Integrated Urban Drainage Pilots

Making Space for Water
Urban flood risk & integrated drainage (HA2)

IUD pilot summary report

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Author:

Elliot Gill, Halcrow Group Ltd

Publishing organisation
Department for Environment, Food and Rural Affairs
Flood Management Division,
Ergon House,
Horseferry Road
London SW1P 2AL

Tel: 020 7238 3000 Fax: 020 7238 6187

www.defra.gov.uk/environ/fcd

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Executive summary

The UK Government's strategy for flood and coastal erosion risk management, Making Space for Water (MSfW), set out a portfolio of approaches to ensure that flood risks are managed more effectively in the future by adopting an holistic, joined-up, and integrated approach. An area of particular concern in MSfW was flooding in urban areas from surface water due to inadequacies in drainage systems; the need for integrated urban drainage management (IUDM) approaches was identified. In MSfW the Government recognised that the physical and institutional complexities of urban drainage systems make it difficult to plan and deliver systems with reduced flood risk. Uniquely in England, within the UK, there are complex institutional and funding arrangements which divide responsibilities between water companies, the Environment Agency, planning departments in local government, housing developers, householders and internal drainage boards. As a consequence urban drainage solutions have not always been as cost effective, sustainable and robust than might have been possible had a more integrated approach been adopted.

To develop new approaches to IUDM, Defra supported fifteen pilot projects in 2007/8 which have worked:

- to understand the causes of flooding in urban areas and the best ways of managing urban drainage to reduce flooding;
- to examine the effectiveness of partnership working between various drainage systems currently and how this partnership can be improved to find solutions to flooding problems, and;
- to test the effectiveness of new approaches to urban flood risk management, including: use of hydraulic models, surface water management plans, sustainable drainage systems (SuDS) and the managed routing of drainage exceedance flows.

Flooding in Summer 2007 served to reinforce the importance of this work as has the work of Sir Michael Pitt who has advised on the nation's response to these events. Some key benefits of IUDM identified by the pilot project work include:

- Working together in partnerships has enabled stakeholders to share information, develop a collective understanding of flood mechanisms and risks, and learn about each other's roles, responsibilities and funding arrangements.
- A variety of modelling tools can be successfully applied to calculate surface water flood risk, a product of flood likelihood and consequence. In line with Foresight, one pilot estimates an increase in flood volumes of 77% by 2085 for the 1 in 100 year event due to climate change and urbanisation.
- Modelling and mapping surface water flood risks can inform planning departments in local authorities when they allocate land for housing development. It can also inform emergency planners identifying safe havens and transport routes for use in extreme weather.

- Options developed through IUDM, to reduce surface water flood risk and improve water quality, combine measures across the urban drainage system that involve all stakeholders. These solutions can be more effective and cost beneficial than ones developed by stakeholders acting individually. Immediate remedial measures or 'quick fixes' can be identified which can have an important impact on flood risk, particularly for frequent flood problems.
- For new developments, drainage strategies can be produced which safeguard downstream areas, protect the development and are adaptable to climate change.

However some challenges have also been identified:

- Data and models for use in IUDM are sometimes poor, not available or not fit for purpose. Using these data and models can result in incomplete or misleading flood risk assessments.
- Pilot projects trialled a variety of techniques for flood risk assessment but new guidance is required to indicate an approach which is appropriate in detail, cost and accuracy for a range of situations. A risk based approach is required to target detailed modelling where it's required. Simplified approaches can be applied elsewhere.
- Current institutional arrangements and responsibilities make it very difficult to coordinate and fund an integrated series of cross stakeholder improvements.
- Many surface water flood risk problems are endemic to urban areas and may only be resolvable through the re-development of town centres and housing so that space can be made for water. The benefits of IUDM may therefore take many years to be realised.
- The skills required to carry out IUDM are in short supply, especially in local authorities who have a key role to play. Efforts are required to build capacity in urban drainage knowledge within local authorities and the Environment Agency.

Two processes are ongoing to build on the benefits identified by the pilot projects and address the challenges. First, Defra is consulting on new policy to address surface water flood risk including the introduction of Surface Water Management Plans (SWMP) [1]. Second, Defra will be publishing guidance for SWMP in 2008 which will support all stakeholders and establish a new framework to deliver the benefits of an IUDM approach. These are key steps in realising the aims of Defra's *Future Water* Strategy[2].

[1] Defra (2008). Improving Surface Water Drainage Consultation http://www.defra.gov.uk/environ/fcd/policy/surfacewaterdrainage.htm

[2] Defra (2008). Future Water, the Government's water strategy for England http://www.defra.gov.uk/Environment/water/strategy/index.htm

Contents

1 Introduction

1.1 Introduction

This report is a summary of the activities of the Defra IUD pilot studies (Figure 1.1 and Table 1.1) which commenced in January 2007 and reported in June 2008. Detailed final reports and appendices from each pilot are now published on the Defra website[3] for further reference. This report is authored by Halcrow Group Ltd who have provided project management services and technical support to Defra throughout the pilot study project. Contributions to the report from IUD pilot project managers together with Environment Agency and Defra staff are gratefully acknowledged.

The overview report provides a thematically based description of the pilots' activities and, in the conclusions section, identifies key learning points for future implementation of integrated urban drainage management (IUDM) through future surface water management plans (SWMP) and other processes. For a detailed understanding of the pilots' activities the reader is encouraged to visit the final reports.

In Autumn 2008 a more comprehensive 'user guide' to SWMP will be published drawing on good practice from the pilots and elsewhere. It will be aligned with emerging policy and regulatory practice.

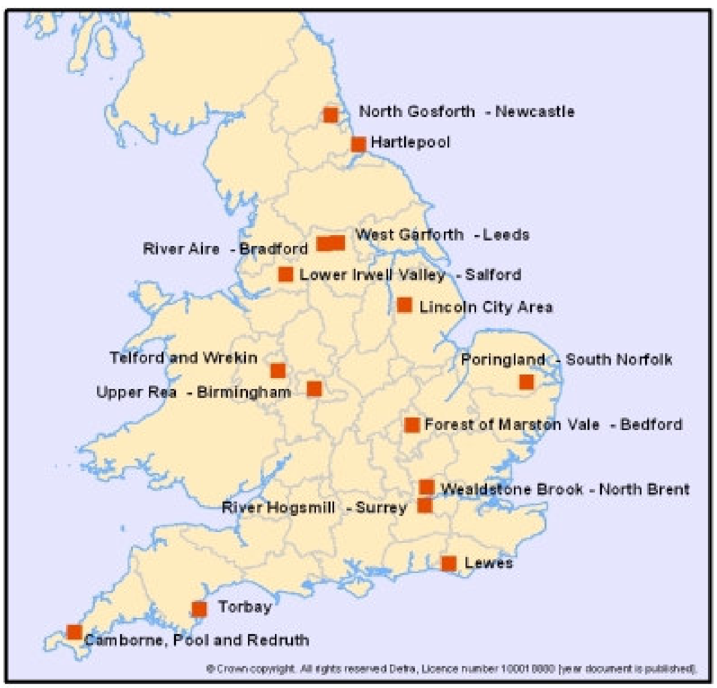

Figure 1.1 Location of 15 Defra IUD pilot projects

[3] www.defra.gov.uk/environ/fcd/policy/strategy/ha2.htm

Table 1.1 Stakeholders and leadership for each pilot project

Pilot	Stakeholders (leader stakeholder in highlighted text)			
	Principal local Authority	Water Company	Environment Agency Region	Other
North Gosforth	Newcastle City Council	Northumbrian Water	North East	
Hartlepool	Hartlepool Borough Council	Northumbrian Water	North East	
West Garforth	Leeds City Council	Yorkshire Water	North East	
River Aire	City of Bradford MBC	Yorkshire Water	North East	
Lower Irwell	Salford City Council	United Utilities	North West	
Lincoln	City of Lincoln Council	Anglian Water	Anglian	
Telford & Wrekin	Telford & Wrekin Council	Severn Trent Water	Midlands	
Upper Rea – Birmingham	Birmingham City Council	Severn Trent Water	Midlands	
Poringland	South Norfolk Council	Anglian Water	Anglian	
Forest of Marston Vale	Bedford Borough Council, Mid Beds District Council, Beds County Council	Anglian Water	Anglian	Bedford Group IDB
North Brent	London Borough of Brent	Thames Water	Thames	
River Hogsmill	Kingston Borough / Epsom & Ewell	Thames Water	Thames	
Torbay	Torbay Council	South West Water	South West	
Camborne, Pool and Redruth (CPR)	Cornwall County Council	South West	South West	CPR urban regeneration company
Lewes	Lewes District Council / East Sussex County Council	Southern Water	Southern	Black & Veatch consultants

1.2 Background

The UK Government's strategy for flood and coastal erosion risk management, Making Space for Water (MSfW)[4], set out a portfolio of approaches to ensure that flood risks are managed more effectively in the future by adopting an holistic, joined-up, and integrated approach. An area of particular concern in

[4] Defra (2005). Making Space for Water – developing a new Government strategy for flood and coastal erosion management in England. First Government response to the Autumn 2004 consultation exercise. www.defra.gov.uk/environ/fcd/policy/strategy/1stres.pdf

MSfW was flooding in urban areas from surface water due to inadequacies in drainage systems; the need for integrated urban drainage management (IUDM) approaches was identified.

