

IN DEEP WATER?

Mapping the impacts of flooding
in the UK since 2007

Helen Jackson

 bright blue

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About the author

Helen Jackson is an Associate Fellow at Bright Blue. Her previous report with Bright Blue was *High and dry? Preventing tomorrow's "flood ghettos"*.

Helen is also the Director of ClimateNode, a not-for-profit aiming to use data science to research climate risks and impacts for public benefit. Helen is an environment and natural resource economist with many years' experience in climate change, energy and environmental policy and economics, working on projects for multilateral organisations, energy companies and governments. She was one of the first people to work for leading climate and energy consultancy Vivid Economics, now part of McKinsey, and has also worked for green finance pioneers the Climate Bonds Initiative on assessing asset-level climate resilience, as well as for the Economist Intelligence Unit. Her research has been cited by The Rough Guide to Economics and the leaders of both the UK Conservative and Labour parties.

Originally trained as a physicist, Helen picked up her coding skills during space and atmospheric physics research projects as a student. She has an Advanced Diploma in data modelling from Oxford University, and has previously designed a database to underpin fisheries management research for the Department for Environment, Food and Rural Affairs (Defra).

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Executive Summary

The COVID-19 pandemic has, sadly, shown that government planning for national emergencies and crises can fail to imagine the full range of risks and responses entailed. We need to make sure this is not the case for flooding.

Flooding is one of the most serious climate-related risks that the UK faces. A clear understanding of how it is affecting or could affect specific key public services and critical infrastructure is fundamental to national resilience. This report aims to do just that.

This report presents the results of analysis which collates information on the impacts of flooding and related hazards on communities, public services, infrastructure and businesses in the UK since 2007 from newspaper articles using a form of artificial intelligence called Natural Language Processing (NLP), explained in greater detail in Chapter Two. It has extracted information on flood events from approximately 7,800 relevant newspaper articles from over 60 local, regional, and national news sites.

Results from this analysis are presented for the following public services, infrastructure types and business sectors: emergency services, health services, education, social care, local government services, transport, water and sewerage, energy, information and communications technology, shops and other town centre businesses, farming, leisure, and manufacturing and industrial estates.

The newspaper articles analysed describe a broad spectrum of

flooding impacts for each of these. As Chapters Three, Four and Five highlight, these impacts range from manageable and discrete to life-threatening or at least highly problematic for response and recovery, community functioning or the local-to-regional economy. Impacts have included power cuts at fire stations, major disruptions to A&E departments, the closure of school buildings for months, significantly affected crop yields, bridge collapses dividing communities, trade in town centres affected for many weeks or months, severe and/or repeat flooding of major roads and key railway infrastructure, disruption to major ports, flooded water treatment works, severance of gas mains, swamped roads around airports, loss of emergency call services and serious damage to community facilities and tourism assets.

In particular, our analysis reveals that the UK has an urban drainage problem, affecting communities in all parts of the UK during heavy rainfall. In fact, newspaper articles corroborate problems with local authorities' capacity and resources for dealing with increasing surface water flood risk which have been described by the Climate Change Committee (CCC), the Department for Environment, Food and Rural Affairs (Defra) and the Association of Drainage Authorities. Sewerage capacity problems are also evident in many local newspaper articles. Heavy rainfall is putting urban drainage and sewerage infrastructure under strain, and in some locations they are clearly at or already exceeding their limits. The overflows from combined sewers which have recently received so much political attention are one symptom of this bigger problem. But it is not just an amenity or environmental concern – it is a public safety issue.

Adaptation to increasing surface water flood risk is lagging other types of flooding. This is due to the nature of surface water flooding, difficulties in modelling it, ambiguity over responsibilities, and the fact that managing the risk mostly falls to resource- and capacity-constrained local authorities. Surface water flooding's intractability has placed it in the 'too-difficult' category during several important policy processes – but it cannot always remain there.

There are a number of ongoing, official policy processes by central

government which provide an opportunity to better mitigate the risks from flooding in the future. These include:

- The National Resilience Strategy (Cabinet Office)
- A review of the Civil Contingencies Act (Cabinet Office)
- The Surface Water Management Action Plan (Department for Environment, Food and Rural Affairs)
- The climate adaptation policy cycle (Department for Environment, Food and Rural Affairs and the Climate Change Committee)
- Ongoing reforms to the planning system (Department for Levelling Up, Housing and Communities)
- A new strategic policy statement for Ofwat (Department for Environment, Food and Rural Affairs)
- Review of the funding framework for local government statutory flood and coastal erosion risk management functions.

This report finds the following key issues in the UK's policy approach to flood risk mitigation and adaptation which may be relevant to these policy processes.

- **Flooding is an issue for the Government's nascent 'levelling up' agenda.** There are many households, businesses and communities across the country, especially in poorer areas, which are simply under-prepared for the changing flood risk they face. We need to move away from an old concept of flooding – an unfortunate event affecting individual properties which by and large fully recover via insurance – and recognise the potential compounding impacts of repeat flooding on communities' economic welfare over the longer term. Flooding competes with other local government funding priorities, and some local authorities face large costs in repairing infrastructure, such as bridges, after flooding. Despite allowances made by the government's flood defence spending formula, the proportion of flood investment going to deprived areas has declined.

- **Urban drainage is a national resilience issue.** Civil contingency planners should ensure they understand the potential consequences of urban drainage not keeping up with the pace of change in heavy rainfall events. There have been numerous examples of urban flash flooding affecting transport and, in some cases, hospitals. Flooded streets can impede the ability of emergency responders and critical national infrastructure operators to get around. The risks of flash flooding for underground transport systems need to be fully understood and acted upon. There has been at least one fatality due to urban flash flooding, and it is conceivable that fatalities could become more common, particularly from people trapped in cars. The fact that surface water flooding is harder to predict and develop a warning system for adds to the risks.
- **Local authorities need more funding and support to manage surface water flood risk.** Various policy and parliamentary documents have expressed concerns about local authorities' capacity and resources for dealing with surface water flood risk. The Department for Levelling Up, Housing and Communities (LUHC) of course already works with Defra on flood risk, but could more clearly and publicly own the particular role it has to play in managing flood risk through support for local authorities and the planning system.
- **Flooding is an issue for the Government's house-building agenda.** Surface water flood risk is not being adequately dealt with by the planning system, and is a frequent reason why people oppose new developments. Those objecting to planning proposals on the grounds of flood risk are generally not knee-jerk 'NIMBYs' who need to be overridden, but people who can see the impact that inadequate drainage or sewer capacity is having on their community. Sometimes they are desperate to prevent repeat episodes of traumatic flooding. Many flood-hit communities already feel let down by various authorities. These concerns, if not adequately addressed, will increase

resistance to new housing. Removal of local democratic scrutiny from some individual planning applications, previously proposed in the Government's Planning Bill but under reconsideration, would be detrimental to trust in the system as flood risk increases. The Government's ongoing planning policy overhaul should tackle the longstanding lack of sufficient progress on this issue.

- **Developers with too much market power and too little accountability are a recipe for climate maladaptation.** The Government's Planning Bill previously proposed greenlighting of development in 'growth' zones determined by local councils. Some of the big developers have an appalling reputation for slapdash standards in the quality of finish of new build estates and customer after-care, and in some cases this clearly extends to drainage problems. This does not engender confidence in their ability to build housing estates which are resilient to flooding and/or which deliver flood resilience benefits to the local area, particularly with reduced scrutiny. The Government needs to ensure developers play their part in mitigating flood risk.
- **Flooding impacts in the UK under climate change will be made better or worse by the state of our infrastructure.** There has been quite a lot of progress in making transport and energy systems resilient to climate change, but there are still gaps, in particular ports, Information and Communications Technology (ICT), the local road network and urban transport systems. Flooding and heavy rainfall have the potential to place additional strain on an NHS estate which already has a significant maintenance backlog.
- **In some areas, the UK's adaptation efforts on flooding could be more preventative and less reactive.** While there are schemes for providing financial assistance to help with community recovery and the costs of councils' emergency responses to flooding

(the Flood Recovery Framework and Bellwin Scheme), there is a case for providing more support to prevent impacts before they happen. For example, action can be taken to prevent bridge collapse. Emergency service vulnerability hotspots could be identified before major flood events put them under unmanageable strain. Additional risks to communities in former coal mining areas should be comprehensively assessed and managed.

Based on these issues we identify, the report in Chapter Six puts forward a range of recommendations, including some directly relevant to the ongoing, official policy processes already described. These recommendations fall into the broad categories of: better preparing key public services and critical infrastructure for flooding; improving community resilience to flooding; and, better supporting local government and improving urban drainage.

Better preparing key public services and critical infrastructure for flooding

Recommendation one: Defra should support and fund an ongoing programme of research to specifically identify and monitor the risks associated with extreme sub-daily rainfall in urban areas.

Recommendation two: Government should introduce a mechanism to ensure the National Security Risk Assessment and National Risk Register incorporate changing climate risk.

Recommendation three: Government should mandate that local authority contingency plans are reviewed periodically when updated flood risk information is available.

Recommendation four: Government should conduct a civil resilience exercise for an extreme rainfall event in a major UK urban area, incorporating significant infrastructure failure.

Recommendation five: Extend Defra and the Environment Agency's new analysis of plausible extreme scenarios for surface water flooding to the emergency services and hospitals.

Recommendation six: NHS England should identify any NHS assets included in the high or significant risk maintenance backlog which are also at risk of flooding or have structural features which may be particularly vulnerable to heavy rainfall and then use this information to ensure such assets are suitably prioritised in NHS capital spending decisions.

Recommendation seven: the Department for Transport should put in place a programme to systematically monitor potential bridge vulnerability to flooding, hydrological change and bridge scour at national level, and investigate bridge collapses.

Recommendation eight: Central government should better support local authorities to identify and repair or upgrade bridges before they experience dangerous failure via new research and existing and even new road transport funding.

Recommendation nine: The Greater London Authority, Glasgow City Region and relevant Combined Authorities should all ensure that risks to underground stations in London, Glasgow, Newcastle and Liverpool from urban flash flooding have been fully assessed, that the assessments are publicly available, and that necessary measures such as improved drainage and Sustainable Urban Drainage Systems (SuDS) around stations are put in place to mitigate any risks.

Recommendation ten: The Climate Change Committee (CCC) should include more explicit assessment of risks to urban public transport systems from flooding, and associated adaptation progress, in future CCC reports to Parliament on climate risk and adaptation, either under the bracket of ‘rail and urban transport networks’, or in a separate section.

Recommendation eleven: Major port operators should be mandated by government to submit reports to the government’s formal Adaptation Reporting process, if participation does not increase voluntarily.

Recommendation twelve: Government should adopt a policy aim of ensuring that electricity substations are equivalently protected from all sources of flooding.

Recommendation thirteen: Require telecoms providers to actively assess and disclose assets at risk of flooding and single points of failure in their networks. In each case, action plans for flood risk management and/or elimination of the single point of failure (SPOF) should be produced.

Improving community resilience to flooding

Recommendation fourteen: Government should implement a comprehensive, major public information campaign covering all aspects of flooding, with the aim of increasing national resilience.

Recommendation fifteen: Defra and the Environment Agency should improve transparency of flood defence spending decisions to allow better scrutiny and ensure fairness across regions and for deprived communities.

Recommendation sixteen: Enable images taken by drones deployed by government agencies during flood events to support Farming Recovery Fund applications and other agricultural schemes relating to flooding.

Recommendation seventeen: Give local authorities the power to allow supermarkets to temporarily remain open longer on Sundays during major incidents linked to extreme weather events.

Recommendation eighteen: The UK Government should set up a scientific taskforce and commission research with the Coal Authority, and Welsh and Scottish Governments, to ensure that the state of knowledge on the risk of flooding interacting with former mine workings is progressed, alongside assessment of risks relating to coal tips.

Better supporting local government and improving urban drainage

Recommendation nineteen: The Department for Levelling Up, Housing and Communities (LUHC) should more explicitly acknowledge tackling flooding amongst its ministerial responsibilities and explicitly designate a minister as responsible for coordinating inclusion of flooding considerations within policies across the department.

Recommendation twenty: Ensure the proposed new developer contributions levy due to replace Section 106 and the Community Infrastructure Levy under the Government's current planning reforms actively encourages the alleviation of flood risk associated with new developments.

Recommendation twenty one: The Government should affirm that sewerage companies have a responsibility to ensure surface water sewer networks are not overwhelmed by increasingly heavy rainfall events as the climate changes, whether that is via Drainage and Wastewater Management Plans (DWMP) or other means.

Recommendation twenty two: Factor the length of roads a local authority is responsible for maintaining into the funding central government allocates to local authorities for flood risk management.

Recommendation twenty three: Defra or LUHC should investigate the funding and other barriers which local authorities face in improving their drain clearing and maintenance programmes, as well as how many local authorities actively prioritise high risk areas in their drain clearing schedules, and encourage any that don't.

Recommendation twenty four: Appoint and commission a new official advisory board to develop recommendations on the most immediate and effective steps central government and local authorities could take to alleviate the UK's growing urban flash flooding problem in existing developed areas.

Chapter 1: Introduction

Flood risk from all sources (rivers, the sea, surface water and groundwater) is projected to increase across the UK.¹ The risk posed to communities and critical infrastructure from flooding is one of the most severe climate-related risks that the UK faces.²

The landmark floods of 2007 prompted the largest peacetime national emergency effort since World War Two. The flooding linked to storm events in the winter of 2015-16, including Storm Desmond, has been demonstrated to be truly historically exceptional.³ The severe winter flooding of 2019-20 left people enduring the first COVID-19 lockdown in flood-damaged homes and contributed to an exceptionally low wheat harvest. High-impact flood events have left deep scars on affected communities.

The Met Office notes that both winters and summers are now wetter in the UK than in the recent past, and total rainfall from extremely wet days has increased, particularly in Scotland.⁴ Climate projections for the UK indicate increased chance of wetter winters and drier summers

1. Sayers et al., "Climate Change Risk Assessment 2017: Projections of future flood risk in the UK", *Climate Change Committee*, <https://www.theccc.org.uk/wp-content/uploads/2015/10/CCRA-Future-Flooding-Main-Report-Final-06Oct2015.pdf> (2015).

2. Climate Change Committee, "The Third UK Climate Change Risk Assessment Technical Report", <https://www.ukclimaterisk.org/independent-assessment-ccra3/technical-report/> (2021).

3. BBC "Storm Desmond: Study says flood was 'largest in 600 years'", <https://www.bbc.co.uk/news/uk-england-cumbria-48351653> (2019); Centre for Ecology and Hydrology, "The winter floods of 2015/2016 in the UK – a review", <https://www.ceh.ac.uk/sites/default/files/2015-2016%20Winter%20Floods%20report%20Low%20Res.pdf> (2016).

4. Met Office, "UK Climate Projections: Headline Findings", <https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp-headline-findings-v2.pdf> (2019).

over the 21st century, but with more intense heavy summer rainfall events⁵.

Recent research in the journal *Nature* confirms that Great Britain is currently experiencing a historically “flood-rich” period in terms of river flooding.⁶ While Europe has experienced many such periods over the past 500 years, the current one is exceptional in terms of the temperature at which it is occurring, and the proportion of floods which are occurring in summer months. Other academic papers have highlighted that the UK is projected to be a flood risk hotspot within Europe under climate change.⁷

Flooding is the most significant climate change-related risk to critical UK infrastructure such as energy, transport, water, waste, and digital communications, and significant infrastructure assets are already situated in exposed locations.⁸ Risks to local communities and economies are closely linked to the resilience of such key infrastructure.

The impact of flooding on local communities

There are numerous well-known examples of places which have been devastated by flood events: Doncaster, the Somerset levels and Calderdale, to name a few. There are also many places – small towns, villages and suburbs – whose stories don’t get told in the national press. Few people in the UK are aware of the floods which devastated Alyth in Perthshire (2015), St Asaph in Denbighshire (2012), Galgate in Lancashire (2017) or farms in County Tyrone (2017). Such stories deserve to be better known.

While once we might have thought about flooding as a misfortune that happens to individual properties which they by and large recover

5. Ibid.

6. Blöschl et al., “Current European flood-rich period exceptional compared with past 500 years”, *Nature* 583, 560–566 (2020).

7. Guerreiro et al., “Future heat-waves, droughts and floods in 571 European cities”, *Environmental Research Letters* 13:034009 (2018); Hirabayashi et al., “Global exposure to flooding from the new CMIP6 climate model projections”, *Scientific Reports* 11, 3740 (2021).

8. Climate Change Committee, “Progress in adapting to climate change: 2021 Report to Parliament”, <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

from through insurance, we now need to consider the more systemic impacts it may have across communities and over time. Repeat flooding, severe flooding and loss of transport links can have economic impacts which are all too apparent to a local community.

There are often reports of strong community responses and iron-willed determination to recover from flood events. However, this is obviously harder in places which have a pre-existing high level of socio-economic deprivation. For example, Rhondda Cynon Taff, which contains some of Wales's most deprived communities,⁹ suffered severe flooding from Storm Dennis in 2020. Residents of deprived communities often describe not having flood insurance. Low financial resilience through lack of insurance and other financial impacts from flooding has the potential to impede the economic recovery and development of the community as a whole over the long term.¹⁰

There have been occasional debates over the social and regional equity of government flood defence spending decisions.¹¹ Deprived areas are weighted more heavily in England's flood defence spending formula, according to Defra.¹² Despite this, in 2021 the House of Commons Public Accounts Committee found a decline in the proportion of flood investment going to deprived areas since 2014, concluding that Defra has not ensured flood defence funding has been allocated to all regions and deprived areas fairly.¹³ The profound short- and long-term implications of flooding for some communities' economies make this an obvious concern for the Government's nascent 'levelling-up' agenda, which aims to reduce regional inequalities, improving coastal and

9. StatsWales, "Welsh Index of Multiple Deprivation", <https://wimd.gov.wales> (2019).

10. Viktor Rözer and Swenja Surminski, "Current and future flood risk of new build homes across different socio-economic neighbourhoods in England and Wales", *Environmental Research Letters* 16:054021 (2021).

11. Mark Tran, "North-south divide cited as factor in Yorkshire flooding devastation", *The Guardian*, <https://www.theguardian.com/uk-news/2015/dec/28/yorkshire-flooding-north-south-divide-york-leeds-london-south-east> (2015); Jonathan Leake, "Flood defence money diverted from south over fears for northern residents' health", *The Times*, <https://www.thetimes.co.uk/article/flood-defence-money-diverted-from-south-over-fears-for-northern-residents-health-85z69lflk> (2020); Department for Environment, Food and Rural Affairs, "Sunday Times article on flood defence spending formula", <https://deframedia.blog.gov.uk/2020/02/23/sunday-times-article-on-flood-defence-spending-formula/> (2020).

12. *Ibid.*

13. Public Accounts Committee, "Managing Flood Risk", <https://publications.parliament.uk/pa/cm5801/cmselect/cmpubacc/931/93105.htm> (2021).

former industrial areas in particular.

Over time, the non-viability of some communities due to risk of coastal flooding and erosion is, unfortunately, likely going to become apparent as sea levels rise. The case of Fairbourne in Wales, the first human settlement in the UK to be decommissioned in anticipation of increased coastal hazards as a result of sea level rise, is well known.¹⁴ The CCC notes that it is not known which other communities might share the same fate,¹⁵ explaining the need for a “dedicated programme of work to identify, and then create plans for, communities that may no longer be sustainable as sea levels rise”.

Communities in coal mining legacy areas face particular risks associated with the landslides from coal tips and subsidence events triggered by heavy rainfall.¹⁶ In January 2021, residents of Skewen in Neath Port Talbot experienced a traumatic flood event when a disused mine shaft filled with water, causing it to burst.¹⁷ While measures to prevent such an incident recurring have now been put in place,¹⁸ Skewen is not the only potentially affected community given how widespread the legacy of coal mining is in South Wales.¹⁹ There was an emergency review of coal tip safety in Wales in 2020 by the Welsh and UK Governments, with approximately 300 coal tips deemed at high risk of landslides or other hazards.²⁰ The risks of flooding interacting with

14. Andrew Forgrave, “Life in a North Wales village set to be the first in the UK to be made extinct by the sea”, *NorthWalesLive*, <https://www.dailypost.co.uk/news/north-wales-news/life-north-wales-village-set-17605572> (2020).

15. Climate Change Committee, “The Third UK Climate Change Risk Assessment Technical Report”, <https://www.ukclimaterisk.org/independent-assessment-cera3/technical-report/> (2021).

16. Climate Change Committee, “The Third UK Climate Change Risk Assessment Technical Report: Chapter 4: Infrastructure”, <https://www.ukclimaterisk.org/independent-assessment-cera3/technical-report/> (2021); Welsh Government, “Coal tip safety”, <https://gov.wales/coal-tip-safety> (2021).

17. Christie Bannon, “The ‘living hell’ of Skewen flood victims still unable to go home and frightened every time it rains”, *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/living-hell-skewen-flood-victims-20632445> (2021);

18. Coal Authority, “Construction begins on Skewen mine water management scheme”, <https://www.gov.uk/government/news/construction-begins-on-skewen-mine-water-management-scheme> (2021).

19. Hannah Neary, “Skewen flood victims could suffer mentally and physically for ‘months to come’”, *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/skewen-flooding-council-mental-health-19714629> (2021).

20. Dan Whitehead, “Wales says climate change could increase risk of landslides from disused coal tips as it marks Aberfan anniversary”, *Sky News*, <https://news.sky.com/story/wales-says-climate-change-could-increase-risk-of-landslides-from-disused-coal-tips-as-it-marks-aberfan-anniversary-12440270> (2021).

former mine workings in Wales and elsewhere are poorly understood.²¹

Information and knowledge are important for resilience. However, two-thirds of people living in areas at risk of flooding in England do not appreciate their property is at risk.²² People sometimes don't understand that they are responsible for their own property-level flood defences and resent the council for not providing them automatically.²³ They might not be aware that their property insurance is a bargain because it doesn't include flood cover.²⁴ There are almost certainly people buying what they believe to be their family's 'forever home' who are not aware it may not be insurable in two decades after the Flood Re scheme, the government's and insurance industry's joint initiative to ensure affordable flood insurance is available to UK households, ends. People may not know what to do in a local emergency: when Lancaster lost power due to flooding in 2015, the local hospital A&E department received calls inquiring where to buy paracetamol and how to heat up baked beans with no electricity.²⁵ If the UK is to be the "most resilient nation", as the forthcoming National Resilience Strategy envisages, then people need to be well-informed about the actions they can take to prepare for flooding and how to respond in an emergency.

