MarshMcLennan

Sunk costs: The socioeconomic impacts of flooding

Rethinking Flood Series, Report 1

Marsh GuyCarpenter Mercer OliverWyman

Contents

KEY TAKEAWAYS

1

Flood risk is underestimated and increasing

Climate change means flood events are on the rise. Population growth, economic development, and urbanization are situating more people and more assets in areas that are at greater risk of flooding. Yet despite being one of the most common and destructive natural hazards, flood risk is systematically underestimated. This contributes to inadequate insurance, underinvestment in flood resilience, and poor policy decisions, resulting in avoidable costs and suffering.

2

The true costs of flooding are greater than we realize

Increasing exposure and more floods means economic damages are increasing rapidly, of which only a small proportion — 12 percent worldwide since 1980 — are insured. The costs of business interruption often approach or exceed physical damages, and global supply chains expose business activities to floods thousands of miles away. Floods also exact a significant toll on mental health, the true cost of which may amount to billions of dollars each year.

3

Flooding deepens economic and social inequalities

Flooding is a social justice issue, disproportionately affecting those at the lowest rungs of the socioeconomic ladder. More marginalized groups, typically with lower incomes and lower levels of economic security, are often more vulnerable to flooding *and* more exposed to flooding.

4

Closing the flood protection gap should be a policy priority

Across the world, climate change threatens a vicious cycle of more frequent flooding and deepening inequality. Increasing insurance coverage among vulnerable communities can break this sequence, enabling people to recover faster so that the last flood does not leave them more vulnerable to the next. More broadly, economies with high rates of insurance penetration tend to be more resilient and enjoy more predicable growth rates.

5

Governments should take a strategic approach to flood resilience

Building national flood resilience must incorporate mutually reinforcing elements such as investment in flood protection and resilience, enhanced access to flood risk data, and smarter land-use planning. In countries with large unprotected populations, narrowing the flood protection gap will be critical. Governments can undertake a range of strategic approaches, from targeting vulnerable groups with community-based flood insurance schemes, to national-level public-private partnerships and public flood insurance programs. Care should be taken to ensure these are administered efficiently, are fiscally sustainable, and do not create perverse incentives or crowd out private insurance.

Global flood risk in numbers

2.2 billion
people exposed to flood[1]

587 million
people living in poverty face high flood risk[2]

of those exposed to flood risk live in low- and middle-income countries[3]

5 in 6
US homeowners do not have flood insurance[4]

Since 1980[5,6]

4,588
flood disasters
across 172 countries

>250,000
people have died
as the result of floods

↗ 181% increase
in average annual reported flood events

↗ 275% increase
in average annual economic losses associated with flood events

>$1 trillion
in damages, accounting for 40% of natural catastrophe losses

only 12%
of losses were insured

In 2020[7]

Costliest event
$21.8 billion
Summer floods in China

Deadliest event
1,922 killed
Floods in India

1. For a 1-in-100 year return period. Rentschler, J., & Salhab, M. (2020). *People in Harm's Way: Flood Exposure and Poverty in 189 Countries.* The World Bank
2. Ibid.
3. See note 1. Poverty is understood to be living on less than $5.50 a day.
4. Swiss Re. (2019). *Global Risks, Trends and Closing the Protection Gap.*
5. Ritchie, H. & Rose, M. (2019). *Natural Disasters.* OurWorldInData.org. Data from EM-DAT: OFDA/CRED International Disaster Database, Université catholique de Louvain — Brussels — Belgium. Retrieved March 10, 2021.
6. Munich RE. (n.d). *Risks from floods, storm surges and flash floods: Underestimated natural hazards.* Retrieved March 10, 2021.
7. United Nations Office for Disaster Risk Reduction (UNDDR) & Centre for Research on the Epidemiology of Disasters (CRED). (2021). *2020: The Non-Covid year in disasters: Global trends and perspectives.*

