Addressing the Challenges of Integrated Urban Drainage

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Introduction

The recent floods of 2007 have once again focused the public's mind on flooding. Over 55000 properties and 7000 businesses were flooded and 13 people lost their lives. As the Pitt Review Interim Report states (Pitt 2007), this was an exceptional event. Rainfall records showed that the summer of 2007 was the wettest on record. At least three events with a return period of over 100 years were recorded across the UK during June and July. Major urban areas were inundated, the more notable being Sheffield, Hull and Tewksbury, and principal infrastructure and communications were affected.

What was particularly unusual was that most of the flooding has not been attributed to river defences overtopping or coastal inundation. Almost all flood defence structures operated as planned. Much of the flooding was caused by surface run-off from localised intense storms. This caused extensive local flooding of urban areas, but also of rural areas, demonstrating the high potential rates of run-off from natural surfaces once they become waterlogged.

The Pitt Interim Report refers to these events as a "wake-up call", and draws a number of important conclusions from the lessons learnt.

Figure 1. Example of Urban Flooding in July 2007

Lessons Learnt from the 2007 Floods

Perhaps the most important lesson is that lessons from previous flood events do not appear to have been learnt. Despite the warnings in the Foresight Report on Climate Change, Floods and Coastal Defence (Evans et al 2004), which highlighted the growing importance of pluvial flood risk, the various drainage bodies were surprised by the speed and scale of the events. In the absence of an adequate warning system for this type of flooding there was little time to protect property or evacuate.

In some areas it was unclear who was in charge of responding to the flooding. In others it was unclear who was responsible for the flooding in the first place. Indeed in many areas the underlying causes of the flooding remains to be established.

As with most floods, water tends to flow down hill and accumulate in low spots. In urban areas the sewerage and drainage systems filled up during the early part of the events and a substantial amount of flood water was then conveyed on the surface. The depth velocity and direction of flooding is often determined by relatively minor detail of the urban fabric, so that flooding was unpredictable and indiscriminate. Buildings are not normally designed to be either flood resistant or flood resilient so that substantial damage was caused from relatively minor depths of flood water. The time taken to reinstate flooded property has in some cases been considerable.

In addition major infrastructure was affected by flooding. River flooding in the area of Tewksbury not only cut off the town for several days, but also inundated the local water treatment works, leaving a large area of England without a water supply for more than two weeks. A spillway on Ulley reservoir near Sheffield collapsed, badly damaging the earth dam and threatening collapse. Many homes had to be evacuated downstream and the M1 motorway was closed for several days. Collapse of the dam would have cut off electricity to over 500 000 people.

The Potential Effects of Climate Change.

A substantial amount of work has been done to downscale rainfall predictions from global and regional climate models to the temporal and spatial scales needed to predict urban flooding. This work has shown that short duration local rainfall could increase in intensity by up to 40% by 2080 (HR Wallingford, 2003). Modelling has shown that this will result in a 40% increase in run-off, a 100% increase in flood volume and a 200% increase in flood damage. Where sewers interact with local watercourses, these impacts could double. The Foresight report showed that the resulting costs of conventional flood alleviation work could rise up to 10 fold by 2080. Such increases are clearly unsustainable in the long term. As the Pitt Review recognises, there needs to be a shift from flood defence to building flood resilience. It also recognises that the problems that arise from the diverse responsibilities for urban drainage also need to be addressed.

To deliver a more integrated approach to urban drainage, Defra and CLG set up a series of Integrated Urban Drainage Pilots in 2007. These aimed to give guidance on how flood risk could be better managed in urban areas. The long term output will be guidance for Surface Water Management Planning. In preparation for these pilots, MWH produced for Defra a structured approach to Integrated Urban Drainage (Balmforth et al, 2006.1), and this is represented by the flow chart in figure 2.