The Government is currently drawing up the new National Resilience Strategy. Connected to this, a review of the Civil Contingencies Act is due to be completed in 2022.²⁶ The Civil Contingencies Act sets out the roles and responsibilities for organisations which help prepare for and

21. Laura Clements, "The thousands of old mine shafts beneath Welsh homes and the chances of another catastrophic flood", *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/flood-mine-shaft-skewen-coal-19741349> (2021).

22. Environment Agency, "National Flood and Coastal Erosion Risk Management Strategy for England", <https://www.gov.uk/government/publications/national-flood-and-coastal-erosion-risk-management-strategy-for-england-2> (2020).

23. Kathryn Anderson, "Perth and Kinross officer tells homeowners it is up to them to protect properties from flooding", *Daily Record*, <https://www.dailyrecord.co.uk/news/local-news/perth-kinross-officer-tells-homeowners-22999710> (2020).

24. Mark Casci, "Don't let it happen to you' - flood hit Fishlake Truffle Lodge owner's warning to business on insurance", *Yorkshire Post*, <https://www.yorkshirepost.co.uk/business/dont-let-it-happen-you-flood-hit-fishlake-truffle-lodge-owners-warning-business-insurance-1742950> (2020).

25. Royal Academy of Engineering, "Living without electricity: One city's experience of coping with loss of power", <https://www.raeng.org.uk/publications/reports/living-without-electricity> (2016).

26. Cabinet Office, "National Resilience Strategy: Call for Evidence", <https://www.gov.uk/government/consultations/national-resilience-strategy-call-for-evidence> (2021).

respond to emergencies. While the National Resilience Strategy will cover a wide range of potential threats, from pandemic preparation to major accidents to malicious attacks, it does provide an opportunity to ensure civil contingency planning is robust to our changing flood risk.

Contingency planning, adaptation and resilience require foresight on emerging serious and systemic risks, and new techniques for horizon-scanning to assist in this process. Resilience requires understanding of the cascading and/or long-lasting impacts which could affect a whole community or broad geographical area, and ideally preventing them. A clear understanding of how flooding is affecting or could affect specific key public services, critical infrastructure and local economies – the prime focus of this report – is fundamental to this.

Focus of this report

The focus of this report is to collate information on the real impacts of flooding and related hazards on key public services, critical infrastructure and key businesses – as well as on communities – across the UK since 2007.

The report achieves this by making use of the large volume of qualitative information on flooding impacts contained in local, regional and national newspaper articles. It analyses newspaper articles through Natural Language Processing (NLP), a form of artificial intelligence explained further in Chapter Two. It has been conducted on behalf of Bright Blue by ClimateNode, a not-for-profit aiming to use data science to support research on climate risks and impacts with a public benefit focus.

Newspapers provide a wealth of information on flooding impacts at the local level, but this is scattered amongst thousands of separate documents. It is hoped that collating and presenting this information will help illustrate the scale of the challenge the UK has in adapting to our increasing flood hazard, including by making it relatable through the experiences of real people. The report brings out the voices of people affected by flooding through pull-out quotes scattered throughout the

text from newspaper articles found during the NLP analysis. Readers are encouraged to explore in more depth how flooding has affected individual communities and sectors through the online UK Flood Impact Map which accompanies this report (see Chapter Two).

Articles nostalgically recalling major flood events in decades gone by are common in local newspapers. The project makes no comment on the degree to which climate change made any individual flood event more likely or more severe, which is beyond the scope of this report. Flooding is a complex phenomenon, and the evolution of flood risk over time in any particular location will be influenced by a range of factors, such as upstream land management, urbanisation and construction of flood defences – as well as changes in rainfall related to climate change. It is simply noted that wetter winters and more intense summer rainfall events, like those projected for the UK,²⁷ will logically make flood impacts progressively worse over time *all else being equal*.

The report reveals the impacts of flooding in all parts of the UK since 2007. However, due to time constraints, it does not present policy recommendations which grapple with differences in arrangements in flood risk management and planning in each devolved nation of the UK. Therefore, some of the policy discussion and recommendations are relevant to the UK as a whole, and some specific to England, or England and Wales, only.

It is also worth noting that many of the flood impacts identified have prompted adaptation efforts and have not remained unaddressed. Billions are being spent on flood defences, and actions are being taken to make infrastructure more resilient. Readers are referred to the National Flood Resilience Review (a 2016 government report which assessed infrastructure resilience to flooding); the Climate Change Committee's (CCC's) biennial reports to the UK Parliament on progress in adapting to climate change; and the National Flood and Coastal Erosion Risk

27. Met Office, "UK Climate Projections: Headline Findings", <https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp-headline-findings-v2.pdf> (2019).

Management Strategy for England (the Environment Agency's statutory flood risk management strategy document) for further details.²⁸ But there certainly remain many gaps, as will be illustrated in this report, and the UK is not adapting to all aspects of its changing flood risk.

Finally, examining newspaper articles generally can only inform us about what has already happened. Climate resilience requires an understanding of what could happen in future, which is a question for climate and hydrological modellers, and the researchers who use their outputs. It is hoped readers will bear in mind that whatever impacts are described here have the potential to get more severe in the future; how severe depends on the level of greenhouse gas emissions in the atmosphere resulting from the actions of all nations, and how well we adapt.

This report seeks to answer the following research questions:

1. Which assets, locations and sectors have been affected by flooding in the UK over the past 10-15 years?
2. What are the knock-on impacts and systemic risks which could emerge should floods recur or become more severe for these assets, locations and sectors?
3. Is Natural Language Processing (NLP) of newspaper articles a useful tool for deriving insights of value to local and national-level flood risk management and climate adaptation strategies?
4. What further policies are needed within the context of current flood risk management policies and practices?

28. HM Government, "National Flood Resilience Review", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf (2016); Climate Change Committee, "Progress in adapting to climate change: 2021 Report to Parliament", <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021); Environment Agency, "National Flood and Coastal Erosion Risk Management Strategy for England", <https://www.gov.uk/government/publications/national-flood-and-coastal-erosion-risk-management-strategy-for-england-2> (2020)

The report is structured as follows:

- **Chapter two** outlines the methodologies used in developing this report, including a review of relevant policy literature and Natural Language Processing (NLP).
- **Chapter three** identifies the different impacts of flooding since 2007 on key public services.
- **Chapter four** unearths the different impacts of flooding since 2007 on critical infrastructure.
- **Chapter five** describes the different impacts of flooding since 2007 on key businesses.
- **Chapter six** puts forward credible policy recommendations to mitigate flood risk and bolster resilience to its effects, both locally and nationally.

Chapter 2: Methodology

This report seeks to highlight the impacts of flooding on key public services, critical infrastructure and key businesses, as well as local communities, across the UK since 2007. It also explores the key issues in current central government policy processes to mitigate and adapt to flooding, before proposing original and credible policy recommendations.

We employed two key research techniques in this project:

- **Natural Language Processing (NLP).** The main research method this project uses is NLP – a form of artificial intelligence – to process a large sample of newspaper articles in order to identify instances of flooding across the UK and its impacts on key infrastructure and local communities.
- **Review of relevant policy literature.** We conducted a review of the relevant policy documents on flood risk management, paying particular attention to how it relates to infrastructure resilience and surface water flooding.

Natural Language Processing (NLP)

Natural language processing (NLP) is the branch of artificial intelligence which relates to using computers to process human language, either as voice data or text.

This report used a particular NLP technique called ‘entity recognition’, which is used to identify and classify instances of place names, organisations and events occurring within a piece of text (such as a newspaper article) via its syntax. The categories of ‘entities’ (types of thing) to look for is defined by the user, who may train the algorithm to recognise the entities of interest through example texts (‘training data’).

The analysis here systematically searched newspaper websites for flooding-related articles using a simple text search. It then ran each article identified through an NLP algorithm to determine whether it was indeed likely about flooding (as opposed to metaphorical floods) as well as to identify locations, assets and events (such as named storms) mentioned. Article URLs and names of entities were stored in a database.

This data was then used, along with geocoding, to generate the UK Flood Impact Map, an interactive map of UK flood impacts accompanying this report (https://www.climatenode.org/maps/UK_flood_map.html). The map displays information on over 2,800 individual places and assets encountered in the analysis, and all of the impacts described in this report, linking each place to the newspaper articles relevant to it. It can be filtered by sector and by individual flood event. See the Annex for more details.

There are many opportunities for a place to be mentioned in an article, even though the focus of the article is not about that specific location. For example, a farmer in Yorkshire might say “I hope the people in Westminster sort this out”. Therefore, our analysis also used a fair amount of rapid human scanning and cross-checking as a quality control measure.

Approximately 7,800 articles from over 60 news sites were processed. The analysis almost entirely used newspaper websites represented by the UK newspaper industry’s collecting society, NLA Media Access (through whom an appropriate licence was acquired), and for any other titles sought permission.

The analysis covers fluvial (river), coastal, surface water, groundwater,

and sewer flooding. It also covers some related hazards: river erosion, coastal erosion, heavy rainfall, landslides, sea level rise and coastal storm damage. Flooding due to ingress through roofs and ceilings is included if it is major, obviously due to very heavy rainfall and/or there is damage to the ceiling (for example, small leaks are not included). It excludes floods due to burst water mains and internal pipework, as these are not clearly attributable to wet weather.²⁹ It also excludes sewer flooding which was not clearly linked to a broader flood or heavy rainfall event. Hail and snow are included only if they contribute to flooding. Impacts which coincide with flood events but are clearly caused by different hazards (such as lightning or wind) are not included.

The major flooding of 2007 is used as a temporal cut-off point, and flood events preceding this are generally not included, not least because the quantity of online information available diminishes for events further back in time. This analysis therefore assesses the impacts of flooding over the past 14 years.

The analysis is not exhaustive. Inevitably, it can only cover a sample of newspapers and the many newspaper articles that have been written about flooding since 2007, and a subset of the places affected. In addition, even local newspapers will not cover all impacts. Attempts have been made to include the major flood events, as well as provide information on a mixture of communities large and small, at city, town, village, business and asset level. In this way, the analysis creates a comprehensive snapshot of flooding impacts over the past 14 years, even if it cannot cover everything.

29. It's worth acknowledging that climate change could influence the frequency of burst water mains via changes in soil moisture levels resulting from periods of exceptionally dry weather. See: Ofwat, "Climate change" <https://www.ofwat.gov.uk/regulated-companies/resilience-in-the-round/climate-change/>.

Chapter 3:

Impacts of flooding on key public services since 2007

This chapter presents the findings from the NLP analysis uncovering the impacts on key public services from flooding since 2007. Key public services include: emergency services, health services, education services, social care services and local government services.

For each service or sector mentioned in Chapters Three, Four and Five, a number of real flood-related impacts which have occurred since 2007 described in newspaper articles and revealed by the analysis are summarised in a box to give the reader a sense of the challenges the sector faces.

The impacts are broadly categorised as follows:

- **Least serious.** Temporary, relatively easily managed and not resulting in significant disruption of services or threats to safety. In addition, there is minimal clean-up in affected buildings.
- **More serious.** Impacts caused or threatened: significant disruption; noticeable loss of services; physical damage to infrastructure; or, economic distress to individual organisations. Some impacts could have posed a significant threat to safety without good emergency management. The impacts required substantial clean-up and/or refurbishment for affected buildings. They can include impacts which cause recurrent annoyance or disamenity, or unusual emotional distress.

- **Most serious.** Impacts may have posed a severe threat to safety, or actually resulted in fatalities. They are impacts with serious knock-on implications for emergency response, public health, public services, the local-to-regional economy or food supply. The impacts may have made buildings rendered permanently unusable.
- **Avoided.** Impacts which could have been consequential, but which were avoided.
- **Long-term.** The risk of impacts in the long-term.

Emergency services

There have been a number of impacts on emergency services during flood events since 2007, as Box 3.1 below shows.

Despite obviously compounding the difficulties faced, it is not clear from newspaper articles that even the most serious impacts on emergency services have resulted in major adverse consequences for emergency response, public safety or law and order; but the potential for this to occur in future is obviously something that should be considered.

Box 3.1. Real impacts on UK emergency services from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Manageable diversion of ambulance crews on a hospital site
- Small-scale vigilantism due to concerns that flooded property may be burgled
- Minor flooding at an ambulance station

More serious

- Public asked to reduce pressure on ambulance services
- Temporary loss of a major access route to an A&E department
- Diverted ambulances
- Ambulances and fire engines stuck in floodwater or congestion due to flooding

- Fire and rescue services described as stretched to their limit
- Power cuts at fire stations with back-up generators
- Volunteers evacuating numerous people without professional help
- A volunteer inshore rescue station temporarily flooded during a flood event
- A small number of cases of burglary in unoccupied properties during a flood event

Most serious

- Severe access restrictions to an A&E department, with army back-up required
- Severe restrictions on movement of a critically ill patient between hospitals
- A fire crew operating out of a motorway service station after their station was flooded
- Fire and rescue crews described as working “to the point of collapse”
- A severely damaged police station no longer suitable for police use

Newspaper articles report instances of communities unreachable by road vehicles due to floodwater or damaged bridges. Occasionally, emergency service vehicles have been reported to be trapped in floodwater. Computer simulations of emergency service response in flooded transport networks have indicated that even low-magnitude floods could lead to reduced compliance with mandatory response times.³⁰

On some occasions, emergency services have been described as stretched to their limit. In 2019, the Climate Change Committee (CCC) noted that a review of emergency planning in England concluded that it has been effective in responding to small and medium-sized events, but the “system is stretched” and needs improvement to deal

30. Yu. et al., “Disruption of emergency response to vulnerable populations during floods”, *Nature Sustainability* 3, 728–736 (2020).

with major events.³¹ More recently, the CCC stated that capacity to respond to incidents “appears to be decreasing” and this decline may lead to emergency response becoming “overwhelmed” by exceptional or parallel events in future.³²

The CCC recommends the preventative identification and targeting of emergency service vulnerability hotspots before major flood events put them under unmanageable strain. The Fire Brigades Union has called for responding to flooding to be made a statutory duty of fire and rescue services in England, as it is already in other parts of the UK, to assist in resourcing and emergency planning³³.

Box 3.2. The impact of flooding on emergency services

Lancashire, 2015

During Storm Desmond in December 2015, army trucks were stationed at the Royal Lancaster Infirmary to act as stand-by ambulances after all access routes but one to the hospital were cut off. Soldiers moved one woman in a coma between hospitals after multiple bridges were shut due to flood damage.

During the same storm, Lancaster Fire Station was flooded with firefighters working out of a service station 35 miles away. There were also power cuts at other fire stations, with back-up generators in use.

31. Climate Change Committee, “Progress in preparing for climate change: 2019 Report to Parliament”, <https://www.theccc.org.uk/publication/progress-in-preparing-for-climate-change-2019-progress-report-to-parliament/> (2019).

32. Climate Change Committee, “Progress in adapting to climate change: 2021 Report to Parliament”, <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

33. Pat Strickland, “Should Fire and Rescue Services have a statutory duty to deal with flooding”, <https://researchbriefings.files.parliament.uk/documents/CBP-7605/CBP-7605.pdf> (2016).

Royal Alexandra Hospital, Paisley

The Royal Alexandra Hospital in Paisley has been described as at high risk of surface water flooding and medium-to-high risk of river flooding by climate risk assessment for the Greater Glasgow region. Roads around the hospital have been described as suffering from surface water flooding by newspaper reports on at least two occasions. In February 2020 an ambulance was stuck in floodwater in Paisley, while in August that year the MSP for Dumbarton raised concerns that congestion relating to flooding could affect ambulance services reaching the hospital.

The National Security Risk Assessment (NSRA) is the government's classified assessment of the key malicious and non-malicious threats that could affect the UK, both domestically and overseas. The National Risk Register (NRR) is the public-facing version of it. Surface water flooding was only included in the National Risk Register for the first time in 2017.³⁴ So it is possible that civil contingency planning may be lagging on this front. In 2016, the National Flood Resilience Review, a government report which assessed infrastructure resilience to flooding, developed plausible extreme rainfall scenarios for river and coastal floods. Work is now underway to extend this process to surface water flooding and this will feed into the next review of the National Risk Assessment as well as the National Resilience Strategy³⁵.

As explained in Chapter One, the National Resilience Strategy and the review of the Civil Contingencies Act provide an opportunity to take stock of whether emergency planning arrangements will remain robust to the UK's increasing flood hazard over the next ten years. As

34. Department for Environment, Food and Rural Affairs, "Surface Water Management: An Action Plan", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725664/surface-water-management-action-plan-july-2018.pdf, (2018).

35. *Ibid.*; Department for Environment, Food and Rural Affairs, "Surface water management: A Government update", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015182/surface-water-management-government-update.pdf (2021).

we propose in Chapter Six, as part of this, foresight on what a truly exceptional rainfall event scenario in an urban area would mean for emergency response could be beneficial to emergency planning.

"It seems to be getting worse every time we get heavy rain now. It's hard to get anywhere when it floods because every route is affected and flooded. God help if the emergency services needed to get through."

Resident of Birchgrove, Swansea³⁶

Health services

A variety of health services – state and private hospitals, primary care, and public health – have been impacted by flooding since 2007. These impacts are detailed in Box 3.3 below.

The main direct impacts have included major disruptions to A&E departments, evacuations and temporary inability to use operating theatres. Indirect impacts have included staff unable to report to work, patient access problems or receipt of patients diverted from flood-affected hospitals. However, the analysis did not find any evidence of fatalities or life-threatening interruptions to patient care from flooding from 2007 onwards in hospitals.

³⁶. John Cooper, "Floodwater turned road into river, shifted parked cars and washed through couple's 'dream home'", *WalesOnline*: <https://www.walesonline.co.uk/news/wales-news/floodwater-turned-road-river-shifted-17198115> (2019).

Box 3.3. Real impacts on UK health services from flooding and related hazards since 2007, encountered in the NLP analysis**Least serious**

- Minor flooding of entrances and waiting rooms with no disruption to services
- Cars damaged in the car park
- Disruption of supporting services such as admin and catering with no adverse consequences for patient care reported
- Minor and/or temporary loss of access routes, but with no adverse consequences reported
- Staff able to attend work only with difficulty
- Loss of administrative records not including patient records
- Cancelled GP appointments with patients diverted to other premises

More serious

- Some staff unable to report to work
- Power loss with use of back-up generator
- Minor disruption to A&E, for example, rerouting emergency patients through a different entrance
- Public asked informally to reduce pressure on A&E
- Temporary disruption of out-patient clinics such as physiotherapy
- Movement of in-patients within the hospital
- Temporary disruption of maternity services with care provided elsewhere
- Elective surgery cancelled for one day or less
- Temporary relocation of emergency surgery within the hospital with continuity of care
- Damage to lifts, fire doors and the mortuary
- Difficult but manageable disruption to prescription and/or pharmacy services
- A GP practice closed for an extended period of time but operating out of alternative premises
- Permanent relocation of a GP practice by choice, for example, from a functioning but flood-prone building

- A primary care centre flooded with no continuity of services, and thus patients travelling many miles to other practices
- Contingency plans drawn up to deal with potential health problems arising from a water shortage and sewage contamination of floodwater
- Evacuation of vulnerable but not physically at-risk in-patients, including mental health and dementia patients

Most serious

- Major disruption to A&E – for example, a major incident declared, patients diverted to other A&E departments, emergency patients moved within the hospital
- Evacuation of in-patients to other hospitals
- Major power outage in part of a hospital
- Extensive flood damage to a primary care centre building making it permanently unsafe

Avoided

- Loss of boiler room function
- Near miss of disruption to an intensive care ward
- Local residents averting a rural GP surgery flood by building makeshift flood defences

Long-term

- Hospitals identified as at risk of flooding long-term

In July 2021, a major incident was declared when two London hospitals were not able to operate their A&E departments effectively due to flash flooding.³⁷ While this incident attracted a lot of attention, there have been at least eleven other NHS hospitals and two private hospitals which have been directly significantly affected by flooding

37. Isabella D'Emilio, "London flooding: Surgery cancelled at Whipps Cross Hospital after flooding sees major incident declared", *MyLondon*, <https://www.mylondon.news/news/east-london-news/london-flooding-surgery-cancelled-whipps-21143555> (2021).

since 2007, where this is defined as internal flooding causing disruption or imminent risk of disruption to patient services or hospital support services. At least eight more hospitals have experienced minor internal or major external (carpark) flooding. There have been at least two major incidents due to surface water flooding, and at least five instances – four of which were NHS hospitals – of significant ingress of water through ceilings in hospitals and/or partial ceiling collapse during heavy rainfall.

"They have all been moved out to different places and as you can imagine, they all suffer from mental health issues and it's all very scary for them ... They were flooded at 3am, but had to wait until 11am to be evacuated by boat – it was a very traumatic time."

Mother of a patient evacuated from a mental health hospital in Warrington during Storm Christoph³⁸

Our analysis found only four NHS primary care centres and one pharmacy which have been affected by flooding since 2007. It is worth noting that newspaper articles used in the study often described high street businesses in general being affected by flood events and it is possible that pharmacies are regularly included among them. GPs are sometimes described as assessing patients at emergency rest centres, but the extent to which flood events increase demand for their time was not clear.

38. Jessica Farrington, "Appeal for funds to help residents of flooded mental health hospital in Dallam", *Warrington Guardian*, <https://www.warringtonguardian.co.uk/news/19037156.appeal-funds-help-residents-flooded-mental-health-hospital-dallam/> (2021).

Box 3.4. The impact of flooding on hospitals

Walsall Manor Hospital, West Midlands

In June 2020, the Acute Medical Unit in Walsall Manor Hospital experienced flooding from water pouring down through the ceiling. Entrances to an intensive care unit, an emergency theatre and some wards were affected. The emergency theatre team was relocated to another part of the hospital and was able to provide emergency cover for the rest of the night.

Victoria Memorial Hospital, Welshpool

In May 2018, the Victoria Memorial Hospital in Welshpool was affected by flash flooding. Midwifery cases were diverted to another hospital 15 miles away, while meals were brought in from the same neighbouring hospital due to the kitchen being out of action.

Newspaper articles usually give an impression of coping and resilience to flood impacts in hospitals, but the full extent of ways in which the health system is affected may not be apparent, including increased demand for services. For example, a study interviewing health personnel about coastal flooding in Lincolnshire in 2013 described the difficulties of caring for vulnerable people at evacuation centres, the interaction of flood disruption with seasonal pressures, the cancellation of services outside flooded areas and a 'surge' in healthcare demand, including mental health support.³⁹ Newspaper articles often reflect the now common understanding that many flood victims suffer subsequently from mental health problems, trauma and anxiety⁴⁰. A small number of incidents of infections from pathogens dispersed by floodwater, even after it has subsided, were described in newspaper articles.