Introduction

Flooding is the most pervasive natural disaster in the world. Since 1980, there have been 4,588 flood disasters across 172 countries; more than 250,000 people have been killed, and damages have exceeded $1 trillion, accounting for 40 percent of natural catastrophe losses during the period.[8, 9, 10] It is also the most insidious of disasters, occurring in the background and rarely receiving the level of attention commensurate with the devastation it wreaks. The year 2020 will be remembered for record-breaking hurricane and wildfire seasons in the US, but flooding across Asia killed more than 3,800 people and caused $67 billion in damages, of which only $3 billion was insured.[11, 12]

Flood presents something of a paradox: despite it being one of the most common and destructive natural hazards, the risk it poses is systematically underestimated. Societal discounting of flood risk contributes to underinvestment in flood protection and inadequate purchasing of insurance — only 12 percent of the $1 trillion in flood damages since 1980 was insured.[13]

Nor are governments exempt from responsibility. Planning regulations that fail to discourage construction on floodplains, low levels of investment in flood resilience, policies that undermine private insurance markets, and out of date or inaccessible flood risk data are only a few of the common public-sector failings that increase exposure and vulnerability to floods.

Climate change and the concentrating of population and economic activity in flood-prone areas are increasing flood risk. This has implications for prosperity and economic security as well as societal wellbeing because flooding, typically, affects the poorest and most marginalized populations more deeply. It is incumbent on governments to build resilience to flood risk. One of the most pressing challenges governments face is that of extending affordable insurance protection to the vulnerable.[14]

Marsh McLennan has unparalleled experience helping governments, insurers, and companies better understand, manage, and transfer flood risk. This paper examines the underlying dynamics — and pathology — of flood risk. It is the first in a series, Rethinking Flood, that synthesizes the insights and perspectives our businesses have gained in 150 years of managing flood risk. The first section explores how flood risk is increasing due to changes in underlying drivers. The second examines the costs of flooding including the implications for the most-affected economic sectors, as well as wider societal and environmental costs. And the final section looks at how flooding increases inequality in the wake of the global coronavirus pandemic and growing tensions in countries over widening socioeconomic disparities — and the role of insurance in mitigating inequality.

Subsequent papers will consider the business implications of flood risk, explore the outlook for flood risk, and set out a new agenda for building national resilience to flood risk in a warmer, and wetter, world.

---

8 Ritchie, H. & Rose, M. (2019). *Natural Disasters.* OurWorldInData.org. Data from EM-DAT: OFDA/CRED International Disaster Database, Université catholique de Louvain – Brussels – Belgium. Retrieved March 10, 2021.

9 G.R. Brakenridge. (n.d.). *Global Active Archive of Large Flood Events.* Dartmouth Flood Observatory, University of Colorado, USA. Retrieved March 10, 2021.

10 Munich RE. (n.d). *Risks from floods, storm surges and flash floods: Underestimated natural hazards.* Retrieved March 10, 2021.

11 UNESCAP. (2021, January 15). *2020: The year when crises converged.* Data from EM-DAT: OFDA/CRED International Disaster Database, Université catholique de Louvain — Brussels — Belgium. Retrieved March 10, 2021.

12 Munich RE. (2021, January 7). *Record hurricane season and major wildfires — The natural disaster figures for 2020.* Retrieved March 10, 2021.

13 Munich RE. (n.d). Risks from floods, storm surges and flash floods: Underestimated natural hazards. Retrieved March 10, 2021.

14 For a discussion of the role of government in building national resilience, see Smith-Bingham, R., Wittenberg, A., et al. (2020). *Building national resilience: Aligning mindsets, capabilities, and investment.* Marsh McLennan Advantage.

WHY FLOOD RISK IS INCREASING

Flood risk is increasing due to climate change and growing concentrations of people and assets in flood-prone areas. The problem is compounded by policy failures, underinvestment in flood protection and poor planning decisions.