In this context, surface water flooding describes flooding from sewers and drains that occurs during heavy rainfall. It also includes pluvial flooding; the inundation of the urban surface which occurs when the design capacity of underground drainage is exceeded. Urban rivers can receive most of their flow from runoff within the built-up area and can therefore be considered part of the surface water or urban drainage system too. Flooding from these rivers should also be considered as part of surface water flooding. Finally, groundwater and runoff from the urban fringe can both contribute to surface water flooding in urban areas. Some of the complexity is illustrated in Figure 1.2 which shows drainage processes in the **Lewes** catchment. The process of working with stakeholders, understanding surface water flood risks and designing and implementing solutions is IUDM.

Another component of IUDM is the management of urban water quality. Although one emphasis of MSfW is flood risk it is also concerned with environmental and social benefits. It's recognised that the design and operation of drainage systems can provide water quality benefits through the proper control of SuDS, combined sewer overflows (CSOs), wastewater treatment and diffuse urban runoff. Water quality aspects of IUDM are addressed fully within the Urban Pollution Management (UPM) Manual[5] and Environment Agency policies.

The Foresight Future Flooding[6] report estimated that currently 80,000 UK properties are at a very high risk of surface water flooding (10% annual probability or greater) causing an average of £270 million of damage each year. Future pressures are predicted to exacerbate these surface drainage problems. Climate change is predicted to increase winter rainfall by 10 – 30% by the 2080s and rainfall intensity could increase by up to 20%. At the same time development pressures and the demand for new homes is increasing the extent and density of urban area and impermeable surfaces. Up to 3 million new homes will be built in England by 2016 and 'urban creep' is increasing hard standing in established urban areas. In London alone, around two thirds of front gardens (equivalent to 22 times the size of Hyde Park) are already partially paved over to provide off-street parking[7]. In combination, these two trends are set to significantly increase surface water flood risks. The Foresight report estimated that the number of properties at risk could increase to 300,000 – 400,000 by the 2080s, potentially leading to billions of pounds of damages on average each year. The events in England in the summer of 2007 were an illustration of what might become more common in the future. The Environment

[5] FWR, Urban Pollution Management Manual, 2nd Edition, October (1998)
[6] Evans E., Ashley R., Hall J., Penning-Rowsell, E., Saul, A., Sayers, P., Thorne, C. and Watkinson, A. (2004). Foresight. Future Flooding. Scientific Summary: Volume I Future risks and their drivers. Office of Science and Technology, London.
[7] Crazy paving: the environmental importance of London's front gardens. www.london.gov.uk/assembly/reports/environment/frontgardens.pdf

Agency estimates that two thirds of the 57,000 flooded homes were flooded from surface water[8].

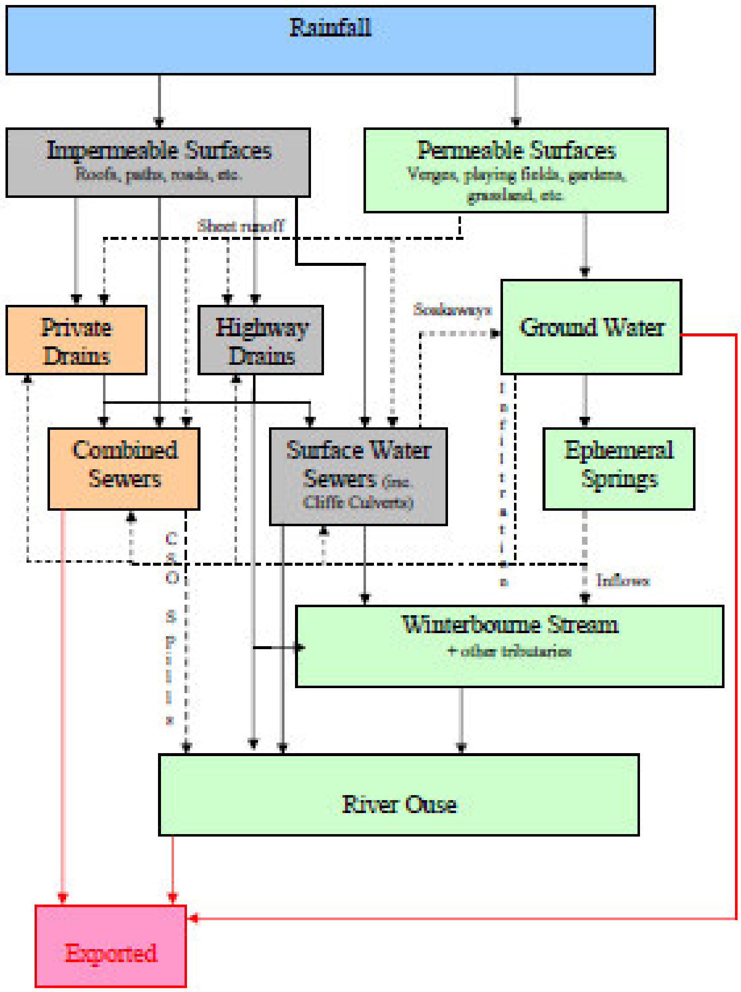

Figure 1.2 Drainage processes within the Lewes catchment

In MSfW the Government recognised that the physical and institutional complexities of urban drainage systems make it difficult to plan and deliver systems with reduced flood risk. The urban drainage system is a complex interaction of the urban terrain, buildings, highways, public sewers, private sewers, rivers and in some cases the sea. Moreover, and uniquely in England within the UK, there are complex institutional and funding arrangements which divide responsibilities between water companies, the Environment Agency, planning departments in local government, housing developers, householders and internal drainage boards. As a consequence urban drainage solutions have not always been as cost effective, sustainable and robust than might have been possible had a more integrated approach been adopted. Current practice is

[8] Review of 2007 summer floods. http://publications.environment-agency.gov.uk/pdf/GEHO1107BNMI-e-e.pdf?lang=_e

especially unsuited to respond to the increasing flood risk drivers of housing growth and climate change.

In response to these challenges, MSfW project HA2, Urban Flood Risk and Integrated Drainage[9], was initiated in 2005 to test three main objectives, through fifteen pilot projects:

- to understand the causes of flooding in urban areas and the best ways of managing urban drainage to reduce flooding;
- to examine the effectiveness of partnership working between various drainage systems currently and how this partnership can be improved to find solutions to flooding problems, and;
- to test the effectiveness of new approaches to urban flood risk management, including: use of hydraulic models, surface water management plans, sustainable drainage systems (SuDS) and the managed routing of drainage exceedance flows.

Project partnerships applied to join the IUD programme and were initially informed by an approach to IUDM developed through a scoping study which reported in March 2006.[10] The pilots were selected to test different aspects of IUDM at a variety of scales. The pilots were funded by Defra (with support from UKWIR) with between £40,000 and £200,000 each. The programme of activies was steered by a Project Board including officials from Defra, the Environment Agency, Ofwat[11], Water UK[12], the Local Government Association, Department for Transport, CCWater[13] and Communities & Local Government.

The principal outcome of the projects will be new national guidelines for implementing IUDM together with evidence to support proposed changes to policy and regulation. The experience of the pilots will also help inform decision makers about where IUDM approaches are required to address flood risks.