39. Landeg et al., "Coastal flooding and frontline health care services: challenges for flood risk resilience in the English health care system", *Journal of Health Services Research & Policy* 24(4):219-228 (2019).

40. BBC, "UK Floods: Victims face mental health 'support vacuum'", <https://www.bbc.co.uk/news/uk-england-55994198> (2021).

Flood events interacted with the COVID-19 pandemic in various ways. First and foremost, a major flood event caused by Storm Christoph occurred during a particularly difficult phase of the pandemic in the UK – the third national lockdown in January 2021. This could have encouraged contagion via evacuations and rest centres. Having to endure lockdowns in flooded-out homes or temporary accommodation affected people’s quality of life in places such as Pontypridd.⁴¹ Flooding on Wrexham Industrial Estate during Storm Christoph raised concerns that the manufacture of the Oxford/AstraZeneca vaccine could be disrupted, although by all accounts the incident was dealt with effectively.⁴² There were also a few instances described by newspaper articles of flooding temporarily affecting vaccination and testing centres.

Our analysis did not uncover any evidence of actual or potential supply chain impacts on health services, although it is worth noting that a major NHS blood manufacturing centre was affected by flooding in 2012.⁴³

Education services

Box 3.5 below shows the different impacts caused to educational services, specifically schools, colleges, and universities, by flooding since 2007.

41. Katie-Ann Gupwell, “Storm Dennis a year on: Flooded residents describe living upstairs for months with homes, cars, and possessions ruined”, *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/storm-dennis-year-on-flooded-19806628> (2021).

42. Cathy Owen, “All the roads closed and flood warnings in place as Storm Christoph causes mayhem”, *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/storm-christoph-weather-flooding-wales-19668695> (2021).

43. Public Health England, “Chemical hazards and poisons report”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/348826/CHaP_report_24_2.pdf (2014).

Box 3.5. Real impacts on UK education services from flooding and related hazards encountered in the study

Least serious

- School closed due to risk of flooding or flooding in the local area for one day or less
- School closed for one day or less, to all pupils or just some year groups, due to isolated flooding
- Flooding affecting the school's ability to enforce COVID-19 or fire safety regulations
- School experiencing isolated flooding but important exams able to proceed
- Flooded playing fields or water collecting in other outside areas
- Access restrictions or difficulties
- Temporary changes to or cancellations of school buses
- Lecture cancellations

More serious

- Significant damage from more than isolated flooding resulting in closure of a fortnight or less
- Contamination from sewage flooding
- Short-term loss of electricity, hot water and heating or catering facilities
- Evacuations
- Fundraising needed for equipment not covered by insurance
- Loss of facilities pupils and teachers regard as special, for example a treasured library
- Children missing one week of school while alternative classrooms are sourced
- Relocation of teaching offsite for a single year group for several weeks or months
- Children on a stranded school bus put up at an army barracks overnight
- Surmountable disruption of school transport due to damaged road infrastructure

Most serious

- Extensive damage resulting in closure and relocation of all or most teaching for several weeks or months, potentially with children spread between other schools or lessons taking place in mobiles for several months
- Emergency services needed to rescue children from a school bus stranded in floodwater in clearly dangerous circumstances
- Teachers describing repeat flooding as impacting pupils' education

Avoided

- A ceiling collapse at a primary school when no-one was present
- A school cut off by flooding over the weekend
- Fire crews or staff and parents averting internal flooding

Long-term

- Schools and colleges at long-term risk of coastal flooding as sea levels rise
- Frequent repeat flooding, for example six times in three years, raising questions over how many flooding episodes in can expect in future

Our analysis identified at least 67 individual state schools and one private school which have been directly affected by flooding since 2007, where this is defined as sufficient water entering buildings to disrupt lessons, or school transport stuck in floodwater. Of these, 22 suffered at least significant damage, and seven extensive damage, bearing in mind the extent of damage is not always described.⁴⁴ Clearly this is only a fraction of the true total, as *The Guardian* reported in 2007 that hundreds of schools were affected by the floods of that year, with some

44. Here 'significant' damage means flooding pervading the ground floor damaging carpets, equipment, furniture etc. resulting in closure of one day to two weeks. 'Extensive' damage is typically of the order of £100,000s resulting in teaching taking place elsewhere for weeks or months while the school is comprehensively refurbished.

seriously damaged.⁴⁵ Many others have been closed for one day due to flooding in the local area, or have had other transport-related problems.

"It will cost at least £100,000 to sort out this damage. There's raw sewage on the carpets and out in the yard. Interactive white boards, a laptop, carpets and requisition equipment — pens and exercise books — for September that we spent £3,000 on — are all destroyed."

Head teacher of a Belfast school affected by flash flooding⁴⁶

Newspaper articles gave an overall impression of schools being generally very cautious when it comes to safety, with head teachers often rapidly taking the decision to close when flooding is taking place in the local area. There were few descriptions of schools evacuating in an abrupt manner and very few describing circumstances where safety was conceivably at risk. The most serious example of a risk to pupil safety was a school bus trapped in floodwater in Yorkshire in 2016, when a driver ignored a 'road closed' sign.

In terms of damage and disruption, schools have shown extraordinary determination and resilience in flood recovery, working intensively to ensure disruption of pupils' education is kept to an absolute minimum. Newspaper articles describe staff working extremely hard to ensure a school flooded on Friday, for example, can reopen on Monday, often with strong community support. The most seriously affected part of the country within the last decade appears to be Calderdale in Yorkshire, as detailed in Box 3.6 below.

45. Martin Wainwright, "Thousands of pupils miss start of term at flood-hit schools", *The Guardian*, <https://www.theguardian.com/uk/2007/sep/06/schools.weather> (2007).

46. Lesley-Anne McKeown and Anna Maguire, "Tears, disbelief and heartbreak of flooding victims", *Belfast Telegraph*, <https://www.belfasttelegraph.co.uk/news/northern-ireland/tears-disbelief-and-heartbreak-of-flooding-victims-28766279.html> (2012).

Box 3.6. The impact of flooding on schools

Calderdale's Boxing Day floods, 2015

The severe Boxing Day floods in Calderdale in 2015 had a highly disruptive impact on some of the area's schools.

Primary schools Burnley Road and Scout Road Academies in Mytholmroyd were both closed for 9-10 months afterwards. In Burnley Road's case, "all but a few rooms were turned upside down by the floods",⁴⁷ while a landslip near Scout Road Academy required the hillside to be stabilised. Pupils were redistributed from Burnley Road and from the primary school in Todmorden to other schools in the area.

In Hebden Bridge, Riverside Junior School was able to open in mid-January, while Year 1 pupils from Central Street Infant School were taught in alternative premises for a while.

Todmorden Primary School and Burnley Road Academy were also badly damaged in 2020. According to the headteacher, the former has been hit by flooding six times since 2017.

Some schools have described design, lack of funds for general maintenance, or on-site drainage problems as contributing factors in their flooding. At least one state secondary school has recently been built in an area at risk of flooding against advice by the flood risk management authority. At least four schools have been built or retrofitted to be resilient to flooding.

There were relatively few examples of further or higher education institutes being affected. Nevertheless, both Lancaster and Aberystwyth Universities have needed to evacuate students from university accommodation. Short-term disruptions to teaching have been described at the Universities of Derby, Cumbria and Lancaster.

47. Halifax Courier, "Joy for pupils as flooded school officially opens doors today nine months after disaster", <https://www.halifaxcourier.co.uk/news/joy-pupils-flooded-school-officially-opens-doors-today-nine-months-after-disaster-1200326> (2016).

Social care services

Box 3.7 below outlines the impacts of flooding since 2007 on social care services and assets, such as retirement homes and sheltered accommodation.

Box 3.7. Real impacts on UK social care services from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Nursing home residents moved upstairs for safety while a flooded basement is pumped
- Temporary access restrictions
- Care home residents describing anxiety over their flood risk

More serious

- Carers unable to reach elderly people in rural areas with family diverted from work and/or flood recovery efforts to step in
- Loss of power, hot water and heating in care homes
- Evacuations and precautionary evacuations
- Care home staff ferried to work in boats
- Residents displaced from a care home for several months

Our analysis identified at least nine care homes and four retirement housing/sheltered accommodation complexes which have been flooded since 2007, all catering for the elderly. Although newspaper articles describe the distress and extra challenges of evacuating elderly people, some of them wheelchair users, our analysis did not find evidence of any cases where the elderly in social care settings had been at particularly high risk or in life-threatening situations.

"I just remember the water was right up to my knees. There was an almighty bang and we were left in the dark ... we spent six weeks at [a hotel] – but one room for two people was just horrible for that long. It was all very traumatic."

Resident evacuated from sheltered accommodation in Bicester, Oxfordshire⁴⁸

While not classifiable as social care, some older people choose to live in a park home, a type of residential mobile home on a protected site, for retirement. Park home sites situated next to rivers can share the same vulnerabilities to flooding as caravan sites, which we describe in Chapter Five. Our analysis identified at least five park home sites which have been evacuated due to flooding, one in a major incident, and two on more than one occasion.

Local government services

Newspaper articles relevant to local government services typically fall into one of three categories: stories describing frustration that local government isn't doing more to combat flooding and improve drainage; stories about planning applications and how development may or may not manage flood risk; and, stories about local government services and property which have been affected.

Local authorities' have an important role as flood risk managers. In England, what are referred to as Lead Local Flood Authorities (LLFAs, that is, unitary authorities and county councils in two-tier counties) are responsible for managing flood risks from surface water, groundwater and smaller watercourses. They are also responsible for highways

48. Naomi Herring, "Christmas flooding fears for Hanover Gardens residents", *Oxford Mail*, <https://www.oxfordmail.co.uk/news/15666016.christmas-flooding-fears-hanover-gardens-residents/> (2017).

drainage in their role as highways authorities⁴⁹.

The analysis revealed numerous local newspaper reports of sudden surface water flooding incidents in all parts of the UK. This is a particular concern for large urban areas. A flash flooding event in London in July 2021, during which a DLR station was inundated and flooding affected the operation of two hospital A&E departments, caught the nation's attention, but it is one illustration of a fairly widespread phenomenon; and the issue perhaps does not receive as much national media attention as it could. These incidents can be highly localised, seemingly random, and apparently minor on the broader scale of UK flooding impacts. But in fact, surface water flooding is a huge national issue; more houses are at risk from surface water flooding in England than are at risk from flooding from rivers and the sea,⁵⁰ though river flooding has greater potential for damage. Its unpredictability and difficulties in modelling means that the national adaptation response on surface water flood risk management is lagging the response to fluvial and coastal flooding.

Complaints that local councils have not done enough to maintain drainage are common after flood events. Residents and small business owners often say they would not have been as severely flooded if the council had more actively cleared out drains. In at least one case, an official report has found that lack of routine drain maintenance has contributed to a major flood event (York, 2015).⁵¹ It is worth asking whether there is any evidence to corroborate these widespread observations at national level.

49. Again, in England unitary authorities and county councils are the highways authorities with responsibility for drainage of roads, except major roads and motorways.

50. James Bevan, "Surface water: The biggest flood risk of all", <https://www.gov.uk/government/news/surface-water-the-biggest-flood-risk-of-all> (2018).

51. Gavin Aitchison, "City failures made York floods worse – Now here's the cost to put things right...", *Glasgow Evening Times*, <https://www.glasgowtimes.co.uk/news/14704871.amp/> (2016).

“The village flood defences are doing their job ... What’s not working are the drains. Water is backing up through the system and flowing out onto the streets”

Resident of Bangor-on-Dee following ‘danger to life’ flooding⁵²

In 2020, Defra published an independent review of arrangements for determining responsibility for surface water and drainage assets, entitled the Jenkins Review⁵³ which provided some interesting insights. While local government revenue spending on flood risk management has increased in real terms since 2010-11, consultees described a “significant fall” in expenditure on road cleaning and gullies due to funding pressures, and reduced standards of maintenance. The Association of Drainage Authorities described “an ever increasing number of blocked road gullies where the level of gully clearance and maintenance has significantly decreased or stopped altogether”. Presumably, it does not help that flood events themselves can damage and clog up the drainage system.

Lead Local Flood Authorities (LLFAs) receive funding from central government to carry out their flood risk management, but it is not ringfenced.⁵⁴ In 2020, a National Audit Office (NAO) report found that the government is unable to assess whether LLFAs have the resources they need to manage flood risk effectively.⁵⁵ Defra has, however, committed to reviewing local government funding for their statutory flood and coastal erosion risk management functions “to ensure it is fair and matches the

52. Andrew Forgrave, “Angry residents of village flooded during Storm Christoph blame ‘inadequate’ drainage”, *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/storm-christoph-bangor-dee-wrexham-19686179> (2021).

53. David Jenkins, “Report of a review of the arrangements for determining responsibility for surface water and drainage assets”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf (2020).

54. Department for Environment, Food and Rural Affairs, “Central Government Funding for Flood and Coastal Erosion Risk Management in England”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/974066/Funding_FCERM_March_2021_Final_accessible.pdf (2021).

55. Environment, Food and Rural Affairs Committee, “Flooding”, <https://publications.parliament.uk/pa/cm5801/cmselect/cmenvfru/170/17002.htm> (2021).

needs and resources of local areas”⁵⁶. While technically local authorities’ responsibilities as flood authorities and highways authorities are distinct, recognition of the importance of road drainage in flood risk management and funding for improved road drainage could be included in this Defra review, as we recommend in Chapter Six.

Funding for local authority surface water projects is a specific issue which Defra has been examining as part of its Surface Water Management Action Plan.⁵⁷ The Jenkins Review found that local authorities have found it difficult to obtain funding for surface water projects compared to other types of flood risk due to their smaller scale and the fact that they benefit fewer properties.⁵⁸ The difficulties of modelling surface water flood risk also can make it harder to demonstrate benefits. Defra has acknowledged this problem⁵⁹ and resulting actions to tackle it may unlock further funding for surface water management. In 2020, Defra announced that changes to government funding arrangements will enable more surface water management schemes to qualify for funding⁶⁰.

“We cannot continue to approach flooding problems with the idea that each agency should deal with their own area of dysfunctional pipework in their own time”

A councillor in North West Leicestershire⁶¹

56. Department for Environment, Food and Rural Affairs, “Central Government Funding for Flood and Coastal Erosion Risk Management in England”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/974066/Funding_FCERM_March_2021_Final_accessible.pdf (2021).

57. Department for Environment, Food and Rural Affairs, “Surface Water Management: An Action Plan”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725664/surface-water-management-action-plan-july-2018.pdf (2018).

58. David Jenkins, “Report of a review of the arrangements for determining responsibility for surface water and drainage assets”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf (2020).

59. Department for Environment, Food and Rural Affairs, “Surface Water Management: An Action Plan”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725664/surface-water-management-action-plan-july-2018.pdf (2018).

60. Department for Environment, Food and Rural Affairs, “Building flood defences fit for the future”, <https://www.gov.uk/government/news/building-flood-defences-fit-for-the-future> (2020).

61. Ben Waldron, “Call for action to stop ‘flooding crisis’ that left road like this”, *Derby Telegraph*, <https://www.derbytelegraph.co.uk/burton/call-action-stop-flooding-crisis-3764780> (2020).

Finally, local residents sometimes report that lines of responsibility between local authorities and water and sewerage companies are unclear. Residents can find themselves expecting actions to be taken by water companies but complaining of unresponsiveness, or not understanding the circumstances in which those actions will be taken.⁶² Defra's Surface Water Management Action Plan of 2018 confirms this, saying "confusion about who is responsible for managing the risks and poor co-ordination between those responsible can add to the problem".⁶³ The Jenkins Review recommended that Lead Local Flood Authorities should ensure there is a clear point of contact for residents with surface water flooding problems.⁶⁴ See Chapter Four for more on the role of water and sewerage companies.

With respect to the planning process, newspaper articles show widespread concerns over development and flooding.

Our analysis found several examples of planning applications which had attracted very strong objections from local residents on the grounds of increased risk of surface water flooding, particularly strongly expressed in areas which had experienced traumatic flood events. These objections are backed up by local councillors and/or flood risk management authorities in some instances, but not all. While there may be the odd case of 'NIMBYs' cursorily adding flood risk to the list of reasons why they oppose a development generally, it is also likely that many residents have valid concerns over surface water flooding which are not being adequately addressed by the planning system.

62. Dan Kemp, "The water was rising around us. But no one answered our call for help", *HullLive*, <https://www.hulldailymail.co.uk/news/hull-east-yorkshire-news/water-rising-around-us-no-3542344> (2019).

63. Department for Environment, Food and Rural Affairs, "Surface Water Management: An Action Plan", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725664/surface-water-management-action-plan-july-2018.pdf (2018).

64. David Jenkins, "Report of a review of the arrangements for determining responsibility for surface water and drainage assets", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf (2020).

“All of us are desperate to not go through it again ... it is clear that the authorities, who have done nothing to mitigate or alleviate the situation, are prepared to increase our risk yet further”

A flooded-out resident objecting to new housing at a planning meeting⁶⁵

Poor standards in new homes by some large developers are well-documented.⁶⁶ There has been at least one instance of a life-threatening incident at a housing estate which was initially rejected by the local authority on flood risk grounds.⁶⁷ There are also numerous examples of residents, or neighbours of new estates, complaining about persistent flooding or inadequate drainage on the site, or increased flood risk elsewhere in the local area. With respect to the latter, again, it's possible there may be the odd person seeking an obvious explanation for the unexpected flooding they have experienced by blaming new developments with little cause. However, there are compelling reasons to believe the planning system is not adequately addressing surface water flooding, and this is simply reflected by the real experiences captured in newspaper articles in our analysis. These concerns, if not adequately addressed, will increase resistance to new housing, undermining the government's housebuilding targets.

The House of Commons Environment, Food and Rural Affairs Select Committee recently stated: “Local planning authorities lack

65. “Galgate residents reveal 'frustration, desperation and depression' after 2017 floods”, *Lancashire Post*, <https://www.lep.co.uk/news/galgate-residents-reveal-frustration-desperation-and-depression-after-2017-floods-850279> (2018).

66. Liam Halligan “Home Truths”, Biteback Publishing (2019); Will Ing, “Most new housing so poorly designed it should not have been built, says Bartlett report”, *Architects' Journal*, <https://www.architectsjournal.co.uk/news/most-new-housing-so-poorly-designed-it-should-not-have-been-built-says-bartlett-report> (2020); Melissa York, “Why can't we build better quality homes in Britain?”, *The Times*, <https://www.thetimes.co.uk/article/why-cant-we-build-better-quality-homes-in-britain-Ogw2rxklq> (2021).

67. Laura Clements, “Father watched helplessly as river swept away garden of new Redrow home right up to its foundations”, *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/father-watched-helplessly-river-swept-17862469> (2020).

the knowledge and/or resources to effectively factor the impacts of climate change into their local plans and development decisions” recommending “the Government must ensure that all local planning authorities have the powers, resources and information they need to perform this function.”⁶⁸

In their two most recent reports on the progress the UK is making on adapting to climate change, the CCC has given the lowest possible progress score to the issue of development and surface water flood risk.⁶⁹ They noted that “homes are being built in areas at risk of surface water that may not have had any expert flood mitigation advice” and that “the planning system has inherent issues for dealing with surface water”.

Sustainable urban drainage systems (SuDS) are widely recognised as a key solution which can be encouraged through the planning process. These are techniques which slow down, divert or retain water, or allow it to infiltrate into the soil, to prevent it overwhelming sewers and drains, causing surface water flooding and/or transporting pollutants to watercourses. Many water and drainage experts hold the view that a key step towards better surface water management in England would be to have statutory standards for SuDS in new developments and incentivise developers to install them by ending the automatic right to connect surface water drains to public sewers.⁷⁰ Wales has already adopted the former approach, and has made the right to connect to the public sewer network contingent on having an adequate SuDS scheme.⁷¹

68. Environment, Food and Rural Affairs Committee, “Managing Water” in “Flooding: Fourth Report of Session 2019–21”, <https://publications.parliament.uk/pa/cm5801/cmselect/cmenvfru/170/17003.htm> (2021).

69. Climate Change Committee, “Progress in adapting to climate change: 2021 Report to Parliament”, <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021); Climate Change Committee, “Progress in preparing for climate change: 2019 Report to Parliament”, <https://www.theccc.org.uk/publication/progress-in-preparing-for-climate-change-2019-progress-report-to-parliament/> (2019).

70. David Jenkins, “Report of a review of the arrangements for determining responsibility for surface water and drainage assets”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf (2020)

71. Welsh Government, “Implementation of Schedule 3 to the Flood and Water Management Act 2010 for mandatory Sustainable Drainage Systems (SuDS) on new developments (DRAFT) Frequently Asked Questions”, <https://gov.wales/sites/default/files/publications/2019-06/frequently-asked-questions.pdf>; Susdrain, “SuDS adoption in England and Wales”, <https://www.susdrain.org/delivering-suds/using-suds/adoption-and-maintenance-of-suds/adoption/SuDS-adoption-in-England-and-Wales.html>, (2021).

The Government's planning reforms, as previously announced in the Planning Bill, are currently being reconsidered.⁷² The Planning Bill aimed to stimulate development through use of a simplified zoning system with development restricted in 'protected' areas – including areas at risk of flooding – and permitted automatically in 'growth' areas. Such a system could be contrary to the cause of better surface water management. Areas at risk of surface water flooding tend to form fine-grained patterns in towns and cities rather than large, continuous, 'zonable' blocks. Accurate surface water flood risk mapping needs local information which is not always available when national-level flood risk maps are drawn up.⁷³ Therefore, local knowledge feeding into individual planning applications is valuable for assessing surface water flood risk.

"When we have heavy rainfall the town suffers with sewage coming through street manholes, across the school playing field and into our local car park ... we would now like to call a halt to further development."

A town councillor in North Yorkshire⁷⁴

Trade-offs between addressing flood risk and development opportunities were sometimes mentioned in newspaper articles. Some protagonists in the planning process believe flood risk assessments have unnecessarily constrained development at times. Flood risk objections are sometimes rebutted by pointing to a lack of historic experience of flooding at a site. The understanding that flood risk is changing and

72. Jack Woodfield, "Planning Reforms: Government Will 'Look Again' at New Proposals", *Homebuilding and Renovating*, <https://www.homebuilding.co.uk/news/planning-reforms> (2021).