Flood risk is the product of three factors (see Exhibit 1): Hazard (the potential threat, defined in terms of severity and likelihood), exposure (people and assets in harm's way), and vulnerability (the susceptibility of affected people and assets to harm). At the global level, vulnerability is generally declining as a result of economic development. However, flood risk is still on the rise due to increasing exposure and hazard trends. Below we explore the underlying developments in each of these components.

Hazard

There are three principal types of flood:

- Fluvial (or riverine) flooding occurs when intense rainfall or snowmelt cause an inland water body such as a river or lake to overflow its banks.
- Pluvial flooding occurs when extreme rainfall creates a flood independent of an overflowing body of water, such as flash floods or surface water overwhelming the drainage in an urban area.
- Coastal flooding, caused by storm surges, high tides, or tsunamis.

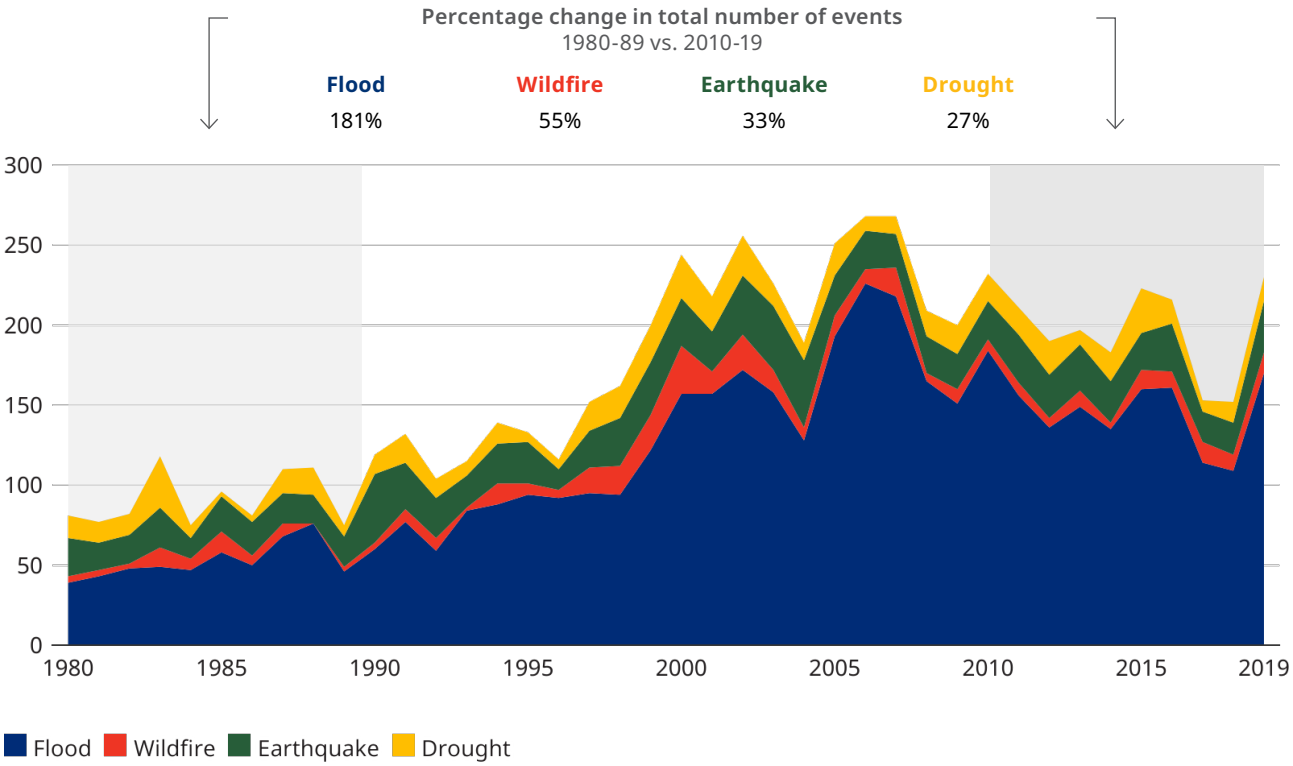
Worldwide, the number of reported flood disasters has been trending upward, with a 181 percent increase in the total number of flooding events in 2010-2019, compared to the 1980-1989 period — notably faster than other natural hazards (see Exhibit 2 on the next page). To a degree, this trend can be explained by increasing exposure of populations and assets to flood hazards (see next sub-section), making it more likely for any given flood to cause a disaster. Improved disaster reporting in recent times may play a role as well. However, none of these fully explain the rise in reported flood disasters, as other natural hazards are increasing at slower rates despite being subject to similar exposure and reporting trends. It's likely that climate change is one of the principal sources for the discrepancy.

