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Adapting Urban Areas to Flooding

Most properties, businesses and related infrastructure at risk of flooding are in urban areas, where more than 80% of the UK population live. This note summarises how urban areas can be better managed to adapt to flood risk from rivers, surface water, sewers and ground water.

Overview

- Extreme rainfall events are predicted to become more frequent and severe in the future as the climate changes.[1]
- Existing urban defences and drainage infrastructure cannot cope with increasingly extreme events, but urban areas can be adapted to reduce vulnerabilities to flooding.
- There is no single solution to manage urban flood risks: a portfolio of solutions will be needed that include traditional flood defences but also flood resilience measures.
- Urban drainage systems that mimic a natural landscape can reduce surface flooding and provide other benefits.
- In England, management of flood risk is fragmented. A more strategic approach may be needed to adapt to changes in climate.

Background

Storms in December 2015 and January 2016 caused widespread flooding across Northern England, Wales, Scotland and Northern Ireland.[2] Around 16,000 properties in England were affected with insured losses totalling £1.3 billion.[2-4] Flood risk arises from a number of sources (Box 1). It is not clear whether the flooding in winter 2015-16 was exacerbated by climate change.[5] However, the Committee on Climate Change (CCC) estimates that without further adaptation expected annual damages due to flooding will rise by 50% under a 2°C climate change projection by the 2080s.[6] An issue for the Government's National Flood Resilience Review and the National Infrastructure Commission to consider will be how the built environment can adapt to, and not contribute to, increased flood risk.

In its 2016 budget, the Government announced an additional £700 million spending on flood defence and resilience. As well as its commitment to £2.3 billion capital investment in 1,500 flood defence schemes by 2021,[7] it will invest £150 million in projects in York, Leeds, Calder Valley, Carlisle and wider Cumbria, areas flooded in 2015/16.[8] The Environment Audit Committee report that the allocation of £700 million was economically inefficient and that Government flood defence funding prioritises areas recently affected by flooding that may not be at the highest risk in the future.[4,9] It advised Government to allow the Environment Agency to prioritise funds without political interference.[9]

Increasing Likelihood and Vulnerability

The risk of flooding is not the same as the likelihood of an extreme rainfall event (Box 2) as it also depends on the vulnerability and exposure in a catchment or urban area.

Likelihood of Flooding

Seasonal

Seasonal differences in rainfall result in differing flood impacts. Winter flooding is usually caused by long periods of heavy rain that tend to trigger river and groundwater flooding affecting areas at a catchment scale. They may be made worse if the ground is already saturated by previous

Box 1. Sources of Flooding

- **Rivers:** When excessive rainfall causes river levels to rise, flow can exceed the capacity of the channel, spilling onto floodplains. It is also referred to as fluvial flooding and lasts hours to weeks.[10]
- **Surface Water:** Localised heavy rainfall can collect in surface depressions causing flooding. Also referred to as pluvial flooding, this may last hours to days.[10]
- **Sewers**: Surface water can exceed the capacity of the drainage systems causing them to flood. There is a risk that sewage may contaminate flood waters.
- **Groundwater:** A high water table can cause flooding. It only accounts for a relatively small proportion of urban flooding, but can increase the impacts of river flooding and lasts days to months.[10]
- **Coastal:** A tidal surge, wave action or a combination of these cause coastal flooding and can last hours to days.[10] This type of flooding is not covered by this briefing (see POSTnote 363).

Box 2. Calculating Flood Likelihood
The likelihood of flooding is given by the chance of it occurring in any given year at a given location. Flooding with a 1 in 100 or 1% annual likelihood will on average occur once in any 100 year period. Engineered river defences are conventionally designed to withstand 1:100 or 1:200 (1% or 0.5%) likelihood of flooding and urban drainage systems to 1:30 or 3.33%. The size and likelihood of a flood is estimated using observed rainfall data and computer models. Accuracy of flood estimation depends on the quality and quantity of relevant data and the accuracy of models, and there can be considerable uncertainty around the likelihood and severity of predictions. Frequently the public and decision makers are unaware of the likelihood of flooding and effective communication may increase support for mitigation measures.[11] The Environment Agency describes the likelihood of flooding from rivers and sea as:
- High-more than 3.33% (1:30) chance in any year
- Medium-between 3.33% (1:30) and 1% (1:100) chance in any year
- Low-between 1% (1:100) and 0.1% (1:1000) chance in any year
- Very Low-less than 0.1% (1:1000) chance in any year

heavy rainfall or flooding. In December 2015, storms Desmond, Eva and Frank occurred in quick succession,[2] with areas of Cumbria flooded twice. Summer flooding is usually caused by short periods of intense rainfall that are more likely to generate localised surface water and small or steep watercourse flash flooding. In June 2012, Newcastle upon Tyne received a month's rainfall in two hours. Drainage systems were overwhelmed causing localised flooding across the city within one hour.[12] The most recent UK predictions for a moderate climate change scenario are that regional average precipitation will increase by 14-23% in winter and will decrease by 17-23% in summer by 2080.[13] These projections will be updated in 2018.[14] Despite reduced average precipitation, regional variation means that this will not result in reduced flood risk overall. Some evidence predicts increased winter rainfall intensities and an intensification of short duration summer rainfall.[15]