73. Department for Environment, Food and Rural Affairs, "Surface Water Management: An Action Plan", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725664/surface-water-management-action-plan-july-2018.pdf (2018).

74. Jacob Webster, "Development of 260 new homes in Boroughbridge rejected", *Yorkshire Post*, <https://www.yorkshirepost.co.uk/news/people/development-of-260-new-homes-in-boroughbridge-rejected-as-councillor-says-plans-were-like-a-sink-estate-in-lancashire-and-on-flood-prone-land-3261845> (2021).

that current flood risk maps do not capture future change is certainly not universal. In time, maps which reflect increasing flood risk under climate change will be available, and this may impose additional land constraints in certain areas which may hinder local authorities' other objectives, such as providing employment opportunities and school places, as Box 3.8 below shows.

"the main risk to people's lives here isn't flooding, it's deprivation and poverty"

Councillor in a deprived English coastal town⁷⁵

Box 3.8. Constraints placed by flood risk on development

Kilmarnock, East Ayrshire

In 2020 the Daily Record reported that "Kilmarnock's development is under serious threat because of flooding with 4000 jobs located in at-risk areas of the town".⁷⁶ A report for East Ayrshire Council had described flood risk as the "most serious" problem for the development of south-central Kilmarnock. Comments by the Council leader suggested that the council is seeking a flexible approach with the Scottish Environment Protection Agency which simultaneously addresses flood risk as well as opening up land for commercial opportunities. He said: "We want the town to expand but we don't want a desolate wasteland in the middle".

Finally, flooding affects local government assets and services. Box 3.9 briefly sets out some of the impacts encountered, excluding social care and transport services, which are covered elsewhere in this report. Most surprisingly the analysis revealed multiple instances of flooding in cemeteries causing distress to bereaved families.

75. Alistair Nelson, "Jaywick: New planning rules will 'encourage development'", *East Anglian Daily Times*, <https://www.eadt.co.uk/news/jaywick-new-planning-rules-will-encourage-development-2020094> (2011).

76. Sarah Hilley, "Future developments in Kilmarnock under threat because of flooding risk", *Daily Record*, <https://www.dailyrecord.co.uk/ayrshire/future-developments-kilmarnock-under-threat-22725543> (2020).

Some leisure centres and swimming pools have been badly affected; for example, the National Lido of Wales was out of action for a year following flooding. Flooding of parks, recreational grounds and sports pitches is very common. Many parks and sports pitches are sited next to rivers, presumably because they are deemed a low risk use. Some park flooding causes not much more than short-term safety issues, while other cases can spark concerns of long-term damage and remedial action. Playgrounds, historic buildings, sports facilities and footpaths in parks can also be damaged.

Box 3.9. Real impacts on UK local government services (excluding social care and transport) from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Parks, recreation grounds, sports pitches and footpaths flooded with no or limited apparent consequences
- Temporary closure of libraries and community centres
- Flooded town hall basements with no apparent adverse consequences for administration

More serious

- Severe damage, such as ceiling collapse, to leisure centres and swimming pools with weeks or months of closure
- Village halls, community centres and libraries severely damaged and closed for prolonged periods of time
- Tenants required to move out of social housing for several months
- Bereaved relatives distressed by flooding in cemeteries
- Flooding and a ceiling collapse at crematoria

Chapter 4:

Impacts of flooding on critical infrastructure since 2007

This chapter presents the findings from the NLP analysis uncovering the impacts on critical infrastructure – economic, social and environmental – of flooding since 2007. Critical infrastructure includes: transport, water and sewerage, energy and ICT.

Transport

Our analysis examined the impact of flooding since 2007 on three categories of transport: road transport; public transport such as rail and buses; and, aviation and shipping. It should be noted that disruption due to wind and lightning, which are common reasons for transport disruption, are not included; and disruption due to wintry conditions is only included if snow contributes to flooding.

Road transport

Predictably, the volume of highly localised traffic information contained in local newspaper articles detailing road closures and/or congestion during flood events was immense and therefore it was not feasible to analyse and include all of it in this report and on our map.

Box 4.1 below illustrates some leading impacts of flooding since 2007 on road transportation.

Box 4.1. Real impacts on UK road transport infrastructure from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Unattended vehicles damaged in flooded car parks, or by 'freak high tides'
- Minor road surface damage fixed in a few days, possibly requiring a temporary traffic light system
- Temporary congestion
- Flooded park and ride car parks
- Pre-emptive closures of bridges and road tunnels
- Temporary closure of minor roads
- Motorway lane closures

More serious

- Temporary closure of sections of motorways and motorway junctions
- A large sinkhole forming on a motorway
- Collapsed bridges
- Flooded bridges
- Several streets in town centres described as 'submerged', with cars struggling to get through water and/or getting stuck
- People needing to be rescued from stranded cars, cars washed down the street
- Parts of roads washed away, for example, part of a street collapsed into a river; total collapse of part of a single track road
- Access to a large town dependent on a single bridge during a flood event with all others closed
- Roads blocked by landslides
- The main road leading into a village 'completely destroyed' by intense flooding
- Sections of roads closed for several days to several months to repair damage
- A bridge permanently made unusable to drivers, but retained for walkers and cyclists
- Flooding in a major road tunnel

- Persistent surface water flooding of a trunk road
- Severe and repeat flooding in an underpass on a major road linking a large city to motorways

Most serious

- Fatalities and near-miss incidents from cars being trapped in floodwater
- A major incident declared due to concurrent flooding of several major roads
- Repeated landslides blocking a road which provides a key access route to a large area of Argyll
- A community ‘practically cut off’ during a flood event by damage to a bridge and road
- Communities divided for months following bridge collapses, with a noticeable impact on the local economy
- A policeman killed while diverting traffic from a collapsing bridge

Long-term

- A key road link to a major international ferry terminal at long term risk from coastal hazards
- Causeways vital to island communities at long term risk from sea level rise

Reports of cars stuck in floodwater are common. Some towns clearly have particular roads or roundabouts which suffer from repeat flooding. Roads passing underneath bridges occur fairly frequently as flooding blackspots, and our analysis found three life-threatening incidents involving cars trapped under railway bridges. Fords are also obvious danger areas.⁷⁷

Large urban areas which have seen repeat incidents of flash flooding badly affecting roads include Merseyside, Birmingham, Bristol, Belfast and Edinburgh.

⁷⁷ AA research has identified four lanes with fords in the Midlands as the UK’s biggest blackspots for flood-related breakdowns. See: “Drivers ‘risk life’ to drive through floodwater”, *Fleet News*, <https://www.fleetnews.co.uk/news/fleet-industry-news/2019/12/20/drivers-risk-life-to-drive-through-floodwater> (2019).

“Unbelievable scenes in Edinburgh. The roads are literally bursting open like geysers. Water up to my headlights”

A driver commenting on flash flooding in Edinburgh in 2019⁷⁸

“I didn’t have anything heavy enough to smash my way out. I was completely helpless and I was expecting to die ... Sixty seconds longer, and I was a goner.”

Man trapped in his car by flash flooding in London 2016⁷⁹

Numerous bridges have been destroyed by flooding, particularly in the north of England. This has obvious implications for cascading impacts and emergency response, and has greatly affected some communities, as Box 4.2 below indicates.

Engineers describe a process known as ‘bridge scour’ – where river erosion removes soil away from bridge foundations – as a mechanism by which climate change could contribute to more frequent bridge collapses in the UK.⁸⁰ In 2016, a bridge in Worcestershire collapsed moments before a school bus crossed it, with the council describing

78. Harriet Brewis, “UK weather: Motorists left stranded on top of cars as heavy rain and flash floods hit Britain”, *Evening Standard*, <https://www.standard.co.uk/news/uk/motorists-left-stranded-on-cars-as-flash-floods-lash-edinburgh-a4174791.html> (2019).

79. Barney Davis, “London flooding: Man who escaped car submerged by flash floods thanks heroic bystanders who saved him”, *Evening Standard*, <https://www.standard.co.uk/news/london/london-flooding-man-who-escaped-car-submerged-by-flash-floods-thanks-heroic-bystanders-who-saved-him-a3266076.html> (2016).

80. RAC Foundation, “Number of substandard road bridges on the rise again”, <https://www.racfoundation.org/media-centre/number-of-substandard-road-bridges-on-the-rise-again> (2021); Lamb et al., “Vulnerability of bridges to scour: insights from an international expert elicitation workshop”, *Natural Hazards and Earth System Sciences*, 17, 1393–1409; Climate Change Committee, “The Third UK Climate Change Risk Assessment Technical Report: Chapter 4: Infrastructure”, <https://www.ukclimaterisk.org/independent-assessment-ccra3/technical-report/> (2021).

bridge scour as a likely cause at the time.⁸¹ Some engineers have called for a body to investigate road bridge collapses because of incidents like this.⁸²

There were 10 full bridge collapses and 30 partial collapses in England, Scotland and Wales in the 12 months up to October 2020, according to the RAC.⁸³ Repairs to bridges caused by damage from the 2019-20 winter storm season cost the councils concerned half a billion pounds in total.⁸⁴ While there are schemes for providing financial assistance to help with community recovery and the costs of councils' emergency responses to flooding (the Flood Recovery Framework and Bellwin Scheme), there is a case for providing more support to prevent such potentially devastating impacts before they happen, as we suggest in Chapter Six later.

81. Tarik Al Rasheed, "Eastham bridge collapse: did fast moving water weaken its foundations?", *Worcester News*, <https://www.worcesternews.co.uk/news/14715296.eastham-bridge-collapse-did-fast-moving-water-weaken-its-foundations/> (2016). A full understanding of the causes has not been established, according to one expert: Claire Smith, "Investigation body needed for UK road bridge collapses to ensure lessons are learned", *New Civil Engineer*, <https://www.newcivilengineer.com/latest/investigation-body-needed-for-uk-road-bridge-collapse-to-ensure-lessons-are-learned-24-05-2021/> (2021).

82. *Ibid.*

83. RAC Foundation, "Number of substandard road bridges on the rise again", <https://www.racfoundation.org/media-centre/number-of-substandard-road-bridges-on-the-rise-again> (2021).

84. Ben Heubl, "Analysis: Damaged bridges pose a challenge to flood-stricken areas", *Engineering and Technology*, <https://eandt.theiet.org/content/articles/2021/01/extreme-floods-pose-a-growing-problem-to-ageing-public-infrastructure/> (2021).

Box 4.2. Economic knock-on effects of flooding impacts to road transport infrastructure

Workington, Cumbria and Tadcaster, North Yorkshire

Workington and Tadcaster are both examples of communities which have been divided by loss of bridges due to floods, with noticeable impacts on the local economy. Workington was without a town centre bridge for six months after it collapsed in 2009, and during that time its second bridge was also closed for safety reasons. The only way to cross the river was via a temporary railway station set up on the north bank giving free crossings to the main station on the south bank. The town's gas supply was also affected. Residents of Tadcaster were forced to take a 10-mile diversion to cross the river after their bridge was destroyed in 2015. Businesses noticed a considerable drop in trade for which they were, of course, not insured.

The A1 near Catterick

In 2018, Highways England and the Environment Agency worked together on a jointly-funded flood scheme for the first time to protect a section of the A1 and the village of Catterick. In 2012, the A1 was closed for two days in this location, and the northbound lane was closed for ten hours in 2015. The 2012 closure was estimated to have cost the regional economy over £2 million.⁸⁵

The long-term resilience of causeways and coastal roads is a concern for some communities. Examples include the Churchill Barriers Causeways connecting South Ronaldsay to the Orkney Mainland, The Strood connecting Mersea Island in Essex to Colchester, and the A487 in Newgale, Pembrokeshire.

The CCC rates the actions of central government and Highways England in planning for the climate resilience of the strategic road

85. Alexa Copeland, "Flood scheme to protect A1 and Catterick village officially open", *The Northern Echo*, <https://www.thenorthernecho.co.uk/news/16186754.flood-scheme-protect-a1-catterick-village-officially-open/> (2018).

network as good.⁸⁶ This includes targets for mitigating flood risk. The local road network, managed by local authorities, however, is faring less well, with guidance but no statutory requirement to take climate change into account in maintaining the local road network, no systemic assessment of disruptions due to flooding, and a shortfall in road maintenance budgets. As discussed in the previous chapter, there has also been a “significant fall” in local government expenditure on road cleaning and gullies.

Neither the National Flood Resilience Review (a 2016 government report which assessed infrastructure resilience to flooding) nor the National Infrastructure Assessment (NIA) of 2018 (an assessment of the UK’s infrastructure needs up to 2050 by the National Infrastructure Commission) had the necessary information to incorporate risks associated with surface water flooding,⁸⁷ with the NIA noting that “further work is needed urgently”. Defra is currently working on assessing the resilience of transport to extreme surface water flooding as part of the Surface Water Management Action Plan.⁸⁸

Public transport

Our analysis looked at the impact of flooding since 2007 on three main forms of public transport: rail, urban public transport systems and buses. This is shown in Box 4.3 below.

86. Climate Change Committee, “Progress in adapting to climate change: 2021 Report to Parliament”, <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

87. National Infrastructure Commission, “National Infrastructure Assessment”, https://nic.org.uk/app/uploads/CCS001_CCS0618917350-001_NIC-NIA_Accessible-1.pdf (2018).

88. Department for Environment, Food and Rural Affairs, “Surface water management: A Government update”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015182/surface-water-management-government-update.pdf (2021).

Box 4.3. Real impacts on UK rail, urban public transport and buses from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Flooding and landslips on railway and urban transit lines causing disruption for one day or less, sometimes with replacement bus services
- Trains stranded for brief periods (2 hours or less)
- Speed restrictions
- Unpleasant but manageable overcrowding on trains/at stations due to disruption
- Disruption of bus services
- Closure of a bus station
- Scheduled disruption due to a railway adaptation project (raising a bridge)
- Minor access restrictions to stations
- Surmountable flooding on platforms, underpasses and concourses
- Passengers wading through floodwater at stations
- London Underground delays, with stations temporarily closed or without step-free access

More serious

- A train stuck in floodwater but with passengers transferred onto another train
- A train hit by a landslip but with no injuries
- Five trains simultaneously trapped on the same railway line due to flooding
- Train services disrupted for several days or weeks, for example due to major landslips or storm surge damaging the track
- Severe or extensive damage to tracks or embankments
- Ballast washed away
- Damage to a railway viaduct
- Severe flooding at railway stations
- Passengers stranded on platforms

- A station closed for two weeks
- A tunnel with a persistent flooding problem on a major inter-city rail link despite improved drainage
- Police required to maintain public safety at a major railway terminus after flooding severely disrupts services
- Terminus closed due to a 'dangerous crush'
- Ankle deep water on the concourse of a major commuting station packed with people whose trains have been delayed
- Minor injuries from a roof collapse at a major railway station during heavy rain
- The main line between two major cities closed for two months due to severe track damage, but with travel still possible via a secondary line
- A submerged booking hall
- Passengers spending the night on a stranded train
- Water pouring into London Underground/DLR stations
- Evacuation of a major tube station during rush hour
- Evacuation of a tube station requiring emergency services assistance
- Evacuation/rescue of bus and tram passengers

Most serious

- A fatal rail accident due to a landslide
- A major incident involving passengers stuck on a train for several hours
- Sudden track damage from coastal erosion at Dawlish
- A derailed train hitting another train, but with only minor injuries
- A bus stuck in floodwater in life-threatening circumstances

Long-term

- Key rail links to a major international ferry terminal at long term risk from coastal hazards
- London Underground stations described as at general risk of flooding
- The railway link to Cornwall at long-term risk from coastal hazards

On casual inspection, the number of newspaper articles describing flooding impacts on railways seems to be increasing over time. Most newspaper articles describe impacts which are short-term but nonetheless disruptive for passengers, particularly when multiple lines to a major terminal are affected.

More serious impacts have occurred, including a fatal accident due to a landslip – in Stonehaven in 2020. There has been severe damage to the main line between Glasgow and Edinburgh, and a major incident when passengers were stuck on a train for several hours at Corby.

It is well known that the London to Penzance railway line passes very close to the sea between Dawlish and Teignmouth, and that this places it at long-term risk from coastal hazards. In 2014 a section of the line was left unsupported after ground slipped into the sea with trains unable to run for eight weeks,⁸⁹ the longest period of closure the line has experienced to date.⁹⁰

Urban transit systems in most of the major metropolitan areas, including Edinburgh, Merseyside and Greater Manchester, have been affected by flooding.

Videos of water pouring into Sloane Square Tube and Pudding Mill Lane DLR stations during flash flooding in London were circulated on social media in July 2021, prompting shock. Newspaper articles show that there have been many other instances of flooding affecting London Underground stations, including at least one instance where emergency services were required to help evacuate a station. There has also been at least one instance of an underground station flooding in Glasgow. According to official figures, 2021 has been the highest year on record for the number of hours London Underground stations have been closed due to flooding, with 66

89. Colleen Smith, "The day the railway line washed away: Dawlish people remember the scariest hours of their lives", *CornwallLive*, <https://www.cornwalllive.com/news/cornwall-news/day-railway-line-washed-away-2490392> (2019).

90. Dawson et al., "Sea-level rise impacts on transport infrastructure: The notorious case of the coastal railway line at Dawlish, England", *Journal of Transport Geography* 51:97-109 (2016).

station closures over the past seven years.⁹¹ There have also been highly concerning instances of underground station flooding in other countries. Populations of all cities with underground systems need to know that risks from flooding are being monitored and acted upon, as we propose later in this report.

“It is remarkable that in the space of a fortnight we’ve had two of these major [flood] episodes. It does highlight how the network is exposed to the flood threat. Authorities right across the UK need to be more mindful of the flood risk, there is arguably a myopic approach to these problems ... and they are often dealt with one at a time”

An engineer commenting on the flash flooding which affected London Underground and DLR stations in 2021⁹²

Aviation and shipping

Box 4.4 below shows the impacts of flooding since 2007 on aviation and shipping which were revealed in our analysis.

91. This may include flooding from burst water mains: <https://www.mylondon.news/news/uk-world-news/london-underground-flooding-how-tube-21732356>.

92. Tim Clark, “TfL ‘needs to reassess’ flood risk after stations left underwater”, *New Civil Engineer*, <https://www.newcivilengineer.com/latest/tfl-needs-to-reassess-flood-risk-after-stations-left-underwater-27-07-2021/> (2021).

Box 4.4. Real impacts on UK aviation and shipping from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Delays and flight cancellations (the precise weather hazard causing these during storms can be unclear)
- Floodwater covering runways
- Cars damaged in airport car parks
- Flooding in the terminal building with no flight disruption
- Nearby roads flooded with access implications not reported
- Temporary flooding of quaysides and harbour roads and walkways
- Brief suspension of a ferry service crossing an estuary

More serious

- Floodwater entering hangars
- Runway damage
- Baggage area flooded at a major airport
- Emergency services called to assist a small group of people on an airport site
- Total closure and/or flights suspended at minor airports for one to a few days
- Significant disruption at a major airport for approximately one day due to a flood-related power outage
- Airport flood defences breached
- Partial ceiling collapse of a terminal building with no injuries reported
- Disruptions to train services to/from the airport
- Cars stuck in floodwaters around an airport with emergency services called out
- Closure of a major port for thirteen hours due to power loss from flooding
- Airport 'extensively water-damaged' and in need of refurbishment
- The drainage network of a new stretch of road serving a major airport overwhelmed by floodwaters on more than one occasion, with intermittent road closures for several days at a time

Most serious

- Damage to a major port from a tidal surge prompting a flood defence upgrade

Avoided

- Large sewage flood at an airport averted

Long-term

- Airports at risk of flooding in the long term
- Key road and rail links to a major international ferry terminal at long term risk from coastal hazards

The most serious impact from flooding to a major airport identified was the disruption which took place at Gatwick on Christmas Eve in 2013.⁹³ Waterways near the airport were at record levels, with flooding affecting three substations and disruption compounded by high winds. Admittedly, the impact could have been worse without flood alleviation plans which were implemented in 2009⁹⁴.

The baggage area at Heathrow Airport was reported to be “under significant amounts of water” during flash flooding in August 2015.⁹⁵ City of Derry and Mid-Wales Airports have both been closed due to flooding, with the former left “extensively water damaged” and in need of refurbishment.⁹⁶ The most serious impact on ports identified was the disruption caused by a storm surge in December 2013, as Box 4.5 explains.

93. BBC, “Gatwick Airport boss apologises over Christmas Eve chaos”, <https://www.bbc.co.uk/news/uk-england-sussex-25646457> (2014); David McMillan, “Disruption at Gatwick Airport: Christmas Eve 2013”, https://www.gatwickairport.com/globalassets/publicationfiles/business_and_community/all_publications/2014/mcmillan_report_feb14.pdf (2014).

94. Richard Davies, “Further Flood Alleviation Plans for Gatwick Airport”, <https://floodlist.com/protection/flood-alleviation-plans-gatwick-airport> (2014).

95. Hannah Al-Othman, “London flooding: Parts of the capital deluged with heavy rainfall”, *Evening Standard*, <https://www.standard.co.uk/news/london/london-flooding-parts-of-the-capital-deluged-with-heavy-rainfall-a2921761.html> (2015).

96. “Marcon lands fit-out contract at City of Derry Airport”, *Irish News*, <https://www.irishnews.com/business/2018/04/17/news/marcon-lands-fit-out-contract-at-city-of-derry-airport-1305930/> (2018).

Box 4.5. The impact of a major storm surge event on ports

The Southern North Sea storm surge event of December 2013

On 5th and 6th December 2013, a storm surge occurred in the southern North Sea, producing the highest water levels on record at several tide gauges, higher than the notorious event of 1953 which killed hundreds of people.⁹⁷ The Port of Dover was closed for thirteen hours, according to a local newspaper report, after it lost power due to the surge. While disruption to the port's transport activities was short-lived, an aggregates facility at the port was closed for several weeks.⁹⁸ Meanwhile, the largest port in the UK by tonnage, Immingham on the Humber Estuary, sustained severe damage.⁹⁹ It later received a flood defence upgrade.¹⁰⁰

The CCC notes that the aviation industry has its own bodies looking at climate adaptation and resilience, however actions to address flood resilience at airports have been historically “reactive”.¹⁰¹ Aviation faces the least significant climate risk of any transport mode in the UK, but interdependencies with other infrastructure need to be managed. Large airports assess flood risk annually. Gatwick and Heathrow Airports are required to produce resilience plans.