The IUD pilots and Sir Michael Pitt's interim report[14] on the 2007 floods have had a direct influence on Government's future strategy towards the management of urban flood risk. In February 2008, Government published its Water Strategy, Future Water (Defra, 2008d), which proposed that Surface Water Management Plans (SWMP) become the vehicle through which it will deliver IUDM and reduce urban flood risk. The proposals are set out in more detail in the Improving Surface Water Drainage consultation (Defra, 2008c) which asked for views on who should lead SWMPs and whether they should be statutory instruments.

[9] www.defra.gov.uk/environ/fcd/policy/strategy/ha2.htm
[10] www.defra.gov.uk/environ/fcd/policy/strategy/scoperev.pdf
[11] The Water Services Regulation Authority
[12] Body representing all UK water and wastewater service suppliers at a national and European level
[13] Consumer Council for Water
[14] Learning lessons from the 2007 floods. An independent review by Sir Michael Pitt. www.cabinetoffice.gov.uk/upload/assets/www.cabinetoffice.gov.uk/flooding_review/flood_report_lowres.pdf

It is proposed that the SWMP should:

- map and quantify surface flows and drainage with sufficient detail to enable local and strategic flooding problems to be tackled;
- produce a delivery plan that clarifies responsibilities and then directs resources at tackling surface water flooding, prioritising areas at greatest risk first;
- influence local planning policy such that new development occurs primarily in areas of low surface water flood risk or where risk can be managed effectively, making use of SuDS where appropriate, and;
- be periodically reviewed, possibly including independent scrutiny of planning and resource decisions to gauge progress in tackling the most serious problems first.

To achieve this, all stakeholders will be required to work together in a collaborative partnership as demonstrated in the IUD Pilots. Once executed a SWMP should deliver:

- Investment strategies in drainage that are the most cost-beneficial to the community in terms of flood risk avoided. For example by removing surface water from sewers to prevent uncontrolled downstream sewer flooding.
- Greater clarity on roles and responsibilities with reduced duplication of effort across different stakeholders.
- New housing and commercial developments where the drainage has been strategically planned and does not increase surface water flooding downstream.
- Emergency plans which are informed by information of where surface water flood risks are greatest.
- Water quality benefits which result from the implementation of SuDS and reduced pressure on combined sewer systems.

Specific elements of a SWMP would include:

- a risk assessment, where the likelihood and consequence of future flooding (factored by climate change and urbanisation effects) is quantified, shared and presented in monetary or other ways, and;
- a rational decision making process where the most cost-beneficial combination of structural (engineering) and non-structural (policy and behavioural) measures are determined by the partnership and implemented by the appropriate stakeholder.

1.3 Report structure

This report is structured to reflect key stages of the proposed surface water management plan approach. Evidence, experience and a range of methods from the pilots projects are thematically arranged in the following structure:

- **Building partnerships** – how the pilots have worked across institutional boundaries and engaged with all stakeholders included the public

- **Data collation and collection** – how the pilots have drawn on existing information to develop a shared understanding of current drainage assets and flood risks.

- **Risk assessment** – how the pilots have used computer models to represent flood mechanisms and understand the likelihood and consequence of flooding

- **Solutions** – how the pilots have either a) developed solutions to existing surface water flooding problems or b) master planned surface water drainage in new developments so that the system is robust and well managed and maintained for the future.

2 IUD pilot activities

2.1 Building partnerships

Table 1.1 sets out the key stakeholders involved in each pilot project and the lead organisation in each case. One of the purposes was to test out different organisations in the leadership role. Most pilot projects had the local authority, the water company or the Environment Agency in a lead role. Others tested the leadership of an internal drainage board (**Forest of Marston Vale**), a regeneration company (**Camborne, Pool and Redruth**) or a technical consultant acting on behalf of the stakeholder partnership (**Lewes**).

The overall experience was that any organisation can contain individuals with the skills and drive to lead integrated urban drainage work. The critical success factor in the pilots were the people rather than the institutions leading; a reflection that IUDM is a new approach where there is currently little embedded experience within stakeholder groups. As anticipated, water companies were effective in leading where surface water management issues were dominated by the operation of the public sewers system in highly urbanised city areas (e.g. **North Brent** and **Hartlepool**) but even here they required input from other stakeholders to understand interactions with water courses and areas contributing runoff from the urban fringe.

Direct links to, and responsibility for, the planning system made local authorities well placed to address the needs of new development. This is demonstrated in the **Telford and Wrekin** pilot where a future surface water drainage strategy (e.g. the use of SuDS) has been considered by the local authority and developers will be required to adhere to instructions embedded as supplementary planning documents within the local development framework. A similar role was played by CRR regeneration company (**Camborne, Pool and Redruth**) for a major brownfield re-development; an approach which has seen SuDS planned on a strategic basis with benefits to water quality and flood risk.

In many areas the complexity of local government organisation or the non-alignment of catchment with administrative boundaries necessitated the involvement of a number of local authority organisations. For example in **Lincoln** the following local authorities were involved: Lincolnshire County Council, City of Lincoln Council and two separate district councils. The **Lincoln** pilot was a successful forum for discussing flooding issues and this is planned to continue through the formation of a Lincoln Drainage Group chaired by Lincoln City Council.

In the **Hogsmill** pilot the river catchment traverses a borough of Surrey County Council (Epsom and Ewell) and a London Borough (Kingston-upon-Thames). Both local authorities were involved in the pilot, though neither was well placed to take a leading role because they did not have mandates or knowledge outside of their boundaries. In this case, the Environment Agency acted to coordinate the work and broker discussion between the two adjacent Authorities (Figure 2.1)

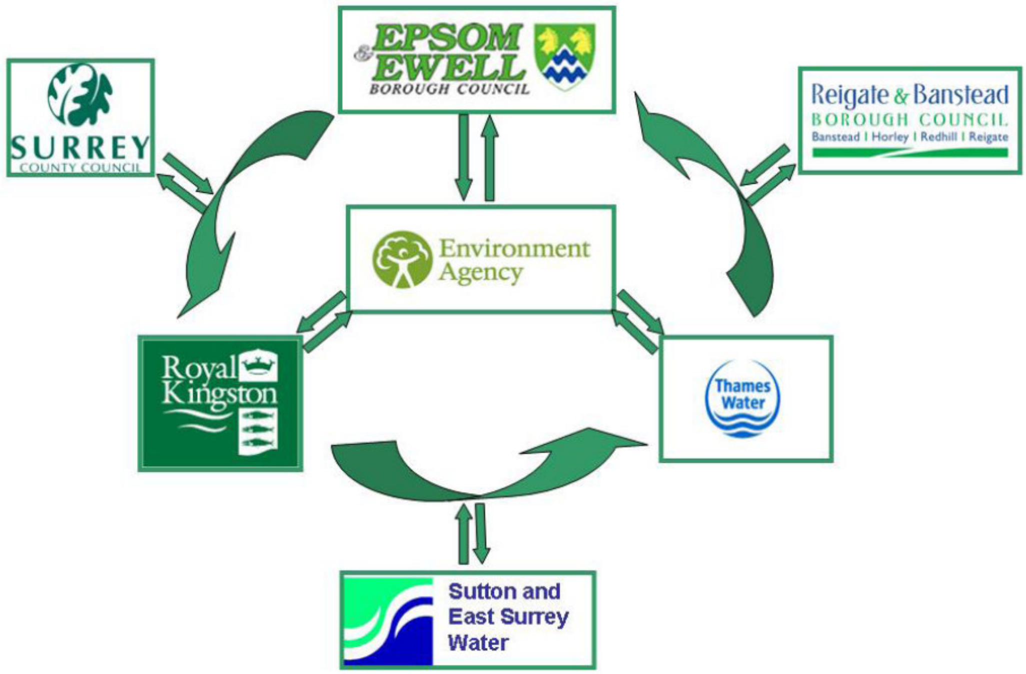

Figure 2.1 Hogsmill pilot stakeholders

A quotation extracted the Hogsmill report highlights the benefits of working across legislative boundaries:

> *"I became convinced of the efficacy of this pilot study when I learned that what we do in terms of development within our Local Authority boundary has a downstream impact on flood risk in Kingston"*
>
> -Mark Berry, Head of Planning, Epsom & Ewell BC

In some cases the pilots built on the good work of pre-existing cross institutional bodies, usually established on a voluntary basis in response to recent flooding incidents. Two examples are the North Brent Flood Working Group (**North Brent**) and the Ouseburn Catchment Steering Group (**North Gosforth**). This type of organisation is already well connected with the local population and is aware of their concerns and the knowledge they can share to develop an understanding of flood mechanisms and pathways. Existing groups are very useful building blocks for integrated urban drainage partnerships. The Marston Vale Surface Waters Plan, produced in 2001 on the initiative of the Bedford Group of Drainage Boards and the Forest of Marston Vale demonstrates the merits and successes than can be achieved through partnership working to devise pragmatic drainage solutions. The **Marston Vale** pilot study has strengthened momentum within the Marston Vale Surface Waters Group; generated an extension in membership parties, and; led to the creation of a spin-off team to progress future revision of the Surface Waters Plan.