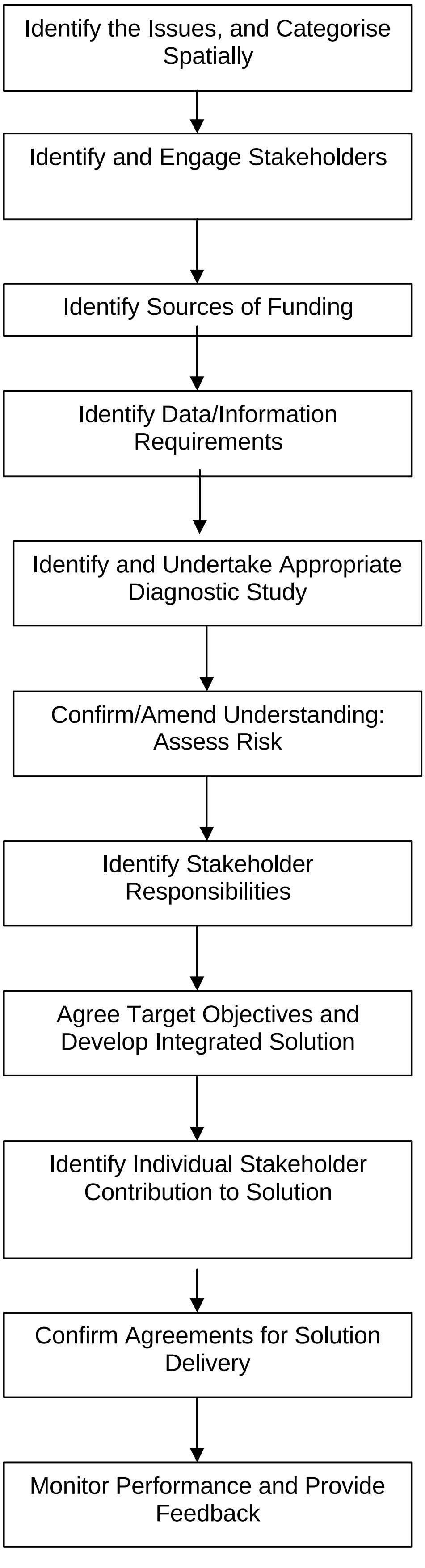

Figure 2. Flow Chart for Integrated Urban Drainage (from Defra IUD Pilots Scoping Study (Balmforth et al, 2006.1))

This approach has been trialled on the current 15 integrated urban drainage pilots of which the North Brent study is one.

The North Brent IUD Pilot

The northern part of Brent, situated to the west of London, has flooded regularly over a period of years. Table 1 below shows the historical "story board" of flooding. What is interesting from this record is that for the three major flood relief schemes delivered in this area over the years, major flooding has occurred within one year of commissioning. Clearly flooding in this area is not easy to solve. Unsurprisingly, important parts of the area flooded in July 2007.

Table 1. Historical "Story Board" of Flooding in North Brent

1910 Population 410 000
1927, 1928 Major Floods
1931 100 miles of trunk sewer completed
1941 Population 1.3 million
1952, 53, 56, 57, 58, 63, 70, 71 Major Floods
1976 First Flood Protection Scheme
1977 Major Flood, 420 homes flooded
1982 Major Flood
1987 Second Flood Protection Scheme
1988 Major Flood
1992 Third Flood Protection Scheme
1992 2000, 2004, Major Floods
2003 Working Group established
2006 Integrated Drainage Study commenced
2007 Major Flood

A stakeholder advisory group had already been formed at the start of the project, and there was an abundance of local historic information on flooding available. Thames Water supplied two sewer network models (foul and surface water) and the Environment Agency supplied a river model of the Wealdstone Brook. MWH as consultants for the project integrated these models into a single InfoWorks CS model. This format was chosen as there was little flood plain flow in the Wealdstone Brook, so little would be lost from using a sewer modelling tool, and there was a considerable advantage in being able to model all the drainage systems in one package.