In contrast, no ports are required to produce resilience plans, and government has limited information on the extent to which the sector is preparing for climate change.¹⁰² We therefore address this in a policy recommendation in Chapter Six.

97. Spencer et al., “Southern North Sea storm surge event of 5 December 2013: Water levels, waves and coastal impacts”, *Earth-Science Reviews* 146:120-145 (2015).

98. Kent County Council, “Monitoring the impacts of severe weather”, https://www.kent.gov.uk/_data/assets/pdf_file/0006/15783/Monitoring-the-impacts-of-severe-weather-for-winter-2013-14-full-report.pdf (2014).

99. Wadey et al., “A comparison of the 31 January–1 February 1953 and 5–6 December 2013 coastal flood events around the UK”, *Frontiers in Marine Science* 2:84 (2015).

100. BBC, “Port of Immingham £7.4m flood defence scheme works approved”, <https://www.bbc.co.uk/news/uk-england-humber-39141063> (2017).

101. Climate Change Committee, “Progress in adapting to climate change: 2021 Report to Parliament”, <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

102. Ibid.

Water and sewerage

Box 4.6 summarises impacts from flooding to water and wastewater services and assets (such as treatment plants, reservoirs and dams) since 2007. Unlike other sectors, water and wastewater infrastructure also have the potential to exacerbate or mitigate flooding impacts, depending on their design, purpose, capacity and condition, and this is also covered in this section.

Box 4.6. Real impacts on UK water and wastewater infrastructure from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Minor or one-off sewage flooding which does not enter buildings

More serious

- Sewage flooding from within or entering buildings
- Minor flooding following overtopping of a flood storage reservoir
- Nuisance sewage flooding in outdoor spaces creating disamenity for local residents
- More frequent combined sewer overflow incidents with noticeable impacts on water quality
- Sewage entering a waterway from a treatment works during a flood event
- Householders requested to limit flushing toilets, taking baths and using washing machines to reduce demands on the sewage system
- Water treatment works flooded but with tankers providing substitute supplies, so no impact on supply for most end users
- Flooding 'affecting' a wastewater treatment works
- A wastewater treatment works operating beyond its design capacity due to increasing urban runoff, resulting in a decrease in water quality in a local water body

- A reservoir not able to alleviate flooding in a downstream town due to it exceeding its capacity during unusually high rainfall
- An overtopping dam but with no adverse consequences reported

Most serious

- Mass evacuations due to risk of dam collapse
- Concerns that emergency situations downstream of dam have been caused by floodgates being opened to relieve pressure on the dam
- Water treatment works flooded and without power, alongside problems transporting tanker and bottled water substitutes, resulting in less water available to end-users
- Water treatment works out of operation for two weeks with noticeable water shortages and rationing, and sanitation 'becoming an issue'

Avoided

- Water supply of a major city put at risk of contamination from an industrial waste site during flooding with diversification measures put in place

Dam safety is one of the major flood risk concerns in the water sector. There have been at least two occasions when dam safety has been at risk during flood events since 2007.

In 2019, the dam holding back Toddbrook Reservoir in Derbyshire was damaged during heavy rainfall and the nearby town of Whaley Bridge was evacuated. In 2007, 700 people were evacuated from near Ulley Reservoir in South Yorkshire. An independent review of reservoir safety was conducted after the Toddbrook event,¹⁰³ which concluded that the observed rainfall was well below the design standard for its dam

103. Department for Environment, Food and Rural Affairs, "Government welcomes findings of independent reservoir safety review", <https://www.gov.uk/government/news/government-welcomes-findings-of-independent-reservoir-safety-review> (2021).

type, and poor design and maintenance were the most probable cause of failure.¹⁰⁴ The CCC note a lack of current mechanisms to ensure that climate risk associated with dams is assessed.¹⁰⁵

Reservoirs are sometimes designed or adapted to play a flood risk mitigation role, storing water high up in the catchment during heavy rainfall and preventing it from flooding downstream communities. There has been at least one instance where concerns have been raised that a reservoir has not adequately helped with flood mitigation during a flood event: Thirlmere Reservoir near Keswick in 2015.

There have been at least three instances of water treatment works flooding. Water companies' business continuity plans have kicked in on these occasions, although not always seamlessly. On a couple of occasions, householders would have noticed service interruption or been asked to reduce their use. Vehicles transporting substitute water supplies being restricted by flooding and road closures is a potential cascading impact worth being aware of, as described in Box 4.7 below.

Box 4.7. Cascading impacts of flooding and water services

Monmouth

In February 2020, residents of Monmouth were asked to limit their water use due to flooding and a power cut at the town's water treatment works. Dwr Cymru Welsh Water faced difficulties transporting replacement water supplies and bottled water due to severe flooding and road closures. Vulnerable customers such as the elderly were asked to contact them directly for prioritisation for bottled water, if needed.

Chapter Three described the regularity with which surface water flooding is described in newspaper articles. Urban run-off, of course, flows into the sewer system. Descriptions of sewer flooding and the strains placed on

104. Climate Change Committee, "The Third UK Climate Change Risk Assessment Technical Report: Chapter 4: Infrastructure", <https://www.ukclimaterisk.org/independent-assessment-ccra3/technical-report/> (2021).

105. Ibid.

sewer systems during heavy rainfall are common in local newspaper articles. The CCC noted that in 2019 “there are many areas at high risk of capacity constraints” in the UK sewer network.¹⁰⁶ Combined sewer overflows (CSOs) – occasions when stormwater is released into rivers alongside sewage during heavy rainfall – recently exploded as a political issue while MPs were voting on an amendment to the Environment Bill, illustrating the strength of public feeling on this issue.¹⁰⁷

Steps are being taken in the right direction. The Environment Act contains measures designed to reduce overflows of raw sewage from combined sewer systems into rivers during heavy rainfall. Sewerage companies will be required to make drainage and wastewater management plans (DWMPs) which address capacity and resilience, and assess future demands on their systems. The Government will also be required to prepare a plan for reducing discharges from storm overflows. However, the fact that sewerage companies have not until now been explicitly required to make long-term plans and assessments regarding sewer capacity,¹⁰⁸ despite population growth and climate change, is a contributing factor to why these problems have become more acute. It is worth noting the framework which will be used in conjunction with DWMPs to assess sewer capacity is currently only intended to cover foul and combined sewer networks, not surface water sewers, but has been trialled for surface water sewers and could be extended in future.¹⁰⁹

106. Climate Change Committee, “Progress in preparing for climate change: 2019 Report to Parliament”, <https://www.theccc.org.uk/publication/progress-in-preparing-for-climate-change-2019-progress-report-to-parliament/> (2019).

107. BBC, “New legal duty promised over sewage as Lords forces issue”, <https://www.bbc.co.uk/news/uk-politics-59052995> (2021).

108. Department for Environment, Food and Rural Affairs, “Surface Water Management: An Action Plan”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/725664/surface-water-management-action-plan-july-2018.pdf (2018).

109. Implications for extending the method to surface water sewers has been researched. See p10 of Department for Environment, Food and Rural Affairs, “Surface water management: A Government update”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015182/surface-water-management-government-update.pdf (2021); Atkins, “A framework for the production of Drainage and Wastewater Management Plans”, https://www.water.org.uk/wp-content/uploads/2020/01/Water_UK_DWMP_Framework_Report_Main_September-2019.pdf (2019); HR Wallingford, “Capacity Assessment Framework – Surface Water Drainage – Initial trial of Surface Water Sewers”, <https://www.water.org.uk/wp-content/uploads/2018/12/Capacity-AssessmentFrameworkSurface-Water-Drainage.pdf> (2018).

“We were paddling in sewage trying to help out. The whole street was underwater ... There were dead rats, tampons, sanitary pads and drug needles all floating down the street and into the house ... it’s been an absolute nightmare and I feel absolutely broken.”

Twice-in-a-week victim of sewer flooding in Ilkeston, Derbyshire¹¹⁰

While obviously an important issue, it is equally important that CSOs do not take up all of the political and media bandwidth on urban drainage. It needs to be more widely recognised that under-performing urban drainage, surface water flooding and sewer flooding are public health and safety issues for our homes and streets (also see the Transport section earlier in this chapter). Furthermore, the spread of impermeable surfaces which create so much urban run-off is beyond the control of sewerage companies and needs to be addressed by local authorities, developers and property owners.

110. George Allen, “Horried mum tells of sewage and rats floating into flooded home”, *Derby Telegraph*, <https://www.derbytelegraph.co.uk/news/local-news/horrified-mum-tells-sewage-rats-4241264> (2020).

Box 3.10. Problems with sewer capacity

Belfast, Northern Ireland

In 2015, the Belfast Telegraph stated that a report for Belfast City Council had described the drainage infrastructure of many towns and cities in Northern Ireland as “inadequate” with “the problems being most acute in the greater Belfast area”. It reported that up to £750 million investment was needed, with one Northern Ireland Assembly member expressing fears that new housing and commercial development may become infeasible unless the problem was addressed. The main wastewater treatment works for the city was described as operating at above design capacity. In 2020, a High Court judge warned of a “a chronically under-funded industry struggling to cope with present day demands” in Northern Ireland during a court case¹¹¹. The Living With Water Programme, drawn up over recent years, aims to address these problems¹¹².

Perth, Scotland

In August 2020, Perth was hit by a month’s rainfall in one day during a thunderstorm. Scottish Water described the intense rainfall as “well in excess of what our sewer network is designed to accommodate” while the local MSP said the city’s drains “were not fit for purpose to deal with the increasingly severe weather patterns”.¹¹³ A local councillor commented “I understand the process of checking the drains would be an expense, but this is nothing compared to the expense to families and the insurance industry [from repeat flooding], which is eventually passed on to all of us”.

111. Alan Erwin, “Worn-out NI water network on brink of a catastrophe: judge”, *Belfast Telegraph*, <https://www.belfasttelegraph.co.uk/news/northern-ireland/worn-out-ni-water-network-on-brink-of-a-catastrophe-judge-39630057.html> (2020).

112. Department for Infrastructure, “Living With Water Programme”, <https://www.infrastructure-ni.gov.uk/topics/living-water-programme>, (2021).

113. Douglas Dickie, “Concerns raised that Perth drain infrastructure cannot cope with heavy rainfall”, *Daily Record*, <https://www.dailyrecord.co.uk/news/local-news/concerns-raised-perth-drain-infrastructure-22606171> (2020).

Some social housing tenants had to be evacuated and the local leisure centre was put out of action for months. According to the Daily Record, “Perth residents reacted with disgust at reports of residents playing in pooled water ‘contaminated’ with water emerging from sewage drains”¹¹⁴. In December 2020, Scottish Water stated: “It is not practical or sustainable to deal with this volume of floodwater via traditional underground drainage systems”, describing a need for more sustainable urban drainage systems in the city¹¹⁵.

Dalton-in-Furness, Cumbria

In 2012, the *Westmorland Gazette* reported that a “freak storm” had overwhelmed the sewer system of Dalton-in-Furness “causing devastating flooding which left people homeless for weeks” after 40mm rain fell in an hour.¹¹⁶ United Utilities described the event as a 1-in-600 year storm hitting a drainage system designed to withstand a 1-in-30 year storm.

Energy

The impact of flooding since 2007 on energy infrastructure is summarised in Box 4.8 below.

Box 4.8. Real impacts on UK energy infrastructure from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Localised short-term power cut due to substation flooding*
- A substation described as flooded with no apparent consequences
- Isolated temporarily flooded petrol and service stations

114. Kathryn Anderson, “Emergency accommodation arranged for residents after storm flooding in Perth”, *Daily Record*, <https://www.dailyrecord.co.uk/news/local-news/emergency-accommodation-arranged-residents-after-22516455> (2020).

115. Kathryn Anderson, “Scottish Water says traditional drains can no longer cope with substantial flooding in Perth”, <https://www.dailyrecord.co.uk/news/local-news/scottish-water-says-traditional-drains-23147760> (2020).

116. Stephanie Manley, “Dalton residents call for answers over flooding”, *The Westmorland Gazette*, <https://www.thewestmorlandgazette.co.uk/news/9911423.dalton-residents-call-for-answers-over-flooding/> (2012).

More serious

- 10,000s households without power for several days*
- Floods hampering power supply recovery efforts: e.g. a bridge carrying power supply cables has been washed away, electricity poles washed away, impassable roads preventing repair teams from accessing damaged assets
- A substation nominally protected against a 1-in-200 year flood is flooded
- Interruptions to gas supply due to bridges carrying pipelines collapsing

Most serious

- Flooding of a substation prevents pumps from working, hampering flood protection
- Substation flooding results in power cuts to a hospital** and fire station, as well as loss of mobile coverage, internet, mains-operated and digital radio, ATMs, shop tills, fuel pumps, traffic lights, etc.¹¹⁷ (Lancaster, 2015)
- Explosions due to gas pipelines being severed when bridges collapse

Long-term

- A nuclear power station which could be cut-off but otherwise unaffected by an extreme flood (Hartlepool)
- Seal Sands in Teeside threatened by coastal flooding but defended (the site includes an oil terminal and natural gas transportation and processing facilities)
- Bacton Gas Terminal at risk from coastal erosion but with a protection scheme in place

* Power cuts due to wind damage and lightning are excluded from the analysis

** While most district general hospitals have backup generators it would nevertheless be preferable and safer for them not to lose power)

117. Royal Academy of Engineering, "Living without electricity: One city's experience of coping with loss of power", <https://www.raeng.org.uk/publications/reports/living-without-electricity> (2016).

Our analysis identified at least twelve instances of flooded electricity substations, in at least one case leading to power cuts which were problematic for emergency response and community resilience. There have been at least five instances of damage to gas pipelines due to the bridges supporting them collapsing.

The location of nuclear sites near coasts is an obvious concern. In 2012, *The Guardian* reported that twelve of the UK's civil nuclear sites are at risk of flooding or coastal erosion, according to 'unpublished' government analysis.¹¹⁸ This information was actually presented in the UK government's Climate Change Risk Assessment of 2012, but without station-specific detail – the described risk of flooding is in the absence of adequate protection. UK Climate Change Risk Assessments have described nuclear sites as having a very high standard of protection.¹¹⁹ Local newspaper articles have provided more nuance on some of these sites. The *East Anglia Daily Times* has presented differences of opinion amongst experts on the extent to which Sizewell in Suffolk is at risk, while the *Northern Echo* reported analysis showing that access roads to Hartlepool Nuclear Power Station could be cut off by a 1-in-1000 year flood event.

Newspaper articles also mention other major energy infrastructure sites at long-term risk from coastal hazards, such as Bacton Gas Terminal in Norfolk and oil and gas infrastructure at Seal Sands in Teeside, and measures taken to protect these sites.

The 2016 National Flood Resilience Review, as described in Chapter One, concluded that the gas network is resilient to flooding because it is a 'sealed system'. It provided details of actions to survey the flood risk of electricity sites serving more than 10,000 people and invest in network resilience,¹²⁰ but did not cover surface water flooding. It also stated

118. Rob Edwards, "UK nuclear sites at risk of flooding, report shows", *The Guardian*, <https://www.theguardian.com/environment/2012/mar/07/uk-nuclear-risk-flooding> (2012).

119. Climate Change Committee, "The Third UK Climate Change Risk Assessment Technical Report: Chapter 4: Infrastructure", <https://www.ukclimaterisk.org/independent-assessment-ccra3/technical-report/> (2021).

120. HM Government, "National Flood Resilience Review", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf (2016).

that the Department for Transport and utilities would work together to identify bridges which present a single point of failure for energy infrastructure operators so that they can mitigate associated risks.

“I don’t think it’s about the money, I don’t think it’s about compensation for a lost Christmas, and it’s not the chaos that comes with the flood – it’s the chaos that comes with being abandoned.”

Resident of Yalding, Kent, offered compensation after several days without power over Christmas due to substation flooding¹²¹

Power loss to pumps and pumping stations is an example of a potential cascading impact which underscores the importance of electricity supply resilience. Our analysis identified at least three instances of power losses affecting the operation of pumps and inhibiting flood response, including one caused by substation flooding.¹²² Pumps may also not be in operation because it is not deemed safe to have the power supply on.¹²³

Information and communications technology (ICT)

The study found limited information on impacts on information and communications technologies from flooding since 2007. The impacts are identified in Box 4.9 below.

121. Channel 4 News, “We saw nobody at Christmas: anger grows as power stays off”: <https://www.channel4.com/news/christmas-storms-floods-power-cuts-electricity-compensation> (2013).

122. Rebecca Tuffin, “Progress being made to protect Yalding from further flood damage”, *Kent Online*, <https://www.kentonline.co.uk/maidstone/news/progress-being-made-in-flood-campaign-223602/> (2020).

123. Stephanie Manley, “Dalton residents call for answers over flooding”, *The Westmorland Gazette*, <https://www.thewestmorlandgazette.co.uk/news/9911423.dalton-residents-call-for-answers-over-flooding/> (2012).

Box 4.9. Real impacts on UK ICT infrastructure from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Intermittent mobile phone services following flooding of a mobile phone company data centre

More serious

- A flooded telephone exchange resulting in loss of landline services to 50,000 households for a day and a half, and loss of broadband services
- A shop unable to do online trading, take calls or accept card payments for three weeks due to flood damage to their remote server
- Broadband infrastructure damaged due to the bridge carrying it collapsing
- Broadband and phone outages due to damage to a telecom post

Most serious

- People unable to make emergency service calls due to a single point of failure rendered out of action from flooding
- Mobile phone coverage, internet services and DAB radio impacted concurrently by a major power cut, at the same time as landline connections also fail due to flooded connection boxes

The most serious incident was the failure by Hull-based telephone and broadband operator KCOM to maintain emergency call services after flooding hit the BT telephone exchange in York during Storm Eva in 2015. It emerged that it had been in breach of Ofcom rules relating to back-up routes for emergency calls.¹²⁴

Ofcom guidance to telecoms service providers on the security and resilience of their networks states that they should consider whether

124. Henry Saker-Clark, "KCOM fined £900k by Ofcom for failing to connect 999 calls", *HullLive*, <https://www.hulldailymail.co.uk/news/kcom-fined-900k-ofcom-failing-295049> (2017).

flood resilience measures are required even at sites at lower risk of flooding, for example, because a site constitutes a single point of failure (SPOF).¹²⁵ However, the CCC notes that Ofcom does not incorporate climate change into its industry guidance and rates adaptation plans in the sector as low.¹²⁶

125. Ofcom, "Ofcom guidance on security requirements in sections 105A to D of the Communications Act 2003", https://www.ofcom.org.uk/__data/assets/pdf_file/0021/51474/ofcom-guidance.pdf (2017).

126. Climate Change Committee, "Progress in adapting to climate change: 2021 Report to Parliament", <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

Chapter 5: Impacts of flooding on key businesses since 2007

This chapter presents the findings from the NLP analysis uncovering the impacts on key businesses, including shops and other town centre businesses, farming, leisure, and manufacturing and industrial estates.

Shops and other town centre businesses

We now describe the impacts on a variety of shops and other businesses commonly found in town centres: supermarkets, shopping centres, high street chains, independent shops, hairdressers, bank branches, post offices, and so on. Our analysis uncovered a range of impacts from flooding since 2007, as highlighted in Box 5.1 below.

Box 5.1. Real impacts on UK shops and town centre businesses from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Short-term access restrictions
- Flooded car parks
- Supermarket delivery staff able to fulfil deliveries despite on-site flooding
- Temporary closure (one day or less) to deal with minor flooding

More serious*

- Closure for 1-2 days
- Power loss
- Supermarket delivery vans stuck in floodwater
- Store and shopping centre evacuations on foot or by dinghy, prompted or assisted by the emergency services
- People stranded in a store, shopping centre or carpark, in one case overnight
- Collapsed ceilings with no reported injuries
- Small businesses such as antiques shops closed for months to repair flood damage and build up stock again subject to cash flow constraints
- A small business flooded after planning consent for flood protection was refused
- A flooded out small business discovering there is no flood cover component of their insurance
- Stress and financial difficulties for small business owners
- Repeat flooding of small businesses
- Closure of high street chain stores for several weeks with loss of stock
- Shopping mall lifts out of order for an extended period of time affecting access for disabled shoppers
- Flooded out post offices, with mobile post offices providing some continuity of service
- Millions of pounds worth of stock dumped from a shopping centre in the run-up to Christmas
- Only one supermarket left open in a city due to a flood-induced power cut affecting payment systems
- Major structural damage and loss of all stock

Most serious*

- Flooding throughout the building rendering a supermarket out of action for several days or weeks – supermarkets may construct temporary alternative premises or operate out of pop up shops temporarily

- Structurally unsafe building with relocation or permanent closure
- Severe flooding rendering a large number of town centre businesses out of action for weeks

Long-term

- Concerns over the long-term economic viability of a town centre due to recurrent flooding

**It is acknowledged that severe flooding and financial distress are maximum seriousness impacts at the individual level. However, refer to the start of Chapter Three for impact category definitions in these boxes.*

The analysis identified at least 31 UK supermarket branches¹²⁷ which have been directly affected by flooding since 2007, where this is defined as a threat to safety and/or apparent loss of trade. Seven of these were cases of flooding following partial ceiling collapses due to heavy rainfall.

In general, newspaper articles give the impression that supermarkets have dealt well with flooding, and that, as was also demonstrated during the COVID-19 pandemic, the logistical expertise of supermarkets is a national resilience asset. There were several examples of supermarkets playing an important role in community resilience during and after flood events, including donating cleaning equipment, homeware and food to flood victims, as well as quickly finding alternative premises for their own branches when they have been seriously flooded. Tesco have erected temporary supermarkets in flood-hit communities on at least two occasions, as demonstrated in Box 5.2 below. There was one example of a supermarket (Asda in Wigan) which has been designed to withstand flooding.

127. Including convenience stores of major supermarket chains, but not including smaller convenience stores or supermarket petrol stations.

“We haven’t seen a massive influx of people coming back to shop in the town. I think we’re still suffering from the floods three years ago, when a lot of customers started going to Skipton and elsewhere”

A comic book store owner in Hebden Bridge¹²⁸

Box 5.2. Supermarket resilience to flooding

Tesco, Carlisle

In 2015, the Tesco store in Carlisle was inundated by six feet of water during Storm Desmond, damaging internal structures and ruining stock. A temporary store was up and running in a week, with many people working overnight to build it. The refurbished original store re-opened eight weeks after the flood.