The **West Garforth** pilot actively sought input from local residents who helped identify pathways and scope possible solutions (Figure 2.2).

Figure 2.2 Drawing of flood routes made by resident of West Garforth

The **Poringland** pilot was studying a large village where there was close involvement with Parish Councillors and community groups, all interested in the operation of their community's drainage systems.

Most pilots shared information and data easily, though in many cases data were insufficient or unreliable (see Section 2.2). There was caution on the part of water companies around sharing information that might be inaccurate or misleading and so in some circumstances Memoranda of Understanding were developed (e.g. in **Lincoln** and **Torbay**) to manage this process. In all circumstances the stakeholders in each pilot found the process of openly discussing surface water and drainage issues very positive. The benefits were understanding one another's priorities, funding sources and constraints. Through a joint understanding of each others roles and responsibilities they were better equipped to propose joint and innovative solutions (see section 2.4) rather than ones relying on default assumptions (e.g. upsizing of sewers).

While all pilots benefited from exchanges among principal stakeholders some (e.g. **Lower Irwell**, **Upper Rea**, **North Gosforth**, **West Garforth**) engaged with a wider circle of developers, the public and national bodies. This helped identify many of the problems with the current management of surface water and drainage systems and the barriers to taking a more integrated approach. The participants in the **Upper Rea** pilot are building on their work through the Birmingham Water Group focussing on planning and flood risk.

2.2 Data collation and collection

Pooling data on drainage assets and historical flooding was an important activity for many pilots. It brought together data not usually assembled in the same place. This is a key first step in developing a shared understanding of the problems. The following sources of data were accessed:

- Foul, combined and surface water sewer records and models;
- Water company sewer flooding records,
- Local authority flooding records;
- Environment agency flood records
- River flood risk assessments (models and maps);
- Digital elevation data;
- Highway drainage records;
- Street gully location records;
- Aerial photography

The data were often incomplete, out of date and sometimes commercial or licensing arrangements made sharing with third parties difficult. The **West Garforth** pilot highlights the absence of any statutory maps of culverted watercourses. Historically this has led to situations where services are routinely laid through culverts, creating substantial reductions in capacity.

Some pilots identified excellent existing holdings of data which were then added to further. In **Torbay**, for example, surface water flooding had been reported on the Environment Agency's Flood Recognisance Information System (FRIS) from 1970 until 2007. Figure 2.3 illustrates these data with the location of flood photographs or video (red triangles), flooded property (green pentagons) and flooding reports (purple crosses).

The pilots have shown that data provision needs to be augmented with stakeholders knowledge of their asset information, data and models. A straight transfer of data is much less valuable than data accompanied by knowledge of asset performance or preferably a knowledgeable person. This is important for understanding data quality and its limitations when being applied in modelling and risk assessments. For example, many existing models of sewer networks were designed for different uses and are not considered 'fit for purpose' when used for strategic scale flood risk assessment. Water companies sewer models and knowledge of their systems has been essential for the pilots in understanding flooding mechanisms at the local scale.

The act of sharing has highlighted cost efficiencies and showed that in the future individual organisations need not purchase the same expensive data products.

Assembling these data on a common GIS platform was a very powerful way of visualising what was currently known about drainage and flooding in the pilot areas. **Hartlepool**, **Upper Rea**, **Hogsmill** and **Telford & Wrekin** all undertook extensive mapping exercises which helped identify areas vulnerable to flooding (because it had occurred there frequently in the past) and began to indicate what the cause might be. The data became more powerful when combined with the results of straightforward GIS based analysis of slopes and flow pathways (e.g. **Aire** and **Hogsmill**).

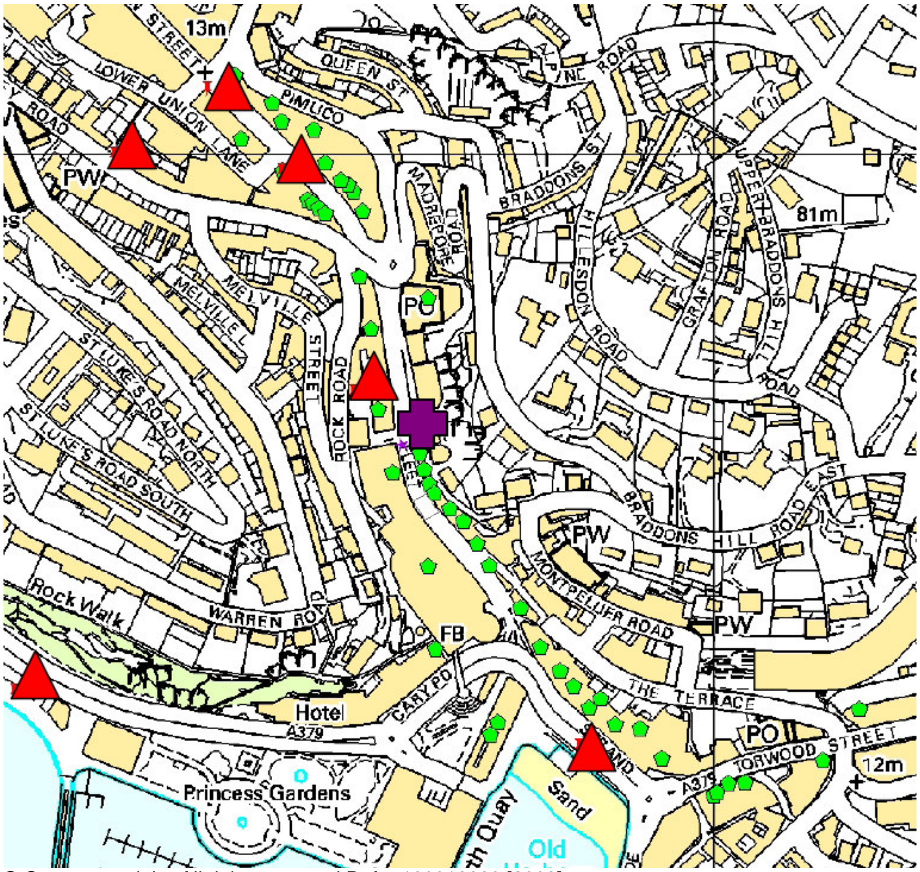

Figure 2.3 Flooding locations in Torbay recorded on EA's FRIS

North Brent, **Torbay**, **West Garforth and Lincoln** all experienced flooding in June and July 2007 and used this experience to develop their understanding of flood mechanisms. Figure 2.4 shows flooding in **Torbay** in June 2007 and indicates the location of a public information kiosk used to publicise the pilots which had been in place a few weeks previously.

The **Lower Irwell** project demonstrated that key spatial data from multiple sources could be consolidated into an easily-distributed interactive, layered, pdf format, which was readily understood by a wide range of stakeholders, especially those without access to a GIS system (Figure 2.5)

Previously, the complex institutional arrangements in urban drainage and surface water management had made this type of data sharing unusual and unlikely to occur on a voluntary basis. Data sharing has proved so informative that **Hogsmill**, **Lewes**, **North Gosforth**, **Torbay, Lincoln** and **West Garforth** have agreed to continue to collate new flood incident data and give due consideration to continuing to work in partnerships after the pilot work completes will be given. Experience in the **Lower Irwell** project, where stakeholder interactions were already good, has reinforced the value of full co-operation and partnership working. This is reflected in the way in which AGMA[15] and other stakeholders are cooperating on the Greater Manchester SFRA[16] work.