Exhibit 1: Components and underlying drivers of flood risk

Examples of underlying drivers	Natural variability Climate change Flood-control infrastructure	Population growth Urbanization Economic growth Land-use planning	Poverty levels Infrastructure resilience Insurance penetration Governance and institutions Access to healthcare and education

Source: Marsh McLennan Advantage

Exhibit 2: Global number of disasters for selected perils



Source: EM-DAT, Our World in Data

The influence of climate change

Across the globe, climate change is increasing flood risk through two channels:

- Rising numbers of extreme rainfall events, caused by a warmer atmosphere holding more water vapor,[15] and changes in regional precipitation patterns.[16]
- Sea-level rise caused by thermal expansion of the oceans and the melting of polar ice and glaciers, contributing to greater coastal flooding; global mean sea level has risen about 21-24 centimeters since the beginning of the Industrial Revolution, and the rate of increase is accelerating.[17]

These trends are affecting different parts of the world to a greater or lesser degree. As a result of groundwater overextraction and urban sprawl, many coastal and delta cities around the world are sinking faster than sea levels are rising — up to 10 times faster in some cases.[18] For those coastal cities where the land itself is sinking, the effective rise in sea level is magnified.

Globally, many regions are seeing an increase in the frequency of heavy precipitation events, with the strongest trends observed in Europe and North America. River flood discharges have increased

15 Allan, R. P. & Soden, B. J. (2008). *Atmospheric Warming and the Amplification of Precipitation Extremes.* Science, 321(5895) 1481-1484.

16 Davenport, F. V., Burke, M., & Diffenbaugh, N. S. (2021). *Contribution of historical precipitation change to US flood damages*. Proceedings of the National Academy of Sciences, 118(4), e2017524118.

17 Lindsey, R. (2020, January 25). *Climate Change: Global Sea Level.* Climate.gov. Retrieved March 10, 2021.

18 Erkens, G., et al. (2015). *Sinking coastal cities.* Proc. IAHS, 372, 189-198.

significantly in northwest Europe, where many areas have seen the return period of what used to be 1-in-100 year floods decrease to 50 or 25 years;[19] in the UK, extended periods of extreme winter rainfall are now seven times more likely.[20] In the US, the average share of land experiencing extreme one-day precipitation more than doubled in the four decades from 1975 to 2015,[21] and rising sea levels indicate high-tide flooding is now twice as likely as it was in 2000, with some cities experiencing greater than fivefold increases.[22]

For areas exposed to tropical cyclones, intensifying precipitation and a rise in sea level are combining to produce hurricanes with heavier rainfall and more damaging storm surges. For example, climate change increased the strength and rainfall of Typhoon Hagibis in 2019 and is estimated to be responsible for three-quarters of Hurricane Harvey's rainfall-related flood damage in 2017.[23, 24]