Shops recover quickly from minor flooding. Others see medium-to-long term impacts from more serious or repeat flooding, including loss of trade during recovery, permanent loss of customer loyalty, higher excesses and insurance premiums, or even uninsurability. Shops don’t have to be flooded themselves for flooding to impact them. Flooding can also affect short-term access, as well as footfall for several days or even weeks or months after the flood event, for example, due to media reports deterring visitors.¹²⁹ Some shop-owners described the dual impact of Covid-19 lockdowns and flooding on their businesses.

128. Emma Sheppard, “One year on from the floods: businesses tell how they picked up the pieces”, *The Guardian*, <https://www.theguardian.com/small-business-network/2016/dec/26/floods-businesses-picked-up-pieces-north-england> (2016).

129. Ibid.

"My customers who are desperate to come back to me will go elsewhere. I can't keep on doing this. I can't keep paying for things to be repaired. It is not normal. It's not right."

A hairdresser in Pentre, Rhondda Cynon Taff¹³⁰

Farming

A number of themes emerge in newspaper articles relating to farming. First, there are the flooding impacts which farmers themselves experience, described in Box 5.3 below. Second, there is the role that farms can play in managing flood risk. Third, there are tensions with risk management authorities and other land users over flooding.

Box 5.3. Real impacts on UK farming from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Livestock discovered in manageable amounts of floodwater or preventively moved
- Surmountable difficulty reaching livestock to feed them
- Milking disrupted for about a day
- Animals brought indoors earlier than normal, adding to costs

More serious*

- Farms cut off by floodwater, possibly with concerns over how livestock can be moved if flooding gets worse
- Damage to fences, walls, bridges, tracks, sheds, vehicles and equipment
- Considerable debris to remove

130. Lydia Stephens, "What is the problem in Pentre and why wasn't it sorted after February's floods", *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/what-problem-pentre-wasnt-sorted-18446688> (2020).

- Damage caused by panicking animals
- Farms only operational after a huge clean-up operation
- Uninsured costs and loss of income
- Heavy rainfall contributing to more problems with plant pests and disease
- Extensive loss of fodder and forage
- Damage to soil structure; topsoil washed away
- Livestock severely threatened or temporarily relocated to other farms, potentially over a wide area; loss of livestock
- Time-critical tasks such as lambing, harvest, muck spreading, sowing and silaging disrupted or missed; farmers unable to put heavy machinery on wet ground to harvest
- Disruption to crop rotation
- Crops badly damaged or ruined and/or requiring replanting; harvested grain lost
- Fields underwater for months, smothered by deposits of mud and silt or potentially damaged by saltwater
- Cash flow problems
- Severe financial impacts leading to potential loss of the farm*
- Concerns over loss of supply contracts with supermarkets
- Problems accessing farm recovery grants
- Inability to meet agri-environment scheme obligations

Most serious*

- Flood and heavy rainfall events compounding over the course of a year, as well as with a dry spring, to significantly affect yields over much of the country (2019/20 wheat production)
- A farmer in a life-threatening situation as he tries to save livestock
- Livelihoods in multiple farms impacted for years
- A rescue from an isolated farmhouse by helicopter
- Farmers getting around by boat with land under several feet of water

Avoided

- Farmers avoiding flooding of homes, farmyards and livestock sheds only with strenuous efforts and/or spending large amounts on fuel for pumps

**It is acknowledged that severe flooding and financial distress are maximum seriousness impacts at the individual level; however, refer to the start of Chapter Three for impact category definitions.*

Flooding has not only impacted individual farms, but also on occasion noticeably dented production of some crops at a national level. In November 2019, farmers in areas such as Northeast England and the East Midlands reported the worst autumn rainfall in living memory, with thousands of acres of prime farmland affected.¹³¹ This compounded with a wet February and dry spring, resulting in the worst wheat harvest since the 1980s in 2020.¹³² Potato yields were also affected by the heavy rainfall of autumn 2019,¹³³ while cauliflower production, which is geographically concentrated in Lincolnshire, was hit by heavy rainfall in June 2019.¹³⁴

In addition to damaged crops, farm impacts have included damage to equipment and fences, disruption to time-critical tasks such as sowing, and heavy rainfall exacerbating problems with pests and disease. Farms can be completely surrounded by water during flood events which poses a threat to human and animal safety. Livestock have been swept away by floods, and many livestock farmers have lost fodder and forage due to flooding. Farmers sometimes use mutual support networks such

131. *Darlington and Stockton Times*, "NFU calls for flexible approach after worst rain in living memory", <https://www.darlingtonandstocktontimes.co.uk/news/18038671.nfu-calls-flexible-approach-worst-rain-living-memory/> (2019).

132. Fiona Harvey, "UK facing worst wheat harvest since 1980s, says farmers' union", *The Guardian*, <https://www.theguardian.com/environment/2020/aug/17/uk-facing-worst-wheat-harvest-since-1980s-national-farmers-union-nfu> (2020).

133. *Ibid.*

134. BBC, "Cauliflower shortages as extreme weather kills crops", <https://www.bbc.co.uk/news/uk-49330210> (2019).

as Forage Aid¹³⁵ and Young Farmers Clubs to deal with the aftermath.

While insurance and the Farming Recovery Fund, a government scheme to help farmers fund repairs following flood events, help farmers recover financially to some extent, they inevitably do not cover all losses. UK farm businesses have absorbed a significant fraction of the financial impact of extreme weather in recent years¹³⁶. According to *Farmers Weekly*, farmers have not historically been insured for damage to crops in the field from flooding, for example¹³⁷. Livelihoods can be impacted for years, and inevitably some farmers have run into severe financial difficulties.

Farmers reported teething problems with the government's Farming Recovery Fund in the early years, resulting from, for example, stipulations for photographic evidence on flood damage being unclear at the time at which they could be taken.¹³⁸

135. A charity/mutual support network which helps farmers source feed and bedding supply for livestock during extreme weather events – see: Suzie Horne, “Video: Forage Aid delivers vital supplies to flooded farmers”, <https://www.fwi.co.uk/news/weather/video-forage-aid-delivers-vital-supplies-to-flooded-farmers> (2020).

136. Suzie Horne, “Flood damage cost to farms rises to £60m”, *Farmers Weekly*, <https://www.fwi.co.uk/business/flood-damage-cost-to-farms-rises-to-60m>; Andrew Meredith, “Which rules are relaxed when farmland is flooded”, *Farmers Weekly*, <https://www.fwi.co.uk/business/compliance/which-rules-are-relaxed-when-farmland-is-flooded> (2014); Suzie Horne, “How to protect farm businesses against extreme weather”, *Farmers Weekly*, <https://www.fwi.co.uk/business/business-management/how-to-protect-farm-businesses-against-extreme-weather> (2020).

137. *Ibid.*

138. Philip Case, “Farmer accuses govt of ‘broken promises’ on flood response”, *Farmers Weekly*, <https://www.fwi.co.uk/news/environment/farmer-accuses-govt-of-broken-promises-on-flood-response> (2014).

Box 5.3. Lincolnshire as a potential flood risk hotspot for farming

Over 1,000 acres of farmland in Lincolnshire were flooded in November 2019.¹³⁹ This is equivalent to around 4-5 farms. Farmers described impacts including losing significant fractions of their crops, damage to soil structure, inability to sow winter crops, and soils which were still too wet in the spring to drill. At least two farms were completely cut off by floodwaters.

Farmers in Lincolnshire have noticed massive variations in rainfall in recent years.¹⁴⁰ Lincolnshire's high quality agricultural land and flatness also make it an obvious area of concern for sea level rise. Damage done to farmland by a tidal surge in 2013 prompted a project to defend a stretch of farmland adjacent to the Wash.

In addition to the effects of flooding on farmers, there is a growing understanding that farmers have an important role to play in flood management, as shown by the recent debate over how this might be reflected in the Government's new Environmental Land Management Scheme (ELMS) of farm support which is to replace the EU's Common Agricultural Policy (CAP) direct payments¹⁴¹, and was heavily shaped by Bright Blue's previous report¹⁴². Farmers, however, have sometimes felt that flood risk management decisions sacrifice their land to protect homes,¹⁴³ stressing the need to make such choices explicit and to be

139. Farming UK, "1,000 acres of Lincs farmland remains flooded", https://www.farminguk.com/news/1-000-acres-of-lincs-farmland-remains-flooded_54354.html (2019).

140. Matthew Lodge, "We've seen a dramatic change" – Fears over impact of climate change on Lincolnshire's farmers", *LincolnshireLive*, <https://www.lincolnshirelive.co.uk/news/local-news/weve-seen-dramatic-change-fears-3741927> (2020).

141. Johann Tasker, "Farmers need key role in water management – NFU", *Farmers Weekly*, <https://www.fwi.co.uk/news/farm-policy/farmers-need-key-role-in-water-management-nfu> (2021); Environment, Food and Rural Affairs Committee, "Managing water" in "Flooding: Fourth Report of Session 2019–21", <https://publications.parliament.uk/pa/cm5801/cmselect/cmenvfru/170/17008.htm> (2021).

142. Ben Caldecott, Sam Hall and Eamonn Ives, "A greener, more pleasant land: a new market-based commissioning scheme for rural payments", *Bright Blue*, <https://brightblue.org.uk/wp-content/uploads/2017/11/Agreenermorepleasantland.pdf> (2017).

143. Johann Tasker, "Farms were 'sacrificed' to protect homes from floods", *Farmers Weekly*, <https://www.fwi.co.uk/news/weather/farms-were-sacrificed-to-protect-homes-from-floods> (2019); Rhian Price, "River Severn dam proposals 'could decimate farms'", *Farmers Weekly*, <https://www.fwi.co.uk/news/environment/river-severn-dam-proposals-could-decimate-farms> (2021).

adequately compensated for any floodwater storage services which their land provides.

“If the Environment Agency wants to flood farmland in order to save houses, they need to do so in an organised, controlled way – where compensation can be paid to farmers for the loss of any crops.”

A farmer in Lincolnshire¹⁴⁴

Tensions have arisen between farmers and flood risk management authorities over dredging, management of water courses contributing to flooding, and maintenance of pumping stations and flood defences.

Greater transparency over the extent to which agricultural impacts are a factor in flood defence spending decisions could possibly help increase trust and confidence with the system within the farming community, as we propose in Chapter Six.

Leisure

For the purposes of this report, leisure includes tourism, hospitality, cultural heritage, recreation and sport. Flooding since 2007 has had a serious impact on a number of tourism and hospitality businesses, as well as cultural and recreational assets. All this is captured in Box 5.4 below.

144. Johann Tasker, “Farmers need key role in water management – NFU”, *Farmers Weekly*, <https://www.fwi.co.uk/news/farm-policy/farmers-need-key-role-in-water-management-nfu> (2021).

Box 5.4. Real impacts on UK leisure from flooding and related hazards since 2007, encountered in the NLP analysis**Least serious**

- Stately home grounds flooded with no or limited apparent consequences
- Cancelled events in parks and showgrounds
- Visitor attraction still functioning despite flooding, but partially closed
- Visitor attractions closed for a day or a few days
- Boats unable to pass temporarily under bridges due to high river levels
- Minor damage to promenades

More serious

- Visitor attractions such as heritage railways closed for months
- Repeat flooding of riverside pubs and bars with loss of insurance cover
- Sporting facilities closed for months due to flooded buildings, damage and debris
- Evacuation by dinghy from a rugby club
- Financial viability of community sports clubs and semi-professional football clubs threatened by flood damage and/or needing alternative premises long term
- Severe damage such as ceiling collapse to leisure centres and swimming pools with weeks or months of closure
- Caravan parks flooding and requiring some emergency service assistance
- Footpaths or towpaths unusable in their full length for months to years due to damage to paths and/or destruction of footbridges, with knock-on impacts on tourism-dependent businesses
- A section of a coastal footpath lost permanently and requiring redirection
- Loss of road bridges in remote, tourism-dependent areas
- Flooded out churches and performing arts venues requiring major refurbishment

- A canal section being closed for several months due to damage
- Loss of leisure boats from very high river discharge and attendant debris surging into a harbour
- Beach huts washed out to sea
- Damage to irreplaceable historical artefacts in museums
- Fish evacuated from an aquarium following a power cut due to flooding
- Significant damage to stately homes and listed buildings, including a pier
- Refurbishment of a building in a World Heritage Site
- A nationally important tourist attraction evacuated due to multiple landslides
- An unplayable golf course going into liquidation
- Permanent closure of hospitality businesses

Most serious*

- Emergency evacuations of caravan parks and campsites
- Caravans and static homes washed away in rivers, potentially creating a downstream hazard
- 1,000+ people evacuated from a holiday park amidst severe flooding
- 51 people with minor injuries and seven with serious injuries following a ceiling collapse in a London theatre during heavy rainfall
- A caravan hanging over a cliff edge due to a sudden coastal erosion incident with an occupant still inside
- Part of an occupied guesthouse suddenly collapsing into a river
- Collapse of a pub straddling a river
- Tourism attractions and businesses closed for more than one year to repair with damage exceeding £ 1 million
- A sizeable proportion of a town's tourist accommodation out of action for a few months, with knock-on implications for businesses in the rest of the town
- The ecology of coastal nature reserves likely to have been permanently altered by storm surges

- Twelve bridges important for the Yorkshire Dales footpath network destroyed in a single flood event
- Fatalities at a rugby club

Avoided

- A historic castle nearly falling into a river
- A scheduled monument nearly flooded

Long term

- Caravan parks at long-term risk of coastal erosion
- World heritage sites or other historic sites at long-term risk of flooding, river erosion, sea level rise or other coastal hazards
- A road important for accessing a national park and key regional tourism centre at long term risk from coastal hazards
- Threats to historic bridges

**It is acknowledged that severe flooding and financial distress are maximum seriousness impacts at the individual level. However, refer to the start of Chapter Three for impact category definitions in these boxes.*

Most striking is the vulnerability of caravan parks and campsites, many of which are sited on flat land next to rivers and coasts or on clifftops. Our analysis identified at least 26 caravan parks, campsites, holiday parks and static caravan parks¹⁴⁵ sustaining significant damage or needing emergency service assistance during flood events or sudden coastal erosion, some in major incidents or clearly life-threatening circumstances, and some more than once.

Many sports clubs and golf courses have been badly affected by flooding. Our analysis identified at least 21 football, rugby and gaelic football grounds¹⁴⁶, including Hillsborough Stadium, which have been flooded badly enough for it to cause problematic damage to pitches, equipment or buildings, to the point of relocation in some cases. As mentioned in Chapter Three, many sports pitches and clubs

145. Excluding park homes, see Chapter Three.

146. Belonging to amateur, semi-professional or professional clubs.

are sited next to rivers, presumably because they are deemed a low risk use.

There are a large number of hospitality businesses which have been seriously impacted by flooding, some repeatedly and to the point of uninsurability. Historic riverside and towpath pubs which eventually become non-viable are likely to be some of the most keenly felt casualties from flooding in the hospitality sector.

“The whole place was wrecked, eleven rooms, and it has been extremely stressful, it takes a lot of getting over ... three weeks ago my sister and I would never have thought we would open in time, we’d been working 10pm each night to get it ready, but we managed. I didn’t want to see the Red Lion go down, we have been here for 55 years.”

Landlady of the Red Lion, Langthwaite, Yorkshire¹⁴⁷

Visitor attractions which have sustained significant damage entailing months or years of closure and repair work include the Jorvik Centre in York and the Severn Valley Railway. There are at least three World Heritage Sites described as at long-term risk from flooding or coastal hazards: Fountains Abbey in Yorkshire, Ironbridge in Shropshire, and the Giant’s Causeway in County Antrim. In the case of Fountains Abbey, a protection scheme has been approved. In addition, Portreath Harbour, which is part of the Cornwall and West Devon Mining Landscape World Heritage Site, sustained some storm damage in 2014 and Saltaire in Bradford was affected by flooding in 2015.

Locally cascading risks from flooding to tourism include: long-

147. Jim Scott, “Dales pub The Red Lion reopens in the face of devastation after floods”, *The Northern Echo*, <https://www.thenorthernecho.co.uk/news/18122157.dales-pub-red-lion-reopens-face-devastation-floods/> (2019).

term damage to footpaths and bridges on long-distance trails whose walkers provide custom to multiple businesses en route; impacts on inland waterways used by leisure boaters; and, flood events knocking out high concentrations of tourist accommodation or attractions which deters visitors, with knock-on impacts for the rest of the local economy.

Box 5.5. The impacts of flooding on tourism-dependent towns

Ballater, Aberdeenshire

Ballater is a village in the Cairngorms National Park fairly close to Balmoral which attracts hikers, nature lovers, golfers and anglers. In December 2015 it suffered devastating flooding from Storm Frank, described as its “worst floods in 200 years”. The flooding affected 60 local businesses, damaged the golf course and closed a locally important footbridge for three years. The caravan park, which provides a significant amount of tourist accommodation in the village was evacuated and lost 40 static caravans to the river, but was able to partially reopen for the summer season. While newspaper articles described can-do determination to recover, an academic study found lasting impacts on residents’ physical and mental health and household finances from what was obviously traumatic flooding, as well as some significant increases in insurance premiums.¹⁴⁸

148. Libby Brooks, “Scottish study reveals ‘significant long-term impact’ of flooding”, *The Guardian* <https://www.theguardian.com/environment/2020/feb/11/scottish-study-reveals-significant-long-term-impact-of-flooding> (2020).

Looe, Cornwall

Looe is reported to be the most frequently flooded town in England. According to the local MP, 65% of its businesses have been flooded, many can no longer get insurance, and repeat flooding is threatening the viability of the local economy.¹⁴⁹ Tidal flooding is relatively predictable, and businesses have adapted to some degree through use of flood boards, but big storms can do a lot of damage. According to the harbour master, the frequency and intensity of flooding is getting noticeably worse. A flood protection scheme for the town is currently being put together.

Manufacturing and industrial estates

The study found some isolated instances of flooding affecting manufacturing, but no suggestion of major impacts for local economies from these cases. Flood risk at industrial estates, which often contain a mixture of businesses such as manufacturers, vehicle repair shops, leisure facilities, logistics centres and so on, was a more consistently recurring theme. Industrial estates are key employers in some locations, and where they are vulnerable to flooding this may present a risk to the local economy. Box 5.6 below highlights the impacts of flooding since 2007 on manufacturing and industrial estates.

149. Charlotte Becquart, "Inside the UK's most flooded town which is battling to prevent a disaster", *CornwallLive*, <https://www.cornwalllive.com/news/cornwall-news/inside-uks-most-flooded-town-3797336> (2020).

“It was like a tsunami. When I first saw the damage, I thought we were finished and would just need to salvage anything we could ... We have worked really hard, but unfortunately we have lost a lot of stock. All the machines have needed new motors, which has cost us another £10,000 ... We are now at about 10 per cent productivity and have been able to give around 20 people work.”

Director of Better Dreams Ltd, Rochdale¹⁵⁰

Box 5.6. Real impacts on UK manufacturing and industrial estates from flooding and related hazards since 2007, encountered in the NLP analysis

Least serious

- Minor flooding at industrial estates
- Very short-term interruption to production

More serious

- Total production shutdown due to severe inundation
- Damaged machinery
- Loss of £100,000s worth of stock
- Partial ceiling collapse
- Relocation due to loss of insurance cover
- Production suspended for months with difficulties fulfilling orders
- Flooding triggering unplanned flaring at an ethylene plant with impacts on the local community
- Staff lay-offs following severe flooding

150. Lisa Gray, “Rochdale firm devastated by Boxing Day floods is battling back”, *Manchester Evening News*, <https://www.manchestereveningnews.co.uk/news/greater-manchester-news/rochdale-firm-devastated-boxing-day-10756567> (2016).

Long-term

- Defence industry sites important for the UK's nuclear submarine program in Barrow-in-Furness and Derby at long-term risk of flooding (Rolls Royce Derby has closed very briefly during a flood event as a precaution on at least one occasion)
- Individual facilities at long-term risk from sea level rise
- Chemical facilities at Seal Sands in Teeside threatened by coastal flooding but defended
- An industrial estate which is a major employer in the area at risk of river flooding but defended

There are at least two industrial estates in Wales where potential employment impacts from flooding featured in discussions over flood defences, as described in Box 5.7 below.

The potential environmental impacts of flooding at manufacturing sites is an issue which often arises in other countries with more extreme flood hazards, and the risks are worth considering in the UK. However, this analysis found only one example of an environmental knock-on impact from flooding at a manufacturing site.

Box 5.7. The economic importance of flood resilience in an industrial estate**Lliswerry, Newport, Wales**

Lliswerry is an area of Newport on the Usk Estuary with industrial sites including the Liberty steelworks and Felnax Industrial Estate. The proportion of people who work in manufacturing is much higher than the Newport average.¹⁵¹ Lliswerry has been identified as one of four areas of Newport at high risk from all types of flooding.

In flood defence plans, Natural Resources Wales noted that many businesses closest to the river already experience small scale flooding, stating “the industrial estate is a key contributor to Newport’s employment and economy” and “a large-scale flood in this area could have a disastrous impact on the local economy and community”.¹⁵²

151. Newport City Council, “Community Well-being Profile: Lliswerry”, <https://www.newport.gov.uk/documents/One-Newport/Lliswerry-Profile-Final-2017.pdf> (2017).

152. Saul Cooke-Black, “£10m flood defence plan for the River Usk in Lliswerry”, *South Wales Argus*, <https://www.southwalesargus.co.uk/news/18703611.10m-flood-defence-plan-river-usk-lliswerry/> (2020).

Chapter 6: Policy recommendations

Based on our analysis presented and discussed in the last three chapters, this chapter makes a number of policy recommendations to achieve three main aims: better preparing key public services and critical infrastructure for flooding; improving community resilience to flooding; and, better supporting local government and improving urban drainage.

Better preparing public services and critical infrastructure for flooding

Recommendation one: Defra should support and fund an ongoing programme of research to specifically identify and monitor the risks associated with extreme sub-daily rainfall in urban areas.