Figure 2.4 2007 flooding in Torbay

Some of the pilots collected new data as part of their work. In **West Garforth** a culverted watercourse was CCTV surveyed which immediately highlighted flow restrictions, some of which were removed. In **North Gosforth** a detailed hydrometric survey was carried out to understand response of the Ouseburn to urban runoff. In **Poringland** a new groundwater investigation was carried out which has informed future policy towards suitability for SuDS in different parts of the village. However, in many cases the absence of data about important drainage assets hampered the pilots' work and there was insufficient time or budget to improve this situation. For example, poor information about culverted watercourses (**Lewes**), highway drainage (**CPR and Lincoln**) and surface water sewers (**North Brent**) prevented a comprehensive consideration of the role these assets played in contributing to flooding.

[15] Association of Greater Manchester Authorities
[16] Strategic Flood Risk Assessment

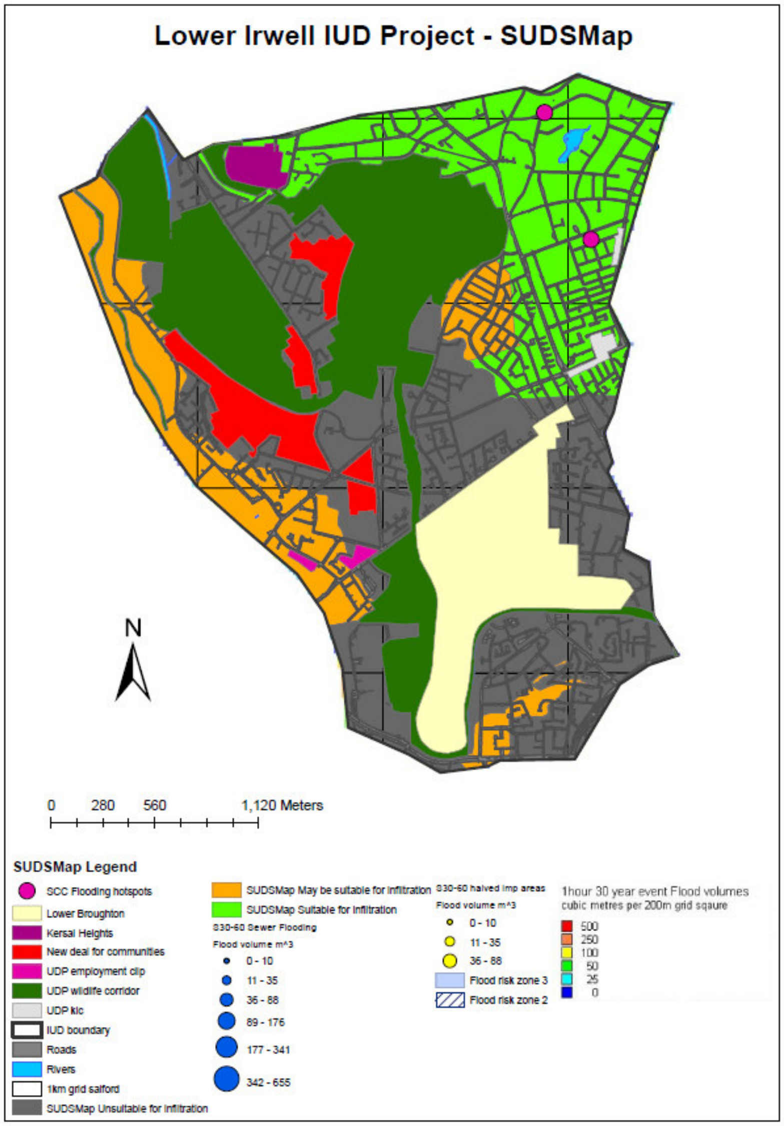

Figure 2.5 Lower Irwell SuDS map

2.2.1 Risk assessment

A risk assessment goes beyond simply looking at when and where it has flooded historically. It uses hydraulic models of the urban area to predict where it will flood for storms of different severities and considers the consequences of the flooding, whether in terms of the number of properties affected or the financial damages caused. It's also able to consider what future conditions may be like through introducing factors such as climate change and urban creep[17].

The range of methods applied by the pilots was extensive and the choice dictated by the availability of existing data and models and the individual flood

[17] The process of increasing impermeable area in urban areas through loss of green space, the paving of front gardens and construction of rear extensions etc.

mechanisms at work. The hydraulic models used represented the sewer system, rivers, culverted water courses and the urban surface. The traditional way of running these models is to operate them individually, but some of the pilots used the latest software tools to run integrated models of the drainage system to gain a fuller understanding of the problems.

An assumption of nearly all the modelling approaches was that surface water flooding comes from surcharged sewers, overloaded beyond their conveyance capacity. Direct surface runoff resulting in pluvial flooding as a result of inadequate drainage systems was not represented because the modelling software used to represent the sewer systems does not readily represent flow generation and routing above ground. It's recognised that this type of flow is very important, especially when the underground sewer system is already surcharged and surface water begins to pond on the surface. Modelling surface water flooding from surcharged sewer systems only provides an approximation of what might happen and identify hotspots. It does not generally consider the hydraulic capacity of road gulleys or the pathways routing surface water towards them so that depth and the consequence of flooding can be calculated.

A simple approach, deployed by the **Hogsmill** and **Lewes** pilots, is to consider the volume of flooding from sewers and relate the volume to the number of properties that might be damaged. The assessment can be made from historical experience or a simple consideration of the topography above ground. The **Lower Irwell** pilot demonstrated how model generated sewer flooding maps could be presented in a new way which was much more informative than reporting the location of 'DG5' [18] properties (Figure 2.6). It was widely recognised that DG5 sewer records report historical incidences of sewer flooding and do not indicate the risk of surface water flooding especially in response to large rainfall events. The question of sharing DG5 data is controversial because the information is easily misinterpreted and may disadvantage individual properties that have flooded without reference to water company programmes to improve sewerage in that area. However, sharing DG5 data within the partnerships was helpful for understanding the consequences of lower frequency events and the location of hotspots suffering frequent sewer, surface and fluvial flooding.

[18] Ofwat Level of Service indicator number 5 relating to Properties/Areas at risk of sewer flooding as a result of hydraulic inadequacy