Steps can be taken to limit the damage from flooding. Flood-control infrastructure such as levees, floodwalls, and dams can be built to reduce hazards. Green and blue infrastructure such as drainage channels, wetlands, urban forests, and green roofs can also mitigate flood risk. These investments have attractive benefit-cost ratios. For example, an analysis by the World Resources Institute (WRI) estimates that for every dollar spent by India today strengthening its dikes, the country could benefit in $248 in avoided damages by the year 2050.[25] In the UK, the government's hurdle cost-benefit ratio for flood defences is 1:8, and a recent assessment estimated that inland flood defenses prevent more than 60 percent of fluvial flood damages, saving £1.1 billion annually.[26] In the US, FEMA estimates that flood hazard mitigation returns $7 for every dollar invested.[27] Conservation and restoration of natural ecosystems can also provide a cost-effective means to reduce flood losses while also contributing to biodiversity. In the US, coastal wetlands prevented more than $600 million in property losses during Superstorm Sandy,[28] while coral reefs are estimated to reduce the economic impact of coastal flooding by $1.8 billion every year.[29] Yet despite such high returns on investment, governments tend to spend significantly more on disaster response than disaster prevention.[30]

---

19 Blöschl, G., et al. (2019). *Changing climate both increases and decreases European river floods.* Nature 573, 108-111.

20 Christidis, N. & Scott, P. (2015). Extreme Rainfall in the United Kingdom During winter 2013/14: The Role of Atmospheric Circulation and Climate Change. Bulletin of the American Meteorological Society. Vol. 96, No. 12.

21 Ritchie, H. & Rose, M. (2019). *Natural Disasters.* OurWorldInData.org. Data from NOAA (National Oceanic and Atmospheric Administration) via the United States Environmental Protection Agency (EPA). Retrieved March 10, 2021.

22 National Oceanic and Atmospheric Administration (NOAA). (2020). *2019 State of U.S High Tide Flooding with a 2020 Outlook.* Technical Report NOS CO-OPS 092.

23 Kawase, H., et al. (2021). Enhancement of extremely heavy precipitation induced by Typhoon Hagibis (2019) due to historical warming. SOLA, 17A, 7-13, DOI: 10.2151/sola.17A-002.

24 Frame, D.J., et al. (2020). *The economic costs of Hurricane Harvey attributable to climate change. Climatic Change 160, 271-281.*

25 Kuznma, S. & Luo, T. (2020, April 23). *The Number of People Affected by Floods Will Double Between 2010 and 2030.* World Resources Institute. Based on investments to increase protection a from 1-in-11 year level to 1-in-25 years.

26 Association of British Insurers (2019). *Inland flood defences save the UK £1.1 billion a year ABI.* Retrieved April 16, 2021.

27 Federal Emergency Management Agency (2018). *Factsheet — Natural Hazard Mitigation Saves Interim Report.*

28 Narayan, S., et al. (2016). *Coastal Wetlands and Flood Damage Reduction: Using Risk Industry-based Models to Assess Natural Defenses in the Northeastern USA.* Lloyd's Tercentenary Research Foundation, London.

29 Storlazzi, C.D., et al. (2019). *Rigorously valuing the role of U.S coral reefs in coastal hazard risk reduction.* U.S Geological Survey Open-File Report 2019-1027, 42 p.

30 Organisation for Economic Co-operation and Development (OECD). (2016). *Financial Management of Flood Risk*.

Exposure

Exposure is increasing around the world due to demographic trends and economic development:

- Population growth means greater human exposure to floods. Since 2000 the population of the world has grown by 1.65 billion people to 7.7 billion, 29 percent of which currently live in areas exposed to 1-in-100 year flood events.[31] By 2050, global population is expected to have reached around 9.7 billion people.[32]
- Urbanization increases the concentration of people and assets in cities, which are often located on coasts or in proximity of other major bodies of water for economic reasons. Urban areas are home to more than half of the world's population[33] and are responsible for more than 80 percent of global GDP.[34] In Africa, there are 19 coastal cities with populations of more than 1 million people,[35] and 70 percent of Europe's largest cities are vulnerable to sea level rise.[36]
- Globally, the growth of coastal cities and megacities is creating concentrations of flood exposure that we may be underestimating. Exposure calculations rely on satellite data that tends to overstate elevation in built-up areas, measuring elevation at the rooftop rather than at ground level. For example, in low-lying densely populated areas of the US, such as Boston, Miami, and New York, this overestimation is almost five meters.[37]

Flood risk is further compounded by the fact that population, urbanization, and economic growth are fastest in developing countries where vulnerability is higher.