The foul sewer network model was verified using a short term flow survey, and the river model was verified using historical rainfall and measured river flows from a local gauging station. In addition, there was a significant amount of video and local rain gauge information available for the July 2007 flood. These showed considerable over-ground flood flow in parts of North Brent. The latest InfoWorks 2D above ground flood inundation model was used to replicate this. Good agreement with observed data was achieved with relatively little additional work needed to set up the model (figure 3).

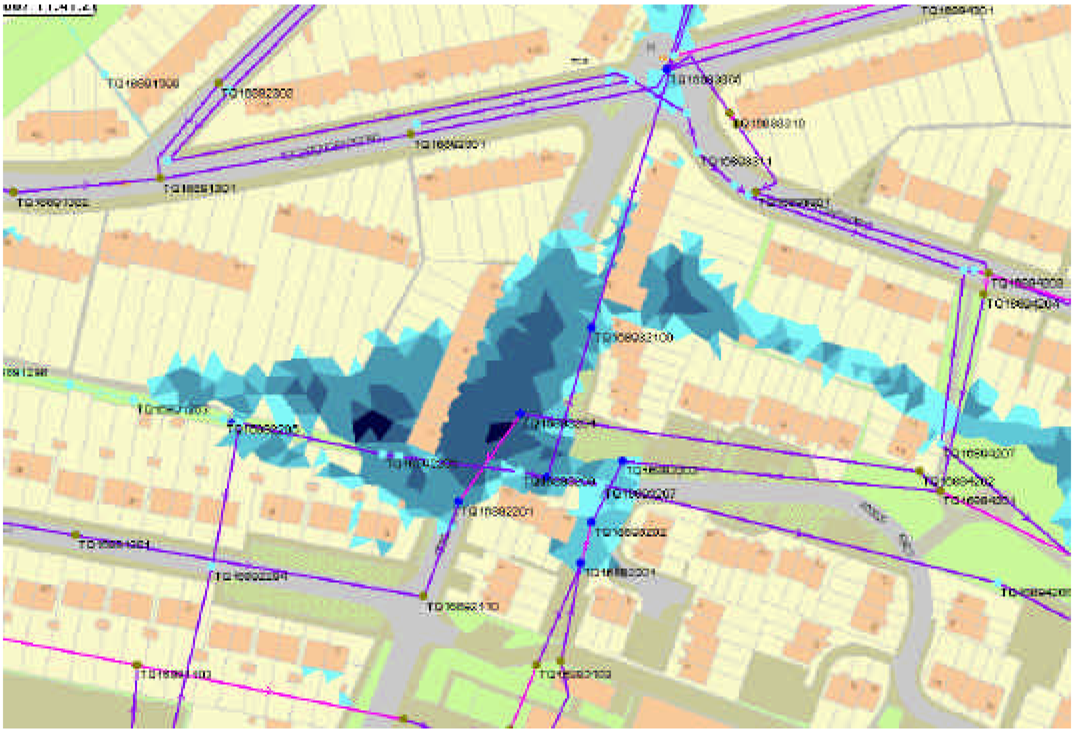

Figure 3. Integrated Model with Full Dynamic Interaction between Sewerage Systems, the Watercourse and Surface 2D Flooding, using InfoWorks 2D.

The three drainage models were initially run independently and then combined into a single model. The integration of the two models needed to correctly replicate the interconnections between the different drainage systems. Although the area is separately drained, there are significant cross connections from the surface water to the foul drainage systems, and a number of overflows from the foul drainage system to the Wealdstone Brook.

The integrated model was compared with running the three individual drainage models independently (table 2). This showed an overall under prediction of flood volume by some 30% for the separate models compared with the integrated model, for a 15 year event, though the differences were greater at some individual nodes. The integrated model showed that whereas the river stayed within bank top for most of the recorded flood event, the high river levels severely affected the capability of the surface water sewerage system to convey flow. In addition, the cross connections from the surface water to the foul system overloaded the latter causing both flooding and pollution of the Wealdstone Brook.