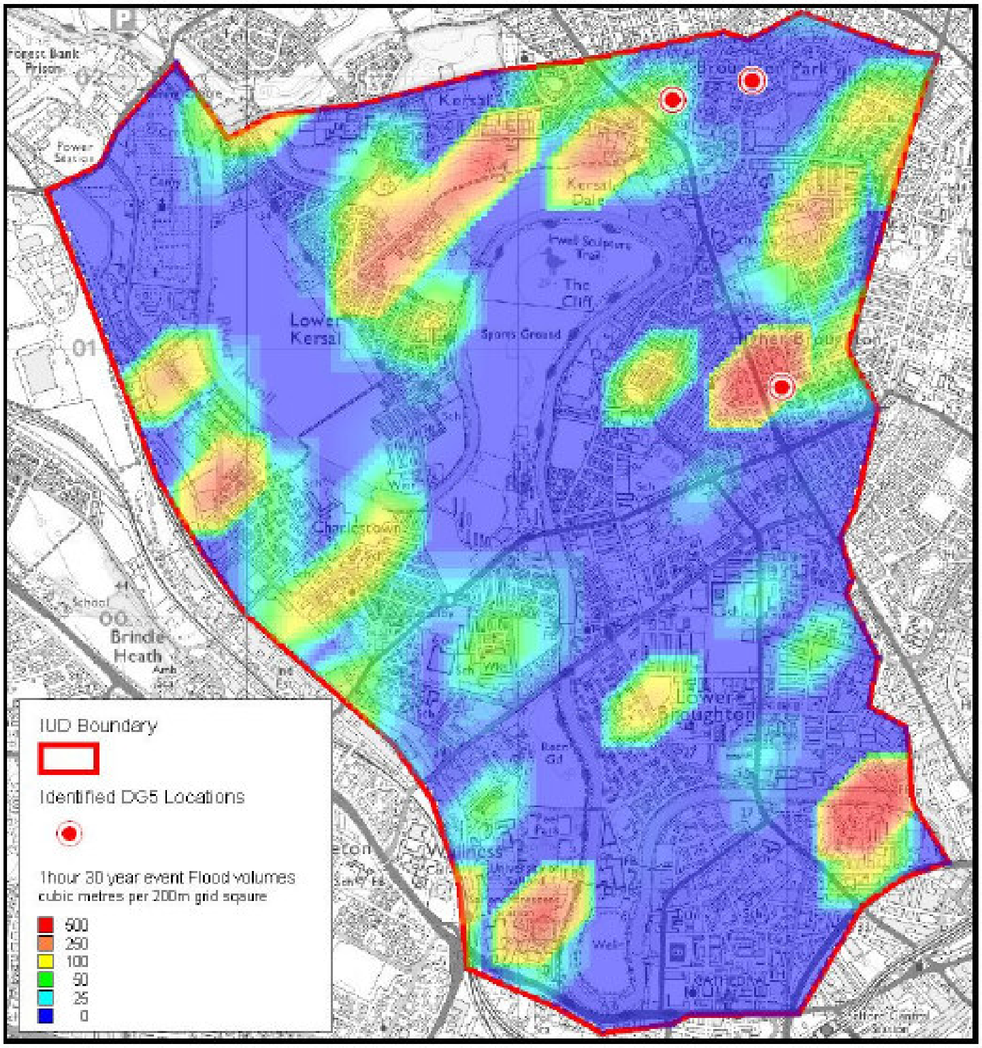

Figure 2.6 Sewer flood risk map and DG5 locations

The next level of analysis is to consider where exceedance flows go once out of the sewer system. Hydrographs of the flood flows can be applied to 2d models of the urban surface built using digital elevation data. These models route flows around buildings, along roads towards watercourses or low points where ponding can occur. The **Torbay** and **Lincoln** (Figure 2.7) pilots used this approach which is informative for understanding the source, pathway and receptor interactions. However, for medium magnitude events it probably over predicts the degree of flooding because flows do not return to the underground system and remain 'trapped' on the surface. For very large events it's a better representation since the underground system is likely to remain surcharged for long periods.

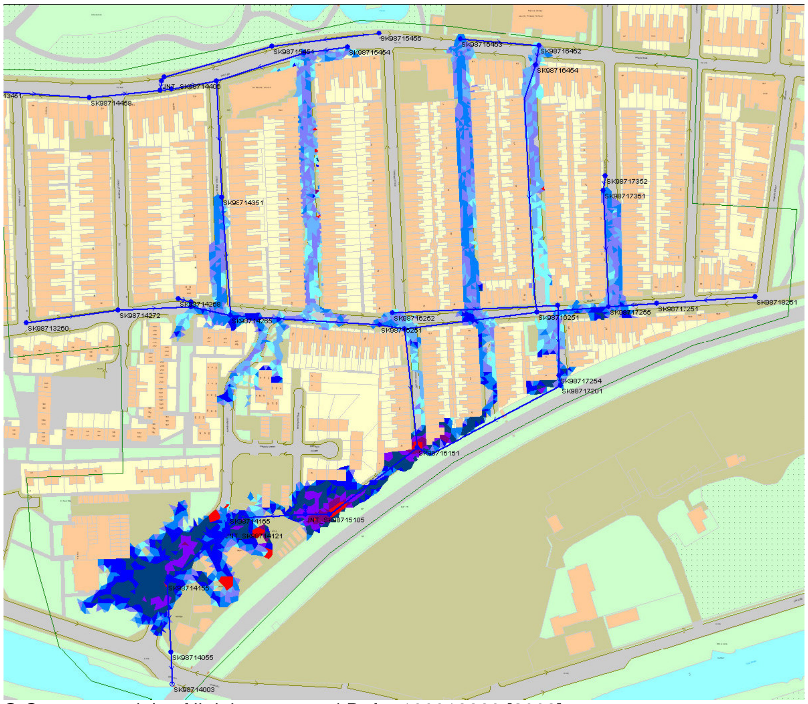

Figure 2.7 Routing of surface water in the Lincoln pilot study

The third level of analysis, used by **North Brent** (Figure 2.8) and **Torbay**, integrates the above and below ground systems more completely, allowing a more realistic exchange between the systems to be represented. This achieves a much improved match between model predictions and observed data. Further complexity can be added by including interactions with urban rivers. The **Upper Rea**, **North Brent, North Gosforth** and **Lincoln** pilots all investigated these interactions and their potential to worsen fluvial or surface water flooding.

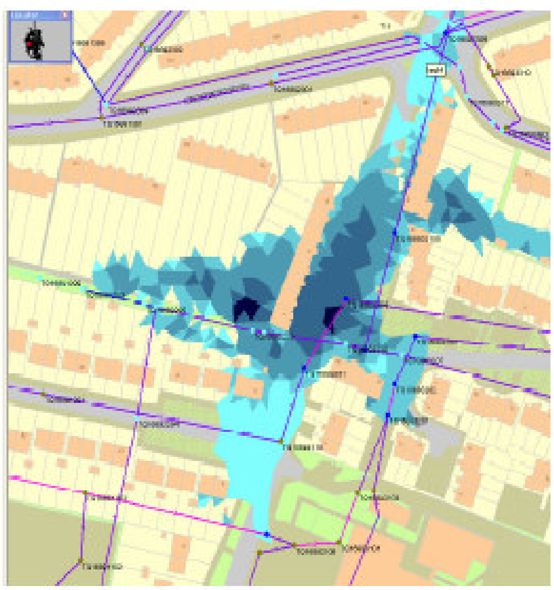

Figure 2.8 Predictions of surface water flooding in the North Brent pilot study

Where a particular issue is of concern the modelling approach can be modified. In **North Gosforth** there was concern about the flood response in the Ouseburn due to contributions from urban catchments. Modelling therefore focussed on predicting river flows without explicit representation of the urban drainage system at all. Model accuracy was improved through using new hydrometric data and the potential for the river to impede operation of sewer outfalls (and hence exacerbate flooding in the drainage system) was investigated.

The **Aire** pilot presented an approach which alters the complexity of modelling depending on flood risk consequences (Figure 2.9). An analysis of flow pathways (derived from the digital elevation data only) is cross referenced with plans of surcharging manholes to establish whether downstream property is at risk. If it is, then a more detailed modelling approach is triggered. It's important to apply the appropriate complexity of modelling for the objective since very detailed modelling is slow, expensive and requires expert modellers.

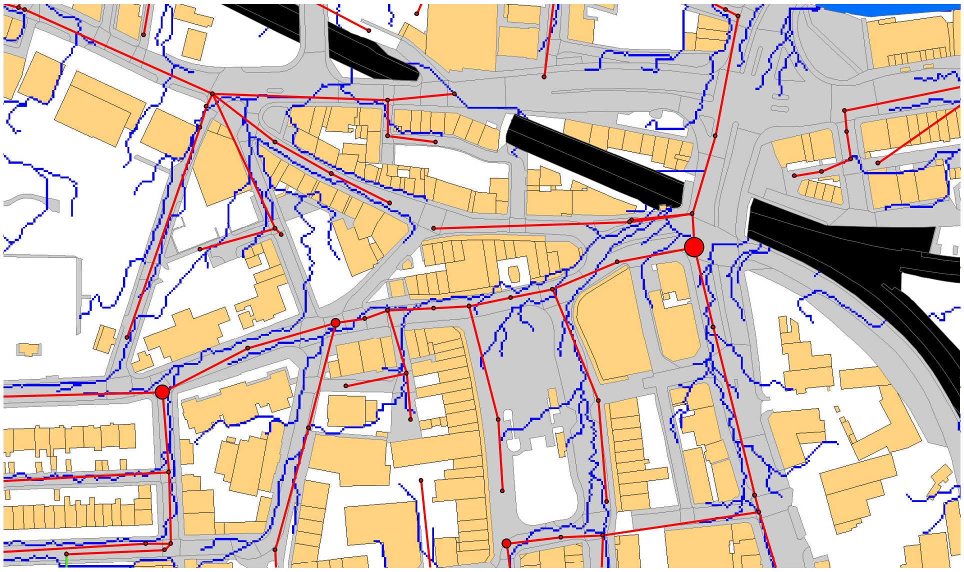

Figure 2.9 Surface water flow pathways identified in the Aire pilot study

An argument can be made for ignoring the operation of the underground drainage system altogether by assuming that an extreme event has completely filled it at an early stage and most runoff remains on the surface. The approach can be modelled by applying rainfall inputs directly to 2d models of the urban area which formula to generate runoff across the surface. The **Telford** and **Upper Rea** (Figure 2.10) pilots deployed this technique and showed areas at risk from ponding or deep and fast flows. An alternative argument suggests that the operation of the underground system is critical because it determines where and when exceedance flows first occur. The range of event return period at which this happens in the pilot projects is between 2 and 30 years. Therefore, for quite modest storm events surface water flooding can occur and will do so frequently. The consequence of frequent low magnitude flooding should be considered alongside that of infrequent higher magnitude flooding.

