/or surface water management to ensure that course content is relevant to the challenges being faced.	<£100k	<1 yr	B9,	8.6
7	A standard agreement for data sharing between integrated urban drainage stakeholders.	G, CB	To create a standard agreement to facilitate the sharing of data, saving time and significant negotiations at the start of a project, whilst also lowering costs.	To have a standard agreement that can be easily used by all stakeholders. Overcome major hurdles in the water industry in safe data sharing. Save time and money and facilitates stakeholder engagement and data sharing quickly.	Development of a standard agreement that can be used nationally to assist in the sharing of data between different stakeholders. This would be supported by developing guidance using a number recognised methods/good examples to achieve good stakeholder integration and working	<£100k	<1 yr	B16	8.5

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
8	Guidance on stakeholder engagement.	G	To compare and contrast various approaches to stakeholder engagement concerned with flooding.	To select and use the most appropriate and cost-effective method of engagement for the issue at hand.	Review main methods of stakeholder engagement. To review approaches to stakeholder engagement used in relation to flooding/exceedance issues. To gather main lessons learned. To develop guidance and best practice.	<£100k	1 yr	B9,	8.5
9	Implementing the Environment Agency Strategic Overview - Common guidance	G	To ensure consistency of approach by the Environment Agency nationally to deal with its responsibility of the strategic overview for surface water management.	Environment Agency staff have clear guidance to implement the strategic overview. Practitioners working with the Environment Agency are clear in how the overview will be implemented across the country.	The full extent of the project will stem from the finalisation and remit of the Environment Agency's strategic overview role. Based upon this, internal/external guidance and information should be developed that clearly states how the Environment Agency's role will be implemented. To ensure consistency, guidance will be developed for all staff to ensure the local delivery is linked and aligned to the strategic delivery role.	<£100,000	Under one year.	B3	8.5
10	Assessment of flood risk for critical infrastructure	G	Establish an approved approach for the assessment and management of flood risk for surface water management assets	This will assists with the identification, assessment and management of flood risk for surface water management infrastructure owned and	Following the flooding of 2007 a number of organisations are developing processes and guidance on the flood risk assessment and management for critical infrastructure. This project will focus on the development of an approved approach for stakeholders that operate surface water management infrastructure.	<£100k	18 months	B12	8.5

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
				operated by different stakeholders					
11	Fact sheets on spatial planning and flood risk management	G, ET, CB	To develop easy to use fact sheets to facilitate a common understanding between spatial planners and those managing flood risk management.	This will facilitate early and effective consultation between different disciplines and help realise developments that are sustainable, manage flood risk and are attractive places to live.	This will produce short, focussed and easy to use fact sheets on key considerations, objectives and processes used by spatial planners or flood risk managers.	<£100,000	Under one year.	B25	8.3
12	Capacity building for those involved in IUDM	ET, CB	Develop and enhance existing networks and forums to facilitate the sharing of information on policy, regulation and good practice related to surface water management.	This will facilitate the sharing of information and the delivery of local solutions for local problems.	This will build on the existing work of networks like LANDFORM, WaPUG to improve the capacity and understanding of stakeholders. It will include a centrally coordinated programme of events, initiatives, training focussed at a regional level providing solutions tailored to specific requirements - facilitating local mentoring and or competitions.	£100,000 – 200,000	Two years	B11	8.2
13	Guidance on engagement with the public on IUD	G	To provide practitioners and different stakeholders with	To help communicate risk and responsibilities	A number of projects (both academic and practical) have used processes to engage with the public often with them actively participating in planning,	<£100,000	One year.	B9	8.2

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
			guidance on public engagement and participation processes for IUD projects.	(including their own) with regards to IUD and manage expectations and implementation of source control solutions. This aligns with Pitt's central theme of engaging with the public.	designing and delivering solutions. This guidance will investigate approaches both from the UK and overseas, and apply them to the challenges of IUD management in the UK.				
14	Easy to use guidance on protecting your home from flooding	AR, G, ET, CB	This easy to use guidance will help the general public and local resilience groups improve local flood risk management by providing guidance on what can be done to maintain drainage within their property boundary, implement source control and flood resistance and resilience measures.	This will benefit general public, local resilience forums and local authorities in educating property owners about responsibilities and what they can do to help manage flood risk locally.	Easy to use guidance on measures to improve local drainage and prepare for flooding. This may provide an approach to encourage/implement source control and communicate risk better.	<£100,000	One year.	B26	7.9

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
15	Developing risk-based standards for drainage components	G, ST	To develop a set of risk-based standards for flood protection during exceedance flow from different drainage components.	Agreed flood exceedance standards throughout the urban environment will lead to less confusion and conflict, and result in better and more rapid solutions.	Review different approaches to flood protection standards by each key stakeholder (Sewerage Undertakers, Environment Agency, IDB, LAs etc). Devise and consult on standards for various drainage components moving from a fixed standard to risk based. Examine implications on test catchments (e.g. using some of the IUD pilots).	£100,000-300,000	Two years.	B3	7.8
16	Risk management framework for integrated urban drainage	AR	To develop an agreed framework for managing risk of flooding in the urban environment	Allows integration of traditionally separate organisations/ disciplines and joined-up solutions to be developed based on a common understanding of the problems and potential solutions.	Develop risk assessment framework that allows incorporation of risk from multiple sources and timescales. Agree definition of standards within framework. Consult key stakeholders. Test on pilot studies (e.g. IUD pilots).	£100,000-300,000	Two years.	B3	7.7
17	Guidance on land and surface water management adaptation for redevelopment and re-	G, DP	To enable practitioners to be able to select and design solutions to manage flows in urban areas	Fill a knowledge gap currently identified. Be the starting point for practitioners to work out how to retrofit	The project will develop guidance based on literature review and engagement of best practices around the world. The guidance will look to use the information to develop a framework for selecting the best method of managing surface water.	£100,000 to 300,000	Two years.	B28	7.7