The relative performance of the drainage systems is in part due to the different standards of flood protection used by the bodies responsible for them. Also, the adverse interactions between the river and the surface water sewerage system would not have been previously identified had integrated modelling had not been undertaken. In this case the benefits of an integrated approach are clear. They enable a full understanding of the causes of flooding to be identified, they enable the responsible bodies to be identified, they foster a joint approach to solution development and they identify the contributions to that joint solution from each responsible body.

Table 2. Comparison of Flooding Between Integrated and Free Standing Models

Location of Flooding according to FHD	Integrated 1 in 15 year event	Flood Volume m^3	Individual 1 in 15 year event	Flood Volume m^3
29 BELVEDERE WAY (HARROW)	YES	14	NO	0
27 BELVEDERE WAY (HARROW)	YES	4	YES	0.1
13 BELVEDERE WAY (HARROW)	YES	26	YES	4.1
16CHAPMANCRESCENT (HARROW)	YES	52	YES	41
17 DONNINGTON ROAD (HARROW)	YES	83	YES	14
9 GORDON AVENUE (STANMORE)	YES	1.8	YES	13
HIGH STREET (HARROW)	YES	54	YES	23
719 KENTON LANE (HARROW)	YES	207	YES	331
613 KENTON LANE (HARROW)	YES	116	YES	16
36 KINGSHILL DRIVE (HARROW)	YES	353	YES	234
25 KINGSHILL DRIVE (HARROW)	YES	353	YES	234
33 RUSKIN GARDENS (HARROW)	YES	31	YES	170
65 THE AVENUE (HARROW)	YES	361	YES	211
2 WATER GARDENS (STANMORE)	YES	60	YES	18
115 WEALD LANE (HARROW)	YES	36	YES	36

Delivering Integrated Solutions

As with most drainage areas, it is unlikely that the drainage infrastructure will be upgraded to meet the sorts of extreme event that caused flooding during July 2007. It is not unreasonable to suppose, however, that a level of protection of the order of 1 in 30 years might be achieved in due course. The role of each responsible body in delivering that solution has yet to be determined. Figure 4 shows the conveyance contributions for the different parts of the drainage system during 30 and 100 year events. This shows that at present there is significant surface conveyance in both cases. For a future scenario it could be argued that surface conveyance should be minimal during a 30 year event, but permissible during a 100 year event, as indicated in the lower half of the figure. A simple figurative representation such as this is helpful in explaining potential flood mitigation strategies to stakeholders