Figure 2.10 Predicted surface water flooding depths in Upper Rea catchment for 100 year event plus climate change

Using a range of modelling approaches pilots have quantified flood risks and how these might change in the future. Some examples are:

- The Hogsmill pilot estimates that for the 100 year return period (1% probability) rainfall event nearly 5,000 properties would be flooded from river, surface water, overland flow, sewers and groundwater. On an annual basis the damages incurred from all sources of flooding are estimated at £3million. Following allowance for climate change, with increased rainfall, these damages are estimated to increase to £7million of which 30% can be attributed to surface water

- The Aire pilot modelled indicative surface water flood volumes, under climate change and urban creep scenarios. Climate change alone was predicted to increase surface water flood volumes by 39% by 2085, for the 1% probability event. When climate change and urban creep were modelled there was a 77% increase in predicted surface water flood volume, compared to current volumes.

- The Upper Rea pilot estimate that 1400 properties are at risk from surface water flooding for the 1% probability event.

- In West Garforth there are estimated annual damages of £1.8 million from surface water, increasing to £2.2 million in 2085 because of climate change.

A flood risk assessment which maps flood extents is a very useful interim output of an integrated urban drainage study. It can be used to inform emergency planning officers about which urban areas and transport routes are vulnerable to surface water flooding. A further purpose is to inform local authority planners which areas are vulnerable to surface water flooding. Planning policy PPS25 (Development and flood risk) establishes a framework for this analysis but current practice tends to overlook the importance of surface water flooding. The

Hogsmill pilot prepared a 'Flood Risk Tool' (Figure 2.11) targeted at local authority planners so that they could easily consider the flood risks, from all sources, for areas considered for new development. The tool is web based and accessible by multiple agencies.

Figure 2.11 Hogsmill's Flood Risk Tool

2.3 Solutions

None of the pilots had the objective of securing solutions to current surface water flood risks. However, some have used the tools developed during risk assessment to propose structural (engineering) or non-structural (policy or behavioural) responses. The greater understanding achieved through an integrated risk assessment has helped identify solutions which can be cost effective (i.e. benefits outweigh the costs) and deliverable through the coordinated involvement of more than one stakeholder. It's recognised that some surface water flooding solutions will take many years to implement possibly alongside the re-development of urban areas; it's only then that more imaginative options that 'make space for water' can be considered. However, in some cases simple 'quick fix' solutions have been identified which will have an immediate and positive impact. For example, in **West Garforth** obstructions in a culverted water course were identified and some were removed. In **Poringland**, drainage ditches were dug out and will be better maintained in the future to improve their effectiveness.

The **Hartlepool** pilot proposes flood risk solutions, developed using an IUDM approach, which could save 20% of the cost of a combination of traditional stand alone solutions to resolve fluvial, surface water and sewer flooding. This is achieved by viewing the drainage system as a whole and introducing upstream storage which benefits properties at risk of flooding downstream.

The **Lewes**, **West Garforth** and **Torbay** pilots conducted cost benefit assessments to justify or prioritise a range of flood mitigation measures. Using a variety of methods they compared the cost of intervention with benefits expressed in terms of flood damages that would be avoided. Some did this in the context of increasing risk through urbanisation and climate change. Overall, the benefits of intervening did not massively exceed costs and the ratios fell below what would normally be accepted in the prioritisation of river or coastal flood defence schemes. This is probably because of the high costs of construction in urban areas compared to the relatively small number of properties which are protected. It's recognised that methods for assessing flood damage and optimising solutions for surface water and urban drainage require further development and that assumptions used in fluvial and coastal assessments might not be appropriate in the urban drainage context.

Table 2.1 shows how the **West Garforth** pilot has tested the costs and benefits of responses to flooding at a number of locations.

Table 2.1 Cost and benefits of responses in West Garforth

Flooding locus	EAD £k		Responses	Costs £k	Performance of responses		Residual EAD £k		EAD benefit ratio**		EAD current cost benefit
	Current	2085			Current (years)	2085 (years)	Current (£K)	2085 (£K)	Current	2085	EAD reduction/£ spent on response
Lowther Road (A)	373	460	1. Replace local pipes to remove adverse gradients 2. Construct new pipe to take flows south 3. Disconnect some upstream inputs (roofs, rainwater barrels)	390 250	10	5 years	108	200	0.29	0.43	0.41
Oak Drive (B)	228	353	1. Storage at school (pond) 2. Swale along Oak Drive 3. Disconnection (roofs rainwater barrels)	70 150 250*	50	15 years	29	127	0.13	0.36	0.42
Barleyhill/Rec. Ground (C)	107	183	Storage pond at recreation ground	120	30	10 years	23	97	0.21	0.53	0.7
Ninelands Lane (D)	477	695	Disconnect factory hard standing (pond)	110	100	5 years	7	288	0.15	0.41	4.27
Richmond Rd/Glebelands (E)	186	246	Only solution is upsized pipes (disconnection removes little inflow)	220	30	10 years	9	65	0.05	0.26	0.80
Various other areas than above	441	279	Local solutions will be required – these are relatively modest problems currently but will increase by 2085	-	-	-	441	279	-	-	-
Totals	1812	2216	-	1560	-	-	617	1056	0.34	0.48	0.77

The solutions which highlight the benefits of an integrated approach include interventions from many stakeholders. The **Lewes** pilot proposes a cross-agency 'delivery plan' which includes elements of flood defence (EA), sewer separation (water company), minor works to culverted drainage (local authority), maintenance of overland flow routes (local authority) and installation of additional road gulleys (local authority).

In **North Brent** it was found that isolated solutions such as partial separation and capacity enhancements would not satisfactorily alleviate flooding in the catchment. **North Brent** proposed three integrated solutions which examined:

1. Partial separation of the foul and surface water system;

2. Partial separation of the foul and surface water system and capacity enhancements, and;

3. Partial separation of the foul and surface water system, capacity enhancements, and river attenuation.

Of the different options assessed, the greatest benefit (in terms of reduction in flood volumes) was achieved with integrated option 3. This option reduced flood volume for the 1 in 30 year event from 175,000m^3 to 58,000m^3.

A subset of pilots (**Telford & Wrekin**, **CPR** and **Forest of Marston Vale**) were concerned with drainage strategies for new development. They focussed on how local authorities and developers need to work together to master plan surface water drainage so that: flood risks downstream are not increased; and terms for the adoption and maintenance of SuDS are agreed. The purpose is to avoid discharge of surface water to water company sewers and prevent the *ad hoc* provision of ponds and structures which are poorly planned and difficult to maintain. The IUDM approach has supported the effective delivery of PPS25 objectives in these areas.