Policy failure and flood exposure

Increasing exposure is not simply an inevitable outcome of economic growth and rising population, it is also a result of bad decisions and policy failures, most notably perverse incentives that encourage development on floodplains and the absence of effective land-use planning to militate against it.

Floodplains are often targeted for development because they provide relatively cheap, flat land, and people will often pay a premium for homes close to water. Governments can limit or prevent the concentration of people and assets in flood prone areas through land-use planning, but in the face of pressures for affordable housing and economic development, national governments and local authorities often allow construction to proceed. For example, in the UK, the number of properties in floodplains is expected to almost double to 4.6 million over the next 50 years.[38] In the US, populations are growing faster in flood prone areas than outside them.[39]

---

31 For a 1-in-100 year return period. Rentschler, J., & Salhab, M. (2020). *People in Harm's Way: Flood Exposure and Poverty in 189 Countries.* The World Bank.

32 United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).* New York: United Nations.

33 United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420).* New York: United Nations.

34 The World Bank. (n.d.). *Urban Development.* Retrieved March 10, 2021.

35 United Nations Human Settlements Programme (UN-Habitat). (2014). *State of African Cities 2014: Re-imagining sustainable urban transitions.*

36 The World Bank. (2010). *Cities and Climate Change: An Urgent Agenda.* Urban development Series; Knowledge paper no. 10. Washington, DC.

37 Climate Central. (2019, October 29). *Report: Flooded Future: Global vulnerability to sea level rise worse than previously understood.* Retrieved March 10, 2021.

38 UK Environment Agency. (2019, May 8). *Long-term investment scenarios (LTIS) 2019.* Retrieved March 10, 2021.

39 Maciag, M. (2018). *Building Homes in Flood Zones: Why Does This Bad Idea Keep Happening?* Governing. Retrieved March 10, 2021.

Increasing exposure is not simply an inevitable outcome of economic growth and rising population, it is also a result of bad decisions and policy failures.

Poor planning decisions are also more likely where there is a lack of current and easily accessible flood maps and risk data.

The problem is often greater in developing countries, where flood zoning is not in place and urban expansion is occurring rapidly and without oversight. For example, despite numerous disasters, construction on flood zones in India is widespread and attempts to implement zoning have largely failed.[40]

In addition to poor planning and inadequate flood risk information, other, often well-intentioned, policies have the unintended consequence of encouraging development on floodplains. For example:

- Government disaster relief and compensation schemes mean communities and developers avoid the true costs of habitation on floodplains.
- Subsidized flood insurance insulates communities and developers from the cost of risk.
- Construction of flood protection structures lead to perceptions of absolute protection and inadvertently encourage development on floodplains.

Vulnerability

Income is a determinant of vulnerability. Poorer nations tend to have worse infrastructure, weaker governance, lesser fiscal resources to spend on resilience and recovery, and lower levels of access to social protection, education, and healthcare, all of which contribute to less favorable outcomes in a flood event. At the household level, lower-income families typically have less resilient homes, fewer financial resources to draw upon after a flood, and lower levels of flood insurance. Additional social and demographic factors can also determine vulnerability, including age, race, gender, health status, educational status, and employment status.[41]

Economic development in low- and middle-income countries is reducing vulnerability. Global fatalities and economic losses as a share of exposed population and exposed GDP are declining for fluvial, pluvial, and coastal floods, with the most dramatic improvements taking place in developing countries.[42]

---

40 Chandrashekhar, V. (2019, July 31). *Give rivers more space: To avoid frequent flooding havoc, India must regulate construction on floodplains.* The Times of India. Retrieved March 10, 2021.