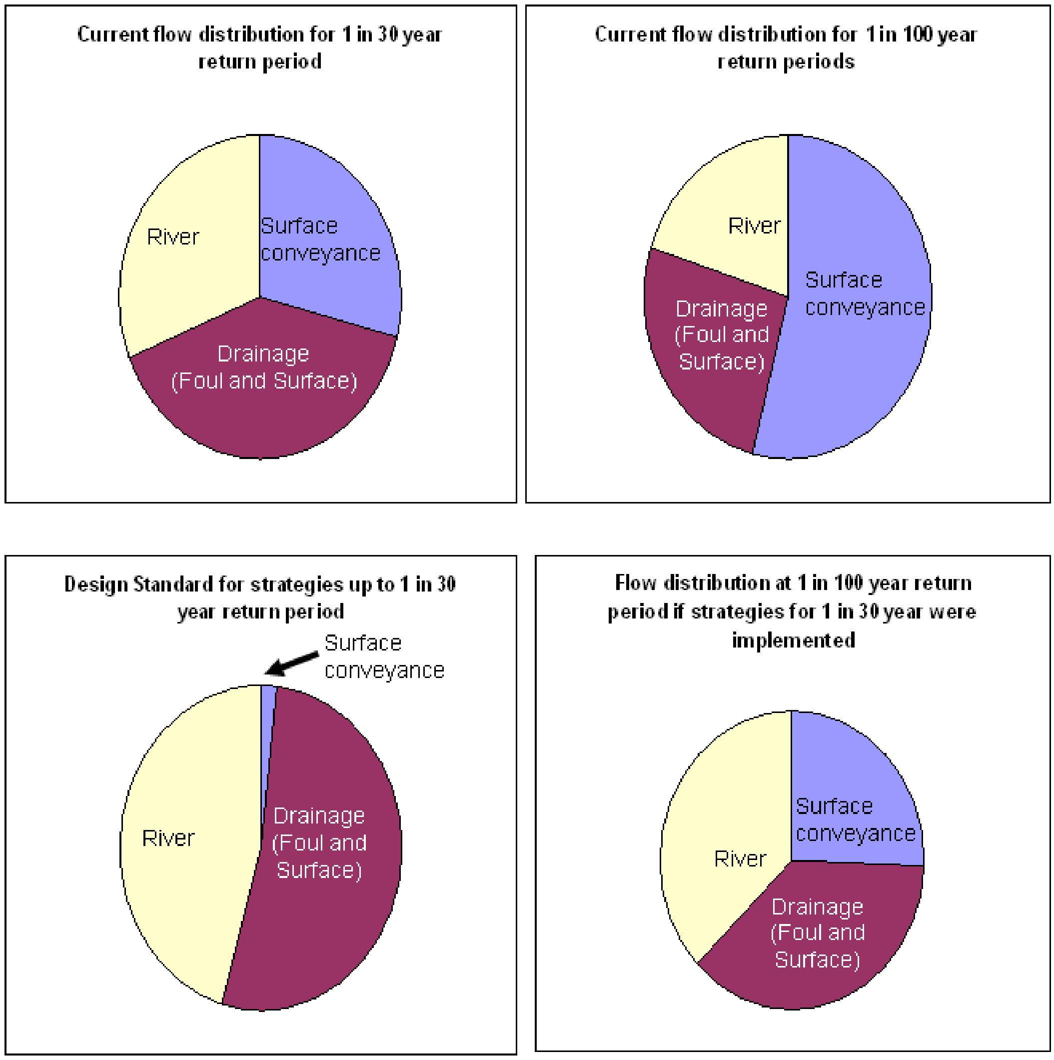

Figure 4. Current and Potential Contributions of the Different Drainage Modes in North Brent

Figure 4 shows that for the 100 year event there is still a significant volume of flood water that would have to be managed on the surface. This would be achieved by improving the flood resilience of the urban area and the flood resistance of property. Guidance on the designation and design of roads and paths as flood channels, and on the dual use of “sacrificial” areas for temporary flood storage, is already available from CIRIA (Balmforth et al, 2006.2). The public can also be involved in providing additional flood resistance and resilience for their homes.

In making urban areas more flood resilient, engineers will have to work more closely with planners and architects to achieve an urban layout that can safely accommodate surface flood flows during extreme events. In addition, the public will need to be fully engaged in the process and the role of the social scientist is therefore likely to become more important. As the Foresight Project demonstrated, only through an integrated approach to flood risk management which encapsulates the concept of flood resilience can we hope to sustainably adapt to the impacts of climate change

Conclusions

Flooding in urban areas is complex, arising from multiple sources and engaging a variety of responsible bodies. This complexity must be addressed in managing flood risk. Problem understanding is a necessary pre-requisite to developing solutions, and modern modelling tools that can replicate all the various strands of urban drainage together will be a necessary requirement.

All the recent research, together with the findings of the various reports into the recent UK flood events, points to future solutions delivering increased resilience measures rather than flood protection. This is because the cost of conventional flood protection measures becomes unsustainable against a background of climate change.

To deliver effective flood risk management strategies will require both stakeholder buy in and public engagement. The skills to deliver this will be different from today. The strengths of all the professionals working in the urban environment will need to be collectively harnessed to meet the future challenge.

Acknowledgments

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