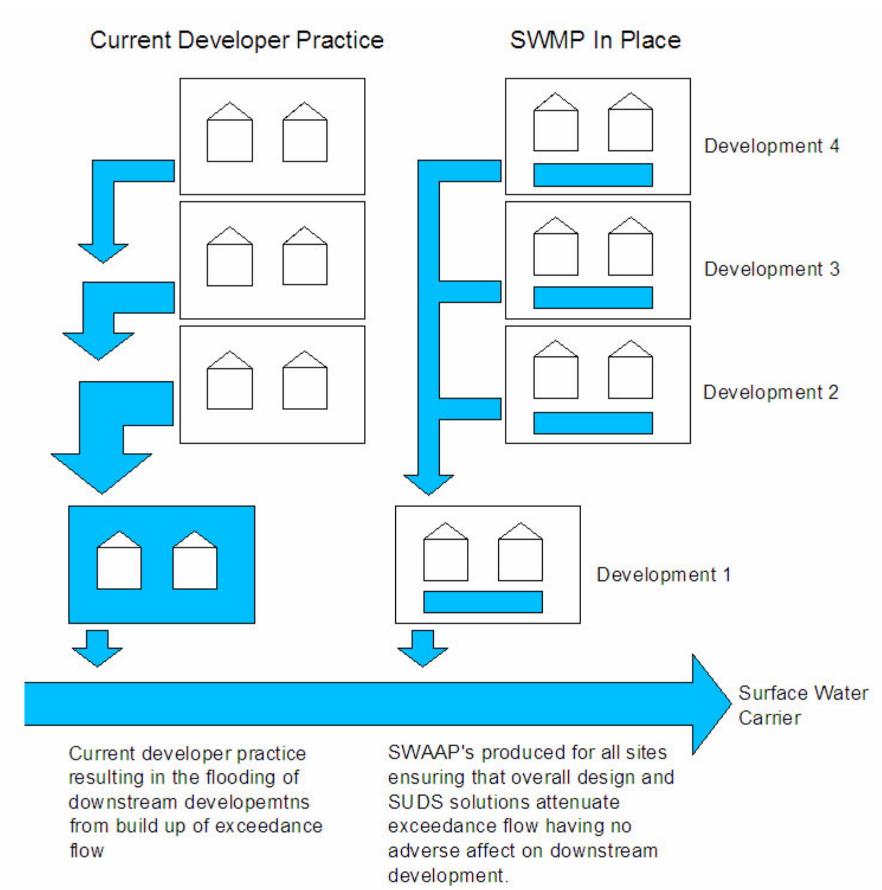

Figure 2.12 **Strategically planned surface water drainage in Telford**

Under the leadership of Bedford Group IDB, **Forest of Marston Vale** pilot reviewed lessons learned from their own Surface Water Plan in place since 2001. This was an early and exemplary effort in providing strategic surface water infrastructure. Important experience has been gained in how to get around legal, financial and technical obstacles.

In **Telford & Wrekin** new development pressures have prompted the development of a surface water management plan which identifies the strategic drainage requirements for each parcel of new development land (Figure 2.12). The purpose is to aid the developer in the design process and speed up pre-development enquiries. The procedures have been embedded in supplementary planning documents (SPD) which form part of the local development framework (LDF). Delivering surface water drainage using the planning system should ensure that the procedures are adhered to by all parties and will result in drainage provision which is effective and strategically planned.

Similarly, in **Camborne, Pool and Redruth** a strategic surface water plan has been developed for a large brown and green field re-development of 6000 homes. Here, a 'drainage trust' is proposed that will provide a strategic network of open channels and ponds into which developments can discharge surface water so long as on-site attenuation to specified standards is also provided by developers. This reduces the burden on developers to provide large drainage structures because the runoff from each site is allowed to exceed existing rates since flows are buffered by the strategic system. At the same time surface water connections to the existing foul sewer system will be removed, releasing capacity for new foul connections and reducing pollution through combined sewer overflows (CSOs) to the coast.

Other pilots (e.g. **Lower Irwell** and **Poringland**) have provided guidance to developers, planners and others on the suitability of different type of SuDS around their catchments identifying where infiltration is and isn't possible due to underlying ground conditions. **Lower Irwell** highlighted certain misunderstandings relating to SuDS. They are not only infiltration devices. Permeable pavements, green roofs and rainwater harvesting, *inter alia*, provide workable SuDS approaches that do not rely on infiltration and may readily be integrated within high-density urban landscapes.

3 Conclusions

The Defra IUD pilot projects were instigated in acknowledgement of the complex physical and institutional factors that result in surface water flood risks that are especially sensitive to pressures from climate change and increasing urbanisation. The flood events during 2007 re-emphasised the need for a new approach to urban drainage and surface water management. These conclusions are drawn from pilot project experiences.

3.1 Benefits

Numerous benefits have been delivered through stakeholders working together, considering surface water flood risks in an holistic way and developing mitigation measures that consider cost and benefit and all parts of the urban drainage system. Some key benefits are:

- Working together in partnerships has enabled stakeholders to share information, develop a collective understanding of flood mechanisms and risks, and learn about each other's roles, responsibilities and funding arrangements. It's recognised that communities are important stakeholders who can contribute to understanding flood risk and selecting mitigation measures.

- There are large quantities of historical data related to surface water flooding that can help stakeholders identify drainage infrastructure and flooding 'hot spots'. When analysed on a common platform, using geographical information systems, these data can help explain flood mechanisms.

- A variety of modelling tools can be successfully applied to calculate surface water flood risk, a product of flood likelihood and consequence. Some approaches consider the role of the underground sewer network while others focus on pluvial runoff in extreme events. Both approaches have a role in understanding flood risks which occur frequently or infrequently.

- It's possible to determine the financial damage caused by surface water flooding and factor in the additional impact of climate change and urbanisation. In line with Foresight, one pilot estimates an increase in flood volumes of 77% by 2085 for the 1 in 100 year event.

- Complex interactions occur between sewers, the urban surface and rivers. These can be represented in hydraulic models which are improving rapidly to meet the needs of the IUDM community. An integrated modelling approach delivers greater accuracy in modelling and an ability to replicate observed flooding. Hence, there is greater confidence in the use of these tools when developing engineering solutions.

- Modelling and mapping surface water flood risks can inform planning departments in local authorities when they apply PPS25 in the allocation of land for housing development. It can also inform emergency planners identifying safe havens and transport routes for use in extreme weather.

- Options, developed thorough IUDM, to reduce surface water flood risk and water quality combine structural (engineering) and non-structural (policy, behavioural) measures across the urban drainage system that involve all stakeholders. These solutions can be more effective and cost beneficial than ones developed by stakeholders acting individually.

- For new developments, drainage strategies can be produced which safeguard downstream areas, protect the development and are adaptable to climate change. Using the planning system ensures consistency of approach and can clarify long term ownership and maintenance responsibilities.

3.2 Barriers & challenges

The pilot projects have also helped identify barriers to successful IUDM which either require remedy through new regulation, policy and funding arrangements and/or more widespread use of good practice. The former is being addressed by Defra through their policy development process which has started with a consultation on options for improving surface water management[19]. The consultation proposes that SWMP will be the vehicle through which IUDM is delivered in high risk areas. The latter is being addressed by new guidance for SWMP which will be published in 2008, drawing on experience from the pilot projects and elsewhere.

Some key barriers, or challenges, are:

- Data and models for use in IUDM are sometimes poor, not available or not fit for purpose. Using these data and models can result in incomplete or misleading flood risk assessments. Stakeholders have legitimate concerns about sharing data which might be misinterpreted and applied incorrectly. The absence of protocols for sharing information remains a significant barrier.

- Flood risk assessment requirements vary depending on data availability, level of risk and scale of application. Pilot projects trialled a variety of techniques but new guidance is required to indicate an approach which is appropriate in detail, cost and accuracy for a range of situations.

- Measuring surface flood risk consequences is difficult, requiring a level of detail which is challenging and expensive to apply across large areas. Best results are obtained from detailed modelling of surface flows resulting from drainage exceedance and pluvial flooding. A risk based approach is required to target detailed modelling where it's required. Simplified approaches can be applied elsewhere.

- Mindsets are still linked to providing solutions that route surface water away through improved sewerage or via water courses. The pilot projects did not

[19] http://www.defra.gov.uk/environ/fcd/policy/surfacewaterdrainage.htm

generally consider how runoff could be managed on the surface, retained in highways and routed safely to storage areas in green space.

- Current institutional arrangements and responsibilities make it very difficult to coordinate and fund an integrated series of cross stakeholder improvements. Although flood risks have been identified and understood, some stakeholders have neither the finance, duty or powers to take appropriate action. Government needs to clarify responsibilities and identify who should lead and oversee surface water manamgent plans.

- While some 'quick fix' solutions to surface water flooding can be identified, many problems are endemic to urban areas and may only be resolvable through the re-development of town centres and housing so that space can be made for water. The benefits of IUDM may therefore take many years to be realised.

- The skills required to carry out IUDM are in short supply, especially in local authorities who have a key role to play. Efforts are required to build capacity in urban drainage knowledge within local authorities and the Environment Agency.