River Catchment Type
The landscape of the area a river drains (catchment) determines the nature of flooding. Land management practices can also reduce or increase the proportion of rainfall that runs off (POSTnote 484). Intense rainfall in steep sloping areas can lead to flash flooding from rivers. If it occurs very rapidly, it can cause considerable damage and pose a serious threat to human life.[16] In the summer of 2004, five hours of intense rainfall caused flash flooding in Boscastle, damaging or destroying five bridges and causing considerable property damage.[17] In areas with a flatter landscape, river flooding is likely to be extensive and last longer. In the winter of 2013/14, flooding on the Somerset Levels lasted 3 months and damaged 3,500 properties.[18]

Flooding and Drought
In 2012, a long period of drought (two years) was followed by severe flooding.[19] Heavy rainfall that occurs after long periods of drought is more likely to run off the dry compacted soil and cause river levels to quickly rise risking flash flooding. Managing the water cycle as a whole will help to reduce the risks of both floods and drought.[20]

Flood Vulnerability and Exposure
Urban areas have developed historically in ways that have tended to increase both the impacts of flooding and the number of properties, businesses and related infrastructure exposed. As urban areas expand, some of this development continues in areas at risk of flooding. The Joseph Rowntree Foundation has highlighted that urban areas are the most vulnerable to flooding because they have a low ability to adapt.[21] In addition, they noted that factors including old age, poor health, low income and social isolation contribute towards vulnerability to the impacts of flooding.[22] At present, 1.8 million people live in areas with a greater than 1:75 (1.3%) annual chance of flooding. Of these, 320,000 live in deprived areas. The number of people in deprived areas at 1:75 likelihood of flooding is predicted to rise at a higher rate than that of the average by 2080.[6]

Increased Paving and Ageing Drainage Infrastructure
Urban areas are increasingly being paved over. Impermeable paving prevents rainfall from soaking into the ground and accelerates runoff which puts increased pressure on drainage systems. Drainage systems built before 1940 usually combine urban runoff in the same pipe as raw sewage. During heavy rainfall, excess combined sewage bypasses treatment works, discharging directly into watercourses through overflow pipes. Untreated sewage poses a risk to human health. Newer systems direct urban runoff and sewage through separate pipes, but surface water, containing urban pollutants, still tends to discharge directly into watercourses without treatment (POSTnote 289). The water industry is working with the Government Water UK 21st Century drainage initiative to improve urban drainage.[23] The Pitt Review recommended that all new development should be drained by sustainable drainage systems (SuDS), such as permeable paving, but this is yet to be fully implemented (see below).[20]

Engineered Defences
Flood embankments, walls and barriers can protect business and property from flooding. However, permanent defences that increase the speed and volume of water in a river may lead to a higher likelihood of flooding downstream communities. Once the capacity of defences is exceeded, flooding occurs albeit less severely. Hard defences may also be susceptible to mechanical failure. For example, the Environment Agency chose to raise the Foss barrier in York in December 2015 because of flood water entering the electrical switch rooms that housed its control panels.[24]

Critical Infrastructure and Interdependencies
Flood damage to homes and businesses can be exacerbated by infrastructure failure. During storm Desmond, flooding at an electricity sub-station left more than 100,000 people in Lancaster without electricity.[25] During the 2007 flooding, 350,000 people lost water supply, and the threat of collapse of the Ulley reservoir dam led to the closure of the M1 in Yorkshire for 40 hours.[20,26] Failure of one type of infrastructure can cascade into others and interdependencies may not always be apparent until flooding actually occurs, with effects stretching well beyond the initial flood extent.[26] December 2015 flooding of BT and Vodafone bases caused wider communication problems: external phone lines to South Tyneside hospital were cut; the police non-emergency 101 number was temporarily down; and there was intermittent disruption to NHS 111. Even if infrastructure can be defended from flooding, operation may be impossible if operators cannot get to site because

transport networks are flooded or ICT system failure impedes network access.

A Range of Solutions

There is no single solution that can manage all flood risk.[27] Instead a portfolio of engineered and natural solutions can be implemented at a range of scales, across the catchment, within the urban area and on individual buildings (POSTnote 484). The selected solutions should be site specific as those that are effective in one urban area may not be effective in another.[28] For example, features that soak water into the soil may not be appropriate for areas with impermeable underlying soils, such as clay. However, natural solutions could play a significant role, including reducing run-off in urban areas. For instance, Water Sensitive Urban Design (POSTnote 419), an integrated approach promoted in Australia, manages surface water flows to reduce flood risks and provide other benefits, such as improving water quality.