The National Flood Resilience Review of 2016 explained that it was only able to examine worst case rainfall accumulations on monthly timescales and large regional scales, which excluded consideration of surface water flooding.¹⁵³ Defra's Surface Water Management Plan describes research due to be completed this winter to develop plausible extreme scenarios for surface water flooding and review infrastructure

153. HM Government, "National Flood Resilience Review: Annex 2", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf (2016).

resilience to them.¹⁵⁴

The flash flooding which London experienced on 25th July 2021 resulted from 41.8mm of rainfall in an afternoon, and 20-30mm in one hour in some locations.¹⁵⁵ This is not at all extreme when compared to the UK's historically most extreme rainfall events.¹⁵⁶ While rare, and acknowledging that meteorologists would need to advise how likely such events are in any given location, rainfall totalling 180-200mm in three hours has been observed twice in rural parts of the UK in the past four years.¹⁵⁷

The consequences of a genuinely extreme rainfall event in a major urban area can only be imagined. Policymakers should assure themselves that they understand as far as possible the present and future likelihood of such a scenario: the potential consequences for public safety and infrastructure failure; and, any constraints science has on being able to provide guidance on these questions (for example, model limitations or exceedance probabilities based on historical data).

Defra's current research on extreme surface water flooding and infrastructure resilience is filling an important gap. Putting in place an ongoing programme of research on this topic might help ensure the National Risk Assessment process stays on top of this threat, for example, by incorporating improvements in modelling as well as observations from materialised events into the policy evidence base.

154. Department for Environment, Food and Rural Affairs, "Surface water management: A Government update", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015182/surface-water-management-government-update.pdf (2021).

155. AP News, "London cleans up after flash flooding drenches homes, subway", <https://apnews.com/article/europe-london-floods-c6901820b0424df2d51186f8bf104d35> (2021); Jane Clinton, "Thunderstorms leave roads and tube stations flooded in London", <https://www.theguardian.com/uk-news/2021/jul/25/thunderstorms-leave-cars-and-buses-stranded-in-london> (2021).

156. Holley et al., "Thunderstorms and extreme rainfall in south Norfolk, 16 August 2020: meteorological analysis", *Weather*, <https://doi.org/10.1002/wea.4038> (2020).

157. *Ibid*; Richard Whitehouse, "Flooding at Coverack was caused by 'most intense rainfall ever recorded in the UK'", *Cornwall Live*, <https://www.cornwalllive.com/news/cornwall-news/flooding-coverack-caused-most-intense-2099898> (2018).

Recommendation two: Government should introduce a mechanism to ensure the National Security Risk Assessment and National Risk Register incorporate changing climate risk.

The National Security Risk Assessment (NSRA) is the government's classified assessment of the key malicious and non-malicious threats that could affect the UK, both domestically and overseas. The National Risk Register (NRR) is the public-facing version of it.¹⁵⁸ The CCC notes room for improvement in incorporating climate change into the NSRA and NRR.¹⁵⁹ Currently, the NRR has a section acknowledging the threat posed by climate change and refers to the UK Climate Change Risk Assessment.

Policymakers should ensure that the NSRA and NRR are informed by the changing nature of flood risk via climate projections and do not rely on an understanding which is overly dependent on historical data. This is particularly important given that the NSRA has a timeframe of up to 20 years. Ensuring the NSRA is forward-looking on flood risk will allow potential threats to UK communities and critical infrastructure to be better flagged and understood in advance, ultimately increasing the chances of effective preventative actions.

Recommendation three: Government should mandate that local authority contingency plans are reviewed periodically when updated flood risk information is available.

Government's recent Call for Evidence on the National Resilience Strategy, a new vision for national resilience to a range of threats currently being drawn up by the Cabinet Office, asked whether the Civil Contingencies Act should mandate review of local authority contingency

158. HM Government, "National risk register: 2020 edition", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/952959/6.6920_CO_CCS_s_National_Risk_Register_2020_11-1-21-FINAL.pdf (2020).

159. Climate Change Committee, "Progress in adapting to climate change: 2021 Report to Parliament", <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021); Climate Change Committee, "The third UK climate change risk assessment technical report", <https://www.ukclimaterisk.org/independent-assessment-cra3/technical-report/> (2021).

plans.¹⁶⁰ Periodic review to ensure such plans by local authorities are robust to changing flood risk, again ensuring they are not overly reliant on a historical understanding of the risk, would seem a sensible idea. For example, plans could certainly be reviewed after the Environment Agency releases maps detailing future flood risk in 2024.¹⁶¹

Recommendation four: Government should conduct a civil resilience exercise for an extreme rainfall event in a major UK urban area, incorporating significant infrastructure failure.

Emergency planners have undertaken a number of exercises over recent years, some of which have looked at the implications of flooding in major urban areas.

Exercise Watermark, at the time the largest civil defence preparedness exercise ever undertaken for England and Wales, took place in 2011 and included simulated surface water flooding in London and West Yorkshire.¹⁶² In 2016, Exercise Triton II simulated response to a major reservoir flooding disaster in Greater Manchester.¹⁶³ A particular challenge of surface water flooding for emergency responders is the inherent difficulty in predicting location and timing with reasonable lead times, although forecasting systems are becoming more feasible.¹⁶⁴

Given these ongoing research developments, Defra's work on extreme surface water flooding scenarios, and increased public awareness following the recurring flooding incidents in London in 2021, it could

160. Cabinet Office, "National resilience strategy: call for evidence", <https://www.gov.uk/government/consultations/national-resilience-strategy-call-for-evidence> (2021).

161. Environment Agency, "National flood and coastal erosion risk management strategy for England", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/920944/023_15482_Environment_agency_digitalAW_Strategy.pdf (2020).

162. Department for Environment, Food and Rural Affairs, "Exercise watermark final report", <https://www.gov.uk/government/publications/exercise-watermark-final-report> (2011).

163. Paul Harrison, "Exercise Triton II held across Greater Manchester", *South Manchester News*, <https://southmanchesternews.co.uk/exercise-triton-emergency-planning/> (2016); Todd Fitzgerald and Charlotte Dobson, "Recap: emergency services in huge major incident training exercise", *Manchester Evening News*, <https://www.manchestereveningnews.co.uk/news/greater-manchester-news/live-major-incident-emergency-exercise-11612577> (2016).

164. Speight et al., "Towards improved surface water flood forecasts for Scotland: A review of UK and international operational and emerging capabilities for the Scottish Environment Protection Agency", <https://www.sepa.org.uk/media/483861/towards-improved-surface-water-flood-forecasts-for-scotland-a-review-final-report.pdf> (2019).

be an opportune time to conduct a civil resilience exercise specifically focussed on an extreme urban rainfall and flash flooding scenario. Such an exercise could contain components relating to cascading impacts from infrastructure failures, for example, serious flooding at more than one underground station concurrently, loss of mobile phone coverage, flooded electricity substations, large numbers of vehicles trapped in floodwater, sewer flooding, impassable emergency services key routes, and so on.

Recommendation five: Extend Defra and the Environment Agency's new analysis of plausible extreme scenarios for surface water flooding to the emergency services and hospitals.

Defra's Surface Water Management Plan describes applying its new analysis of extreme surface water flooding scenarios to water, energy, transport and telecommunications, but not the emergency services or healthcare assets. Doing so could be useful for identifying potential cascading risks for emergency response during flood events.

Emergency services have had an online tool to help them assess which routes may be affected by surface water flooding during high rainfall events since 2020.¹⁶⁵ Identifying key emergency service access routes which could be unusable in future events well in advance could help emergency planners identify which populations are at risk of not being reachable (particularly vulnerable groups), and plan how they would respond to this eventuality. It could also feed into local government flood risk management prioritisation, as we recommend later in this chapter.

The National Flood Resilience Review, a government report which assessed infrastructure resilience to flooding, examined the vulnerability of health facilities to flooding in England and identified only a small number of locations where service provision could not be diverted to

165. Climate Change Committee, "Progress in adapting to climate change: 2021 Report to Parliament", <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

another hospital in the event of flooding. It should be reiterated that this assessment did not incorporate surface water flooding,¹⁶⁶ which has sparked major incidents at hospitals on at least two occasions in recent years.¹⁶⁷ The extreme surface water flooding scenarios should therefore be used to better understand the risks to hospitals and identify possible risk mitigation actions.

Recommendation six: NHS England should identify any NHS assets included in the high or significant risk maintenance backlog which are also at risk of flooding or have structural features which may be particularly vulnerable to heavy rainfall and then use this information to ensure such assets are suitably prioritised in NHS capital spending decisions.

Heavy rainfall and flooding have the potential to do more damage where maintenance is not up to date. Earlier this year, health service managers highlighted that the NHS backlog maintenance bill in England has increased rapidly and now stands at around £9 billion.¹⁶⁸ Around a sixth of this is deemed ‘high risk’ backlog,¹⁶⁹ indicating where repairs must be addressed to prevent catastrophic failure or major disruption to clinical services.¹⁷⁰

There have been at least three cases of ceiling collapses in NHS hospitals due to heavy rainfall since 2014: Bath (2014), Altrincham (2016) and Whipp’s Cross, London (2021). While patient care was disrupted in two of these cases, injuries were not reported, fortunately. The risk that similar episodes may occur and eventually result in casualties, however, should be considered, particularly in facilities with roofs known to be

166. HM Government, “National flood resilience review”, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf (2016).

167. These relate to Whipp’s Cross and Newham Hospitals in July 2021, and Birmingham Heartlands Hospital in June 2016.

168. David Forrest, “Experts cite “alarming” figures as NHS backlog maintenance bill skyrockets”, *Hospital Times*, <https://www.hospitaltimes.co.uk/alarming-figures-as-nhs-backlog-maintenance-bill-skyrockets/> (2021).

169. NHS, “Estates returns information collection 2019/20”, <https://digital.nhs.uk/data-and-information/publications/statistical/estates-returns-information-collection/england-2019-20>, (2021).

170. Nick Carding, “High risk’ estates maintenance cost continues to spiral”, *Health Service Journal*, <https://www.hsj.co.uk/finance-and-efficiency/high-risk-estates-maintenance-cost-continues-to-spiral/7026166.article> (2019).

in an extremely bad condition (such as the Queen Elizabeth Hospital in King's Lynn¹⁷¹). Recently, £110 million was set aside to prevent roof collapses in a small number of hospitals due to an outdated and unsafe type of concrete plank which can be made more vulnerable by severe weather, according to the Local Government Association.¹⁷² There may be other types of structural features which pose risks.

While those most familiar with NHS requirements need to establish priorities for capital spending, identifying where flooding and heavy rainfall have the potential to interact with high risk backlog may help prevent future incidents where patient care is disrupted or safety is at risk.

Recommendation seven: The Department for Transport should put in place a programme to systematically monitor potential bridge vulnerability to flooding, hydrological change and bridge scour at national level, and investigate bridge collapses.

The RAC compiles data on the number of substandard road bridges (bridges unable to carry the heaviest vehicles) in England, Scotland and Wales annually. Their analysis draws attention to the fact that bridges can be moved into this category where maintenance does not keep pace with environmental stresses such as flooding, and highlights the need to ensure they are assessed for deterioration due to bridge scour.¹⁷³ The proportion of substandard bridges has been stable at around 4.5% since 2017,¹⁷⁴ and it is not clear from the RAC analysis how many have moved in or out of this category due to deterioration or repair.

Central government needs to pre-emptively tackle potential bridge

171. Chris Bishop, "More props needed to stop hospital roof collapsing", *Eastern Daily Press*, <https://www.edp24.co.uk/news/health/more-props-needed-at-crumbling-qeh-kings-lynn-8240550> (2021).

172. Jordan Marshall, "More than £100m set aside to fix hospitals with faulty concrete", *Building News*, <https://www.building.co.uk/news/more-than-100m-set-aside-to-fix-hospitals-with-faulty-concrete/5112392>. article (2021); Local Government Association, "Information on reinforced autoclaved aerated concrete", <https://local.gov.uk/information-reinforced-autoclaved-aerated-concrete-raac> (2021).

173. RAC Foundation, "Number of substandard road bridges on the rise again", <https://www.racfoundation.org/media-centre/number-of-substandard-road-bridges-on-the-rise-again> (2021).

174. Comparison of figures from RAC analyses since 2017.

collapse by recognising several things. First, the reasons why climate change could make road bridge collapse more likely. Second, that identifying bridges which may be prone to collapse is an important public safety priority. Third, that repairing them in advance likely represents a cost-saving.

The Department for Transport (DfT) should improve knowledge of the scale of the problem by setting up a formal procedure to investigate bridge collapses and consulting on the best way to identify bridges which may be at risk of deterioration and/or collapse. DfT should also routinely compile data on bridge failures and changes in bridge condition, as well as causes.

Recommendation eight: Central government should better support local authorities to identify and repair or upgrade bridges before they experience dangerous failure via new research and existing and even new road transport funding.

The expanded evidence base proposed in the previous recommendation could then be used to help local authorities identify vulnerable bridges, and might well help make the economic case for ensuring local authorities have adequate funding for bridge maintenance in the years to come. The costs of physically replacing a bridge are typically in the order of millions.¹⁷⁵ This does not include losses to the local economy from prolonged lack of connectivity, or the role bridges often play in carrying gas, water, telephone, internet and electricity pipes and cables.

Government should commission research on how this information could be reflected, via formal cost-benefit analyses or other means, in road transport funding decisions, either through the local highways maintenance funding formula, one of the periodic capital funding programmes administered by DfT, or even a dedicated climate

175. Harrogate Informer, "Tadcaster bridge repairs to cost around £3million", <https://www.harrogate-news.co.uk/2016/01/04/tadcaster-bridge-repairs-to-cost-around-3million/> (2016); Martin Wainwright, "Workington's shiny new bridge is lowered into place", *The Guardian*, <https://www.theguardian.com/uk/the-northerner/2011/sep/05/workington-navvies-bridge-cumbria-floods-allerdale-sustrans-nuclear-decommissioning> (2011).

adaptation programme.

National targets could be set on preventing bridge damage and collapse, for example: ensuring that over time there is no net increase in the number of substandard bridges due to river erosion and flood damage; a target of zero annual river bridge collapses on A and B roads; or, an overarching policy goal that, at the very least, the total stock of road bridges does not decline due to climate change.

Recommendation nine: The Greater London Authority, Glasgow City Region and relevant Combined Authorities should all ensure that risks to underground stations in London, Glasgow, Newcastle and Liverpool from urban flash flooding have been fully assessed, that the assessments are publicly available, and that necessary measures such as improved drainage and Sustainable Urban Drainage Systems (SuDS) around stations are put in place to mitigate any risks.

The public should be assured that this risk to public safety in major cities is being addressed. Glasgow City Region's 2018 climate risk assessment¹⁷⁶ stated that the risk of subway station flooding is low, but it is not clear whether it looked at surface water flooding. West Street Station in Glasgow was closed due to flash flooding on 8th August 2021.¹⁷⁷ In London, 2021 has been the highest year on record for the number of hours stations have been closed due to flooding.¹⁷⁸ London Underground put together an unpublished review of flood risk to its network in 2014 warning that heavy rainfall could be expected to

176. Climate Ready Clyde, "Climate change risk and opportunity assessment for Glasgow City Region", <https://www.crc-assessment.org.uk> (2018).

177. Ava Whyte, "West Street: commuter chaos as Glasgow subway station closes due to flooding", *Glasgow Times*, <https://www.glasgowtimes.co.uk/news/19499435.west-street-commuter-chaos-glasgow-subway-station-closes-due-flooding/> (2021).

178. Callum Marlus, "London underground flooding: How the tube is fighting to beat the capital's extreme weather", *MyLondon*, <https://www.mylondon.news/news/uk-world-news/london-underground-flooding-how-tube-21732356> (2021).

seriously affect the underground network in the near future.¹⁷⁹

The general lack of transparency surrounding London Underground flood risk means that independent experts cannot scrutinise the adequacy of assessments and plans to address it. If it's possible that passengers' lives could be put at risk from flooding in underground stations, such risk assessments should be publicly available.

The risk of surface water flooding affecting underground stations can be mitigated by improving the capacity of street gutters, implementing sustainable urban drainage around stations and protecting subway entrances.¹⁸⁰ The Greater London Authority and other authorities responsible for urban transport systems with underground stations should implement such measures.

Recommendation ten: The Climate Change Committee (CCC) should include more explicit assessment of risks to urban public transport systems from flooding, and associated adaptation progress, in future CCC reports to Parliament on climate risk and adaptation, either under the bracket of 'rail and urban transport networks', or in a separate section.

Urban public transport systems are a gap in the CCC's current climate risk and adaptation progress reporting processes, possibly because they are a matter for sub-national authorities. The CCC's Third UK Climate Risk Assessment does mention London Underground flooding in passing, but flood risks to urban transport systems do not appear to be methodically considered. The CCC's Adaptation progress reports contain sections on ports, airports, the rail network, the strategic road network and the local road network,

179. Damian Carrington, "57 tube stations at high risk of flooding, says London Underground report", *The Guardian*, <https://www.theguardian.com/uk-news/2016/apr/10/57-tube-stations-high-risk-flooding-london-underground-report> (2016); Charlie Lawrence-Jones, "The London Underground stations most likely to flood in an emergency", *My London*, <https://www.mylondon.news/news/zone-1-news/london-underground-stations-most-likely-17653640> (2020).

180. Klaus Hans Jacob, "A subway flood expert explains what needs to be done to stop underground station deluges", *The Conversation*, <https://theconversation.com/a-subway-flood-expert-explains-what-needs-to-be-done-to-stop-underground-station-deluges-167254> (2021).

with urban transit and underground systems not fitting within any of these categories.

While adaptation of urban transport systems is only really an issue for large urban areas, failure to adapt could result in disruption, economic knock-on effects and risks to public safety potentially affecting large numbers of people. It should therefore be considered whether risks and adaptation progress can be monitored more effectively within the UK's routine adaptation policy cycle. This would help flag up emerging problems and stimulate measures to tackle them.

Recommendation eleven: Major port operators should be directed by government to submit reports to the government's formal Adaptation Reporting process, if participation does not increase voluntarily

Under the Climate Change Act 2008, the Secretary of State can direct key organisations to report on the steps they are taking to adapt to climate change.¹⁸¹ Six harbour authorities contributed to the second round of adaptation reporting in 2015, and the number of ports covered is apparently lower in the current third round.¹⁸² Of the 40 ports operated by the UK Major Ports Group,¹⁸³ seven are covered. The Ports of Dover, Felixstowe and Immingham have been included both times.

No ports are required to produce resilience plans, and according to the CCC, the government has limited information on the extent to which the sector is adapting and preparing.¹⁸⁴ While risks to UK ports are low by global standards,¹⁸⁵ it is reasonable to expect port operators

181. Department for Environment, Food and Rural Affairs, "Climate change adaptation reporting", <https://www.gov.uk/government/publications/climate-change-adaptation-reporting> (2010).

182. Department for Environment, Food and Rural Affairs, "List of organisations reporting under adaptation reporting power: third round", <https://www.gov.uk/government/publications/climate-change-adaptation-reporting-third-round/list-of-organisations-reporting-under-adaptation-reporting-power-third-round> (2021). Compare with the equivalent list for the second round.

183. UK Major Ports Group, "About us", <https://ukmajorports.org.uk/about-us/> (2021).

184. Climate Change Committee, "Progress in adapting to climate change: 2021 Report to Parliament", <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

185. Izaguirre et al., "Climate change risk to global port operations", *Nature Climate Change* 11, 14–20 (2021).

to periodically communicate to the government that they understand and are managing their risks associated with sea level rise, storm surges and other hazards, particularly given the economic importance of some ports, and expenditures of public money on protecting them.¹⁸⁶

Boosting participation in the official adaptation reporting progress would increase the chances that potential problems come to light and plans are made to address them.

Recommendation twelve: Government should adopt a policy aim of ensuring that electricity substations are equivalently protected from all sources of flooding.

Adaptation of infrastructure assets to surface water flooding is likely lagging adaptation to river and coastal flooding, partly due to its general omission from the National Flood Resilience Review and National Infrastructure Assessment.

According to the CCC, the number of electricity substations at significant risk of surface water flooding is projected to increase substantially by 2050 assuming current levels of adaptation, while they will generally be protected from river flooding.¹⁸⁷

The engineering standard which guides flood risk management for electricity transmission and distribution assets was updated to incorporate surface water flooding in 2016.¹⁸⁸ Moreover, Defra is working on assessing the risks to energy networks from extreme surface water flooding and will develop actions based on this research.¹⁸⁹ These and further actions could be guided by the aim of eliminating this projected adaptation shortfall which exists for surface water flooding compared

186. BBC, "Tilbury Port: Work starts on £34m flood defences", <https://www.bbc.co.uk/news/uk-england-esssex-55919819> (2021).

187. Climate Change Committee, "Progress in adapting to climate change: 2021 Report to Parliament", <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

188. National Grid, "Climate change adaptation: Second Round Adaptation Response", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/566151/climate-adrep-national-grid.pdf (2016).

189. Department for Environment, Food and Rural Affairs, "Surface water management: A Government update", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015182/surface-water-management-government-update.pdf (2021).

to other types of flooding. This would help ensure the future resilience of the electricity network at a time when electrification will be vital to the decarbonisation process and for transport.

Recommendation thirteen: Require telecoms providers to actively assess and disclose assets at risk of flooding and single points of failure in their networks. In each case, action plans for flood risk management and/or elimination of the single point of failure (SPOF) should be produced.

Ofcom guidance to telecoms service providers on the security and resilience of their networks states that they should consider whether flood resilience measures are required even at sites at lower risk of flooding, for example, because a site constitutes a single point of failure (SPOF).¹⁹⁰ It is noted that they could face investigations following a flood incident. This approach, while acknowledging flood risk, is reactive and does not monitor or pre-emptively ensure that telecoms service providers are adequately addressing flood risk.

The National Infrastructure Commission recommended that government should introduce clear, periodically reviewed resilience standards for digital services.¹⁹¹ Telecommunications providers could be required to actively assess and disclose whether they have assets at risk of flooding, as well as single points of failure (SPOFs) in their networks. If so, they could produce an action plan for flood risk management and/or elimination of the SPOF, or at least explain why this is not feasible. This would proactively help reduce the future chances of emergency service call failures during flood events, rather than resting on an assumption that the prospect of penalties will motivate companies to assess and mitigate these risks.

190. Ofcom, "Ofcom guidance on security requirements in sections 105A to D of the Communications Act 2003", https://www.ofcom.org.uk/_data/assets/pdf_file/0021/51474/ofcom-guidance.pdf (2017).

191. Climate Change Committee, "Progress in adapting to climate change: 2021 report to parliament", <https://www.theccc.org.uk/publication/2021-progress-report-to-parliament/> (2021).

Improving community resilience

Recommendation fourteen: Government should implement a comprehensive, major public information campaign covering all aspects of flooding, with the aim of increasing national resilience.

The forthcoming National Resilience Strategy's vision of creating the 'most resilient nation' means that people need to be well-informed about the threats they face and how to prepare for and react to them. The National Risk Register suggests the public can be better prepared for civil emergencies if they read Chapter 4 of the NRR and their local community risk register.¹⁹² Frankly, it is not realistic to assume that most people will do this.