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
	generation		better and more sustainably to reduce flood risk locally and downstream.	surface water management techniques in urban areas. Encourage practitioners to consider what can be achieved, and identify case studies where it has, which could be visited.	The project will identify and write up a number of case studies where such measures have been implemented. The guidance in particular will be targeted at areas that are undergoing redevelopment or regeneration.				
18	Performance of different modelling approaches for assessing flood risk in urban areas	G, AR	To compare different modelling approaches to simulate urban flooding from different sources and to document their capabilities in respect of assessing flood risk.	This builds on work for the Pitt review to give more comprehensive guidance to end users on the use of different modelling approaches in different circumstances.	Using a small number of different drainage areas to represent the range of typical physical characteristics, run software representative of the different modelling approaches and compare modelled output with known occurrence and extent of flooding. The results to be mapped to allow easy comparison with the different methods. The resources used and costs to be quantified in each case.	£100,000-£300,000	One year.	B20	7.6
19	Whole life costs of urban flood risk mitigation	AR	To demonstrate through the assessment of actual mitigation work the benefits gained by intervening and reducing flood risk.	Provides the evidence base of what drainage interventions cost and their benefit on a wider catchment scale. Using wider catchment	This will build on work already completed in identifying unit costs for drainage components, and move to a more detailed level looking at a number of catchments where flood risk measures have been implemented or are required. The cost of the measures and benefits they bring will be determined. The catchments will	£100,000 to 300,000	Two years.	B23	7.5

Project No.)	Project Title	Project Type	Project Aim	Project Benefits	Project Description	Estimated contractor's cost <£100,000, £100,000 to £300,000, >£300,000	Estimated Duration	Key Gap	Average Score
				scale will enable a national picture to be developed so supporting policy-makers and regulators in funding decisions.	be selected to be typical of those experienced in England and Wales. This will enable a national cost and benefit analysis to be developed.				
20	Mapping flood risk in urban areas based on stakeholder responsibilities	G, ST	To develop an approach to attribute flood risk to source (generation) and represent the impact of this spatially.	Gives spatial representation of flood responsibilities linked to attribution of risk. Ideal for stakeholder buy in and response to flood protection and clean up.	Develop concept of whole risk, rather than risk associated with rainfall return period. Further enhance attribution of risk in relation to source of flood flows and stakeholder responsibility. Link exceedance flow models to new risk concepts and represent responsibilities spatially. Test on pilot studies (e.g. IUD).	> £300,000	More than three years.	B3	7.4

Project No.	Project Type	Project Title	Project Description	Gap No.	Overall Average
21	AR, G	Regulations to encourage better local flood protection and surface water management.	This guidance and regulations will help promote and encourage their implementation.	B1	7.6
22	DP, ST	Identifying extreme event flow pathways for strategic planning and emergency response.	To develop a rapid visualisation tool which highlights flood pathways for use in strategic planning and emergency response, and advise on approaches to pathway protection.	B20	7.6
23	G, CB	Local leadership for flood risk management.	This easy to use guidance will provide a framework for local leadership signposting and detailed guidance.	B3	7.6
24	AR	An evidence base to support legislative/regulatory change.	To develop a well-documented database of evidence to support potential legislative and regulatory change in integrated urban drainage.	B1	7.5
25	G, AR	Evaluation and improved implementation of SUDS adoption	Model agreements through CIRIA and the Interim Code of Practice for SUDS have been available since 2004. Their use is not well known. This project will evaluate their use and facilitate wider adoption of SUDS in the interim before legislation is put in place.	B13	7.5
26	CB	Local capacity building initiatives	This is to facilitate a learning culture that integrates participation in decision-making for communities and relevant stakeholders.	B24	7.4
27	G	Preparing critical infrastructure during flooding emergencies	To develop guidance on the management of critical infrastructure as part of emergency response during the planning and operation phase for all stakeholders with critical assets.	B12	7.4
28	G, ST, AR	Review of SUDS modelling software	To review and assess the capability of commercially available software to predict the flow quantity and quality performance of SUDS	B19	7.3
29	G	Building adaptive capacity into SUDS	To build on existing guidance to demonstrate how SUDS can be designed and adapted to cope with extreme events.	B28	7.3
30	AR, G	Using highways to accommodate exceedance flows	To understand key barriers to using highways as exceedance pathways and develop the science to provide confidence in using them in the future, dealing with health and safety concerns, constructability, maintenance and carriageway integrity.	B6	7.2
31	AR	Comparing the statistical	To compare and evaluate the (extreme) statistical distributions of rainfall,	B21	7.1

Project No.	Project Type	Project Title	Project Description	Gap No.	Overall Average
		distributions of urban rainfall, run-off and flooding. Improving land use modelling in 2D surface models for urban areas.	run-off and flooding based on analysis of time series rainfall and urban drainage model output. Use this to develop 2D models that account for varying urban land use and rainfall loss accurately and address current shortcomings.		
32	G	Guidance on building SUDS	To produce easy to use and durable guidance for contractors on the construction of SUDS, including simplified check lists.	B7	7.1

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