Catchment Led Approaches

Flood risk management approaches that consider the whole catchment can reduce flood damage in urban areas without passing on problems to downstream communities. Solutions such as woodland planting and ditches that store and slow surface runoff have the potential to increase the resilience of existing structural defences and may contribute to wider catchment management. Purpose built reservoirs and embankments in upstream areas can store and controllably release excess water during high river flows. Flood storage can be effective both upstream and in floodplains. Storage areas may have multiple uses, such as recreational areas during normal river flows. However, this requires land availability and may entail compulsory purchase or land owner compensation when flooded.[29] Despite a number of small scale test schemes, where networks of natural features have been shown to effectively reduce surface runoff, there is a lack of evidence that these reduce flood peaks at a larger catchment scale (POSTnote 484).

Reducing Urban Runoff

Green Infrastructure (GI), such as parks, reduces urban runoff by enabling rainfall to soak into the underlying soil. SuDS provide natural drainage processes through a network of predominantly above-ground surface water management features (POSTnote 448). They channel, slow and store surface water and control the rate it enters sewers and watercourses while helping to remove urban pollutants. SuDS have similar costs to conventional drainage systems and can provide a range of additional benefits, such as improving biodiversity, amenity, and air quality, as well as reducing the warming effect of densely packed buildings in urban areas.[28] Considering multiple long-term benefits increases their cost effectiveness.[30] Responsibility for maintenance and adoption of SuDS is not addressed by current legislation and this may hinder uptake (Box 3).

Retrofitting Existing Urban Areas

There is a disparity between SuDS requirements for new and existing developments (Box 3).[31] However, to reduce surface water flooding significantly, retrofitting of SuDS and GI to existing developments will be required. This can be strategic, in response to flood risk or other drivers, or opportunistic, taking chances to retrofit measures in areas during redevelopment.[30] There are a number of challenges for existing developments including excavation around underground gas and electricity services, reduced land availability, high land value and longer construction times.

Designing for Exceedance

Underground drainage systems cannot be built to withstand the most extreme events. When rainfall exceeds drainage capacity, water will follow overland pathways and can indiscriminately flood properties and infrastructure.[32] Defra's consultation Making Space for Water identified that roads can be used to carry excess water during extreme rainfall.[33] Through careful design of kerb height and building location, roads can be designed to carry surface water away from properties to 'sacrificial' storage areas, which under dry conditions would be used for other purposes such as playing fields. It is considered good practice by developers' organisations. In new developments, over land flow pathways can be designed by careful building placement. Public concern for surface water flows and the number of stakeholders involved in surface water management may be barriers in designing for drainage capacity exceedance. Early stakeholder engagement and partnership working has contributed to the success of a number of schemes.[34]

Property Level Resistance and Resilience

There is a lack of specialist capacity in the building industry for assessing flood risk for individual properties.[35] Assessments are needed to determine all routes by which water may enter a property. Industry-approved property-level barriers are accredited for water tightness under the British Standard Institute Kitemark scheme. Measures that reduce the likelihood of flood water entering a building, including raising floor levels, flood proof doors and valves preventing sewage backup, are termed 'property resistance'.[36,10] Even with these features, water may still enter the property through seepage and via service openings (e.g. toilets). Measures incorporated into the building fabric to reduce damage from water entering a property, including raised gas and electrical services, waterproof wall finishes, concrete or tiled floors and metal kitchen units, are termed 'property resilience'.[36,10]

In its 2012 report, the CCC Adaptation Sub-Committee (ASC) identified that adoption of such property level protection was insuffiicent.[37] A study after the 2007 floods found that 46% of respondents chose not to include resistant and resilient measures in repairs because they wanted their home exactly as it had been before, and others believed it was not their responsibility.[20] There is no obligation on insurers to repair and replace with such measures (Box 4). Property-level protection is susceptible to human error as temporary defences need to be erected or closed prior to flooding, and when homes are bought or sold, awareness of property-level features may be lost.