Effective systems exist to warn people of flooding in their area, but there is much more government could do to inform people about our national flooding problem, taking the information to them rather than assuming they are already aware of government documents and processes. Advice on knowing your flood risk, how to react during a flood event and improve the flood resilience of your property needs to be disseminated at a national level rather than community level campaigns, because of the widespread nature of surface water flood risk and because two-thirds of people living in areas at risk of flooding in England do not appreciate their property is at risk.¹⁹³ Many people wrongly believe they are not at risk of flooding, and people also may have vulnerable relatives who live in high flood risk areas.

Huge emerging national threats deserve public information strategies with top level ministerial support which make an impact. Many who were alive in the 1980s may remember the 'Don't Die

192. HM Government, "National risk register: 2020 edition", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/952959/6.6920_CO_CCS_s_National_Risk_Register_2020_11-1-21-FINAL.pdf (2020).

193. James Bevan, "Surface water: The biggest flood risk of all", <https://www.gov.uk/government/news/surface-water-the-biggest-flood-risk-of-all> (2018); Environment Agency, "National flood and coastal erosion risk management strategy for England", <https://www.gov.uk/government/publications/national-flood-and-coastal-erosion-risk-management-strategy-for-england-2> (2020).

of Ignorance' government campaign about AIDS. The impact this campaign made has often been attributed to the fear it generated. In the case of flooding, the aim should be not to instil fear, particularly as many people are sensitive to what they view as politically-motivated 'propaganda' around climate change, but certainly to acknowledge the scale of the problem and help communicate a practical sense of how we deal with it. Box 6.1 below outlines suggestions for the key content of a possible communications campaign.

Box 6.1. Possible content to be included in a comprehensive nationwide public information campaign on flooding

- What to do during a flood emergency or flood-induced blackout
- What you can expect from your local authority if a flood event occurs
- Where to receive emergency warnings and flood risk information
- Understanding the flood risk of your property, that it could be changing, and that flood defences can fail
- Understanding responsibility for your own property-level protection and what you can do to make your property more resilient (including preventing sewage backflow)
- Understanding whether your home is eligible for insurance via Flood Re, and that the scheme will end in 2039
- Ensuring your insurance includes flood cover
- How you can support your Local Resilience Forum as a volunteer and decrease flood risk as a community by decreasing impermeable surfaces in gardens; awareness that this also helps prevent sewage pollution from entering waterways
- Risks of driving through floodwater
- Risks of people and pets contracting an infection through contact with floodwater
- What to expect from your water and sewerage company
- Awareness that this is a national problem which will get worse because of climate change; awareness of coastal change

Recommendation fifteen: Defra and the Environment Agency should improve transparency of flood defence spending decisions to allow better scrutiny and ensure fairness across regions and for deprived communities.

As Chapter One highlighted, flooding already places, and will continue to place, difficult emotional and economic strains on especially deprived communities and individuals. This has the potential to exacerbate feelings of resentment and injustice. Ensuring fairness over government flood defence spending in the long-term is vital.

At the moment it is difficult for outside parties to scrutinise patterns of government flood defence spending or understand the factors which go into decisions. This encourages speculation that certain parts of the country are not getting their fair share, or that decisions are biased towards the socially advantaged.

Defra has already committed to making funding to local authorities for their statutory flood risk management functions fairer and more transparent¹⁹⁴. With respect to mainstream flood protection, Defra and the Environment Agency could improve transparency by publishing a public-facing document which clearly explains for non-specialists how flood defence spending decisions are made, and which factors (for example, what is included in consideration of economic benefits) determine whether a project is funded and/or prioritised.

Defra and the Environment Agency already publish information on the costs of flood defence capital schemes on an individual scheme basis.¹⁹⁵ They could also publish data every year showing a regional breakdown of progress in flood risk management. This would need to be done with care. Crude comparison of annual flood defence spending figures for different areas could mask important factors in decisions,

194. Department for Environment, Food and Rural Affairs, "Central Government funding for flood and coastal erosion risk management in England", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/974066/Funding_FCERM_March_2021_Final_accessible.pdf (2021).

195. Department for Environment, Food and Rural Affairs and Environment Agency, "Leicester flood management scheme – conveyance works", <https://environment.data.gov.uk/asset-management/index.html?element=http%3A%2F%2Fenvironment.data.gov.uk%2Fasset-management%2Fid%2Fcapital-project%2FTRC000E%2F00A%2F531A> (2021).

such as levels of risk, viability of project options or historic investment. Indicators which allow for meaningful regional comparisons could be explored, for example, level of spending per property at risk, or properties protected as a proportion of properties at risk in the absence of defences.

The House of Commons Public Accounts Committee has also recommended that national flood risk indicators incorporate risks to agriculture and small businesses for better monitoring of these issues.¹⁹⁶

Recommendation sixteen: Enable images taken by drones deployed by government agencies during flood events to support Farming Recovery Fund applications and other agricultural schemes relating to flooding.

As explained in Chapter Five, some farmers reported difficulties in accessing the government's Farming Recovery Fund in the early days of the scheme. For example, applications were refused because stipulations for photographic evidence on flood damage were not clear at the time at which it was possible to take them. Government could explore the use of drone images to help with assessment of agricultural payment schemes relating to flooding, if applicable.

Use of drones by loss adjustors is well-developed in assessing agricultural flood damage in the USA, due to a long-standing federal crop insurance scheme.¹⁹⁷ Drones have a wide range of applications in flood risk and emergency management.¹⁹⁸ They are already used by the Environment Agency and police to survey flood-hit areas, and the Environment Agency has a dedicated geomatics team.

Images and footage which are already being taken by government agencies could be routinely passed on to Defra to help it assess Farm

196. Public Accounts Committee, "Managing flood risk", <https://publications.parliament.uk/pa/cm5801/cmselect/cmpubacc/931/93105.htm> (2021).

197. Barbara Horvatic, "Using Drone Mapping for Crop Insurance", *PrecisionAg Global*, <https://www.precisionag.com/in-field-technologies/drones-uavs/using-drone-mapping-for-crop-insurance/> (2019).

198. Salmoral et al., "Guidelines for the use of unmanned aerial systems in flood emergency response", *Water* 12(2):521 (2020).

Recovery Fund applications. Or, such images could be made publicly available for farmers to use to support their applications. This could reduce the chances of administrative snags hindering farmers' financial recovery, although presumably they couldn't replace all photographic evidence.

Over time, the images could also be used to research the impacts of flooding on farming for public policy, and possibly be used to verify schemes to pay farmers to retain floodwater on their land.

Recommendation seventeen: Give local authorities the power to allow supermarkets to temporarily remain open longer on Sundays during major incidents linked to extreme weather events.

On Sunday 6th December 2015, there was only one supermarket in Lancaster operating normally due to a flood-induced power cut, but it was not able to extend its opening hours in order to serve all customers due to Sunday trading laws.¹⁹⁹ In future similar situations, relaxation of Sunday trading laws during serious flood emergencies could help ensure food, cleaning supplies and replacement personal items are available to those who need them.

The Government recently explored relaxation of Sunday trading laws during the COVID-19 pandemic, but received objections from the Union of Shop, Distributive and Allied Workers.²⁰⁰ In order to allay concerns of diminishing workers' rights, the circumstances under which any such relaxation occurred would need to be tightly defined and very clearly temporary. Major incident status could be one way of defining the circumstances under which this power could be used.

199. Royal Academy of Engineering, "Living without electricity: One city's experience of coping with loss of power", <https://www.raeng.org.uk/publications/reports/living-without-electricity> (2016).

200. Lorraine Conway, "Shop opening hours and Sunday trading", <https://researchbriefings.files.parliament.uk/documents/SN05522/SN05522.pdf> (2020).

Recommendation eighteen: The UK Government should set up a scientific taskforce and commission research with the Coal Authority, and Welsh and Scottish Governments, to ensure that the state of knowledge on the risk of flooding interacting with former mine workings is progressed, alongside assessment of risks relating to coal tips.

The Welsh and UK Governments set up the Coal Tip Safety Taskforce in 2020 to assess the safety of coal tips in Wales following a landslip in Tylorstown, Rhondda Cynon Taf.²⁰¹ The results showed that approximately 300 coal tips in Wales are deemed at high risk of landslides or other hazards.²⁰²

Around 5.7 million people in England, Scotland and Wales live on former coalfields.²⁰³ The risks of flooding interacting with former mine workings in Wales and elsewhere are poorly understood.²⁰⁴ The Coal Authority monitors known mine entries and mine water systems, but many tunnels, shafts and entrances are unmapped. Experts describe mine burst events such as the one experienced in Skewen as virtually impossible to predict and the risk level hard to determine.²⁰⁵

Clearly it is not satisfactory for large numbers of people to be potentially at risk from a hazard about which so little is known, and one which could present itself more often under future rainfall patterns. The Government should therefore consult with the relevant scientific experts to determine what is required to advance the state of the knowledge of this risk – for example, using geophysical surveys. They should then put in place a programme of research and, as far as the science allows, risk assessment resulting from their recommendations, working with the Coal Authority, and Scottish and Welsh governments.

201. Welsh Government, “Coal tip safety”, <https://gov.wales/coal-tip-safety> (2021).

202. Climate Change Committee, “The third UK climate change risk assessment technical report: Chapter 4: infrastructure”, <https://www.ukclimaterisk.org/independent-assessment-ccra3/technical-report/> (2021).

203. BBC, “Former mining communities ‘still scarred by past’”, <https://www.bbc.co.uk/news/uk-england-50069336> (2019).

204. Laura Clements, “The thousands of old mine shafts beneath Welsh homes and the chances of another catastrophic flood”, *WalesOnline*, <https://www.walesonline.co.uk/news/wales-news/flood-mine-shaft-skewen-coal-19741349> (2021).

205. *Ibid.*

Better supporting local government and improving urban drainage

Recommendation nineteen: The Department for Levelling Up, Housing and Communities (LUHC) should more explicitly acknowledge tackling flooding amongst its ministerial responsibilities and explicitly designate a minister as responsible for coordinating inclusion of flooding considerations within policies across the department.

Defra is the lead department for climate adaptation and flood risk management, but there are some aspects of the problem which are clearly within the remit of LUHC. These include: ensuring that the planning system and housing market work to mitigate flood and coastal erosion risk; ensuring local authorities have the resources and capacity to discharge their flood risk management responsibilities; limiting the spread of impermeable surfaces in urban areas; community resilience; and, emergency coordination.

These responsibilities are split within the department between the current Parliamentary under Secretary of State, the Minister for Housing and the Minister for Building Safety and Fire. While there is obvious logic in this split, LUHC should ensure flood risk is being addressed in a coordinated way across these different ministerial briefs in a manner commensurate with its importance as a national issue.

This is particularly important for ensuring progress is made on surface water flooding, given that managing this risk is not within the operational responsibilities of the Environment Agency. Many local authorities are clearly having difficulties, and tackling surface water flooding through the planning process is an area of clear adaptation policy under-performance, according to the CCC. LUHC should explicitly designate a minister as its lead point of contact for flooding and minister responsible for coordinating flooding-related policy across the department, working closely with counterparts at Defra.

Recommendation twenty: Ensure the proposed new developer contributions levy due to replace Section 106 and the Community Infrastructure Levy under the Government's current planning reforms actively encourages the alleviation of flood risk associated with new developments.

Local authorities need more money to discharge their flood risk management responsibilities. Concern over surface water flooding and sewer capacity constraints are common reasons for planning objections. It is therefore worth asking whether flood risk management projects could be funded more routinely through Section 106 agreements, or their proposed successor. Among the reforms proposed in the Planning Bill was a more streamlined approach to developer contributions, replacing Section 106 and the Community Infrastructure Levy with a single levy.²⁰⁶ The Government's planning reforms are currently being reconsidered by ministers at LUHC. This presents an opportunity to consider whether developer contributions could be deployed more regularly and effectively for local government flood risk management measures such as SuDS.

The current Housing Minister, The Rt Hon Christopher Pincher MP, has said that the planning system should provide ways to incentivise development by giving local communities more control over design, and that the new levy will help ensure the infrastructure communities were expecting actually gets built.²⁰⁷ Planning applications which effectively address local concerns over flood risk will receive fewer objections.

However, reasons why local authorities did not use Section 106 agreements more often have included issues around maintenance

206. Local Government Association, "The future of the planning system and the upcoming Planning Bill", <https://www.local.gov.uk/parliament/briefings-and-responses/future-planning-system-and-upcoming-planning-bill-house-commons> (2021).

207. Jessica Hill, "Ministers reveal details of planning reform rethink", *Local Government Chronicle*, <https://www.lgcplus.com/services/regeneration-and-planning/ministers-reveal-details-of-planning-reform-rethink-08-10-2021/> (2021); Grainne Cuffe, "Pincher: replacement of Section 106 to put 'more ammunition in the hands' of councils", <https://www.insidehousing.co.uk/news/pincher-replacement-of-section-106-to-put-more-ammunition-in-the-hands-of-councils-73170> (2021).

of SuDS and lack of skills.²⁰⁸ Government should consult with local authorities to ensure the design of the new levy is compatible with helping to address local communities' concerns over flooding, while being aware that these other barriers may also need to be tackled.

Recommendation twenty one: The Government should affirm that sewerage companies have a responsibility to ensure surface water sewer networks are not overwhelmed by increasingly heavy rainfall events as the climate changes, whether that is via Drainage and Wastewater Management Plans (DWMP) or other means.

Local authorities are usually viewed as being mainly responsible for surface water flooding, but of course sewer capacity has a direct bearing on how quickly surface water can be conveyed away. Sewerage companies have a duty in law to provide a system of public sewers to ensure the area they serve is 'effectually drained'.²⁰⁹ Customers pay for rainwater removal from their own properties and for highway drainage through their bills.²¹⁰

Given this, it is not clear why ensuring sewerage companies are doing enough to prevent surface water flooding through adequate sewer capacity is not more widely viewed as part of Ofwat's role.²¹¹ The Government is drawing up a new Strategic Policy Statement for Ofwat. The recent draft highlights the need for sewerage companies to reduce storm overflows and ensure their network capacity is robust to population growth and

208. Karen Potter and Tudor Vilcan, "Managing urban flood resilience through the English planning system: insights from the 'SuDS-face'", *Philosophical Transactions of the Royal Society A* 378: 20190206 (2020).

209. Gov UK, "Water Industry Act 1991", <https://www.legislation.gov.uk/ukpga/1991/56/section/94> (2021); David Jenkins, "Report of a review of the arrangements for determining responsibility for surface water and drainage assets", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf (2020).

210. Ofwat, "Your water bill", <https://www.ofwat.gov.uk/households/your-water-bill/unmetered/> (2021).

211. Ofwat's current performance commitments for water and sewerage companies includes metrics on internal sewer flooding, risk of sewer flooding in a storm and pollution incidents, but no explicit metrics on sewer capacity for managing surface water flood risk. Defra's Surface Water Management Action Plan states additional performance measures may be required and included in future Price Reviews.

climate change.²¹² However, as mentioned in Chapter Four, the framework currently proposed to assess future sewer capacity only applies to foul and combined sewers, not surface water sewers.

While the industry and Defra are of course aware of this, it nevertheless brings the risk the issue will slip between the gaps, with so much political attention focussed on combined sewer overflows. Government should set an expectation that future capacity requirements for surface water drainage assets are addressed by sewerage companies, either via methodologies linked to Drainage and Wastewater Management Plans or other means, and engage with them to overcome any barriers to achieving this. It should also direct Ofwat to champion the interests of householders experiencing surface water flooding when this is partly due to lack of sewer capacity.

Recommendation twenty two: Factor the length of roads a local authority is responsible for maintaining into the funding central government allocates to local authorities for flood risk management.

The Highways Act 1980 places a duty on unitary or county councils to ensure that highways they maintain are not dangerous to the traffic that uses it.²¹³ Defra recently told the House of Commons Public Accounts Committee that it will work with LUHC to review whether the money intended for flood risk management which local authorities receive from central government could better reflect local flood risk.²¹⁴ While technically local authorities' responsibilities as flood authorities and highways authorities are distinct, the importance of road drainage in flood risk management should be recognised and not siloed.

212. Department for Environment, Food and Rural Affairs, "The government's strategic priorities for Ofwat: Draft for consultation", https://consult.defra.gov.uk/water-services/government-new-sps-consultation/supporting_documents/newstrategicpolicystatementofwatdraftforconsultation.pdf (2021).

213. David Jenkins, "Report of a review of the arrangements for determining responsibility for surface water and drainage assets", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf (2020).

214. Public Accounts Committee, "Managing flood risk", <https://publications.parliament.uk/pa/cm5801/cmselect/cmpubacc/931/93106.htm> (2021).

Accordingly, the most appropriate way to ensure local authorities have sufficient funds for drain clearing and maintenance should be examined.

In practical terms, this could mean factoring road length data, which the government already collects, into funding allocation decisions.²¹⁵ This data is already used by the Department for Transport (DfT) to calculate its local highways maintenance funding, but this money is only for capital expenditures.²¹⁶ Flooding can also damage roads, including by causing potholes, which much DfT funding is intended to address.²¹⁷ It's possible that allocating money to prevent surface water flooding of roads through better drainage would reduce the number of potholes²¹⁸ and generate cost savings.

Recommendation twenty three: Defra or LUHC should investigate the funding and other barriers which local authorities face in improving their drain clearing and maintenance programmes, as well as how many local authorities actively prioritise high risk areas in their drain clearing schedules, and encourage any that don't.

Respondents to the Jenkins Review described a deterioration in road gully clearing and maintenance over recent years.²¹⁹ Government should survey local authorities to establish the facts and whether there are any other barriers preventing them from undertaking this activity more frequently.

Some local authorities explicitly prioritise locations with a history

215. Department for Transport, "Road length statistics", <https://www.gov.uk/government/statistical-data-sets/road-length-statistics-rdl> (2021).

216. Transport Committee, "Local roads funding and maintenance: filling the gap", <https://publications.parliament.uk/pa/cm201719/cmselect/cmtrans/1486/report-files/148605.htm> (2019).

217. Daily Telegraph, "Pothole-related breakdowns increase after roads were damaged by winter flooding", <https://www.telegraph.co.uk/news/2020/04/30/pothole-related-breakdowns-increase-roads-damaged-winter-flooding/> (2020); Department for Transport, "Highways maintenance funding formula allocations, 2021 to 2022", <https://www.gov.uk/government/publications/highways-maintenance-funding-allocations/highways-maintenance-funding-formula-allocations-2021-to-2022> (2021).

218. Department for Transport, "Prevention and a better cure: potholes review", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/3995/pothole-review.pdf (2012).

219. David Jenkins, "Report of a review of the arrangements for determining responsibility for surface water and drainage assets", https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911812/surface-water-drainage-review.pdf (2020).

of flooding, and it could be useful to understand how widespread this practise is. It's possible greater use of optimised schedules for clearing drains and gullies could help. For example, if local authorities undertake to routinely clear the gullies on a particular class of road twice a year, they could focus this effort more seasonally in anticipation of winter storms and summer flash flooding. Key access routes for the emergency services and critical infrastructure operators could also possibly be identified and prioritised, as well as obvious low points, such as beneath railway bridges.

Recommendation twenty four: Appoint and commission a new official advisory board to develop recommendations on the most immediate and effective steps central government and local authorities could take to alleviate the UK's growing urban flash flooding problem in existing developed areas.

Universal, good-quality sustainable urban drainage systems (SuDS) in new developments would be a big step forward, but would not address the large swathes of concrete and tarmac surfaces which already exist in our towns and cities. Sewer capacity upgrades can be expensive, disruptive and take years to deliver results.

The work of the government's Storm Overflows Taskforce will likely have some relevance to flood risk management, but is particularly focussed on preventing water pollution from combined sewer overflows²²⁰.

Government should seek expert advice explicitly focussed on the extent to which urban flash flooding could be alleviated in existing developed areas in the next 5-10 years, for example, through greater use of retrofit SuDS, water companies programmes to boost take-up of property-level SuDS, encouraging property-owners not to lay impermeable surfaces, and so on, seeking clear, actionable recommendations on how to advance this agenda.

220. Gov UK, "Storm overflows taskforce", <https://www.gov.uk/government/groups/storm-overflows-taskforce> (2021).

Annex: UK Flood Impact Map guide

This report is accompanied by an online map where you can explore the flooding impacts described in more detail, as well as finding links to relevant newspaper articles. The map can be found at: https://www.climate-node.org/maps/UK_flood_map.html

Please note the following when using the online map:

- As mentioned in Chapter Two, the online map provides information on flood impacts since 2007 without consideration of whether flood events were made more likely or severe by climate change, which is well beyond the scope of this report. Many of the places marked obviously have a history of flooding. Inclusion on the map simply implies there is information about flooding relating to that place.
- Most pop-ups on the map provide brief, formulaic summaries of what has happened in each location, but it is recommended users look at the linked newspaper articles for full information.
- These summaries result from analysing a large number of newspaper articles at high speed, and there will be occasional inaccuracies. In addition, the information the summaries contain is only as accurate as the information in the newspaper articles.
- The timeframe of impacts presented is 2007 to 2021. When a pop-up says “this place has experienced flooding”, it means between 2007 and 2021. A small number of links are retained about earlier flood events.

- Pop-ups give information about the place mentioned in the header, which may be a whole city, not just about the precise coordinates of the marker.
- Judgements have been made about which information is significant enough to present on the map and which isn't. Information about routine flood warnings, minor, isolated patches of surface water flooding, and rivers moderately overtopping their banks with no impact, and so on, are generally not presented.
- It has been possible to analyse only a sample of newspaper stories about flooding in the UK, and impossible to do justice to every affected community's story. The author apologises to any user who feels their community's story is not presented.
- Summaries may refer to flood defences which were announced many years ago and which have subsequently been built, but this will not be mentioned if the information is not contained in any of the newspaper articles examined.
- Some places are referred to in a photo essay rather than the main text of a newspaper article, and users may need to click through photos to find the relevant information about the place.

Flooding is one of the most serious climate-related risks that the UK faces. A clear understanding of how it is affecting or could affect specific key public services, critical infrastructure and key businesses is fundamental to improving national resilience.

Using a unique methodology based on artificial intelligence, this report assesses the impacts of flooding and related hazards in the UK since 2007. It puts forward a range of recommendations to bolster the UK's resilience towards flooding in the decades ahead.

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