Policy Framework

Flood risk management in the UK is a devolved matter.[2] The Environment Agency and the Scottish Environment Protection Agency have published flood risk management plans for all river basins in England and Scotland in accordance with the Flood and Water Management Act 2010, the Flood Risk Management (Scotland) Act 2009

Box 3. Regulatory Framework for SuDS
Schedule 3 of the Flood and Water Management Act (2010), which introduced standards and established approving bodies for SuDS, was not brought into force.[38,39] In April 2015, responsibility for SuDS approval in England was passed to local authorities under the National Planning Policy Framework (NPPF). Local authorities, water companies or private management companies may adopt SuDS maintenance responsibility and this can be contained within planning conditions. However, this is not mandatory and there is no monitoring of SuDS uptake in planning applications. A 2014 ASC survey of 100 planning applications in flood risk areas found less than 15% proposed the use of SuDS.[40] According to the NPPF, developments of 10 properties or more should include SuDs unless an economic test demonstrates it is not viable, exempting them.[41] This test does not account for long term environmental and social costs of conventional drainage. New developments also have an absolute right to connect to existing drainage networks once planning permission has been granted,[39] despite the Pitt Review recommending that this be removed.[20] In Scotland, SuDS are mandatory on any new or brownfield site that connects to a watercourse or separate sewer system, under the Water and Environment (Controlled Activities) (Scotland) Regulations 2011.[42]

and the EU Flood Directive 2007.[38,43,44] In England, urban flood risk management is fragmented,[45] with responsibility for sources of flooding shared between the Environment Agency (EA), Lead Local Flood Authorities, water companies (sewerage operators), highways and local authorities, internal drainage boards and individual property owners.[46,47] The Flood and Water Management Act (England and Wales) (2010) gives the Environment Agency strategic overview of flood risk in England.[37] Lead Local Flood Authorities are responsible for preparing flood risk strategies for ordinary watercourses, surface water and groundwater. In 2015, the CCC recommended a more strategic approach is needed to adapt to future risks.[48]

Funding for Flood Defence
In line with Government policy,[49,50] the Environment Agency carry-out cost benefit analyses for capital flood defence spending in England.[51,52] For each pound spent, the EA achieves an average benefit of £8 for flood management schemes and £18 for maintenance work.[52,53] This ensures that, typically, only the best value for money projects are taken forward.[54] In 2011, Defra introduced partnership funding, enabling schemes with lower benefit-to-cost ratios to receive top-up funding from private and local investors, but these are less feasible in areas with higher social deprivation. Central government funding accounts for this by paying higher rates in more deprived areas. It pays 45p in the most deprived areas and 20p in the least deprived for each £1 in damage reduction from defence measures.[22,55] In response to flooding in 2013/14, the Government introduced repair and renew grants of up to £5,000 for property-level protection of homes and businesses. Similar schemes are available to householders affected by flooding in December 2015 as part of the Community Recovery Scheme.[56,57]

Planning
Planning applications in England are required to pass a sequential risk-based test to steer development towards areas at low risk of flooding. Development may be allowed in flood risk areas if it passes an exception test, whereby it is shown to have wider economic benefits, will be safe for its lifetime and will not increase flood risk elsewhere.[61,39] However, in 2012 the CCC Adaptation Sub-Committee found that development in floodplains had continued at a faster rate than in other areas.[37] In 2014/15, 8% of new residences were built in areas of high flood risk.[62] In England and Wales, the Environment Agency and Natural Resources Wales are statutory consultees for development in areas at risk of flooding. Lead Local Flood Authorities are statutory consultees in major planning applications with surface water drainage implications, but water companies are not. In its 2015 report, the CCC recommended that DCLG make water companies statutory consultees.[48]

In 2014/15, the Environment Agency objected to 3,237 planning applications on the grounds of flood risk. Of the 2,272 outcomes it is aware of, 96.4% of their recommendations were accepted. These outcomes may be: refusal, or withdrawal of the application; further investigation; or redesign by the developer to become more flood resilient.[63] In February 2016, the Environment Agency published changes to its advice on flood risk assessments to account for climate change, including updated predictions for river flows.[64] The advice could result in the requirement for more flood risk management measures for some proposed developments in areas of high flood risk.[65]

Box 4. Insurance and FloodRe
There were 22,000 insurance claims after the winter 2015/16 flooding.[3] Areas at risk of flooding are likely to have high insurance premiums and excesses.[46] Not all providers will insure properties at high risk and specialist brokers may be required. Providers calculate flood risk using various levels of sophistication; some insurers use proximity to a watercourse whereas more specialist providers may carry-out in-depth flood modelling. The insurance industry operates on a principle of no betterment; which means that providers are not obliged to repair and replace using resistant features or resilient construction methods. They are obliged to replace and repair according to building regulations, which do not currently require the use of resistant and resilient measures in properties at risk of flooding.

The FloodRe reinsurance scheme was launched in April 2016.[58] It enables affordable insurance for an estimated 350,000 eligible properties, funded through a £180 million annual levy on UK home insurers. Residential dwellings, built before 2009 with council tax bands A to I are eligible for the scheme. Small and Medium enterprises (SMEs), leasehold and properties built after 2009 are not included. The scheme will operate for 25 years, after which a transition to risk-based pricing has been proposed.[59] An LSE study recommended that the scheme should be amended to reduce flood risk by encouraging and rewarding property-level measures.[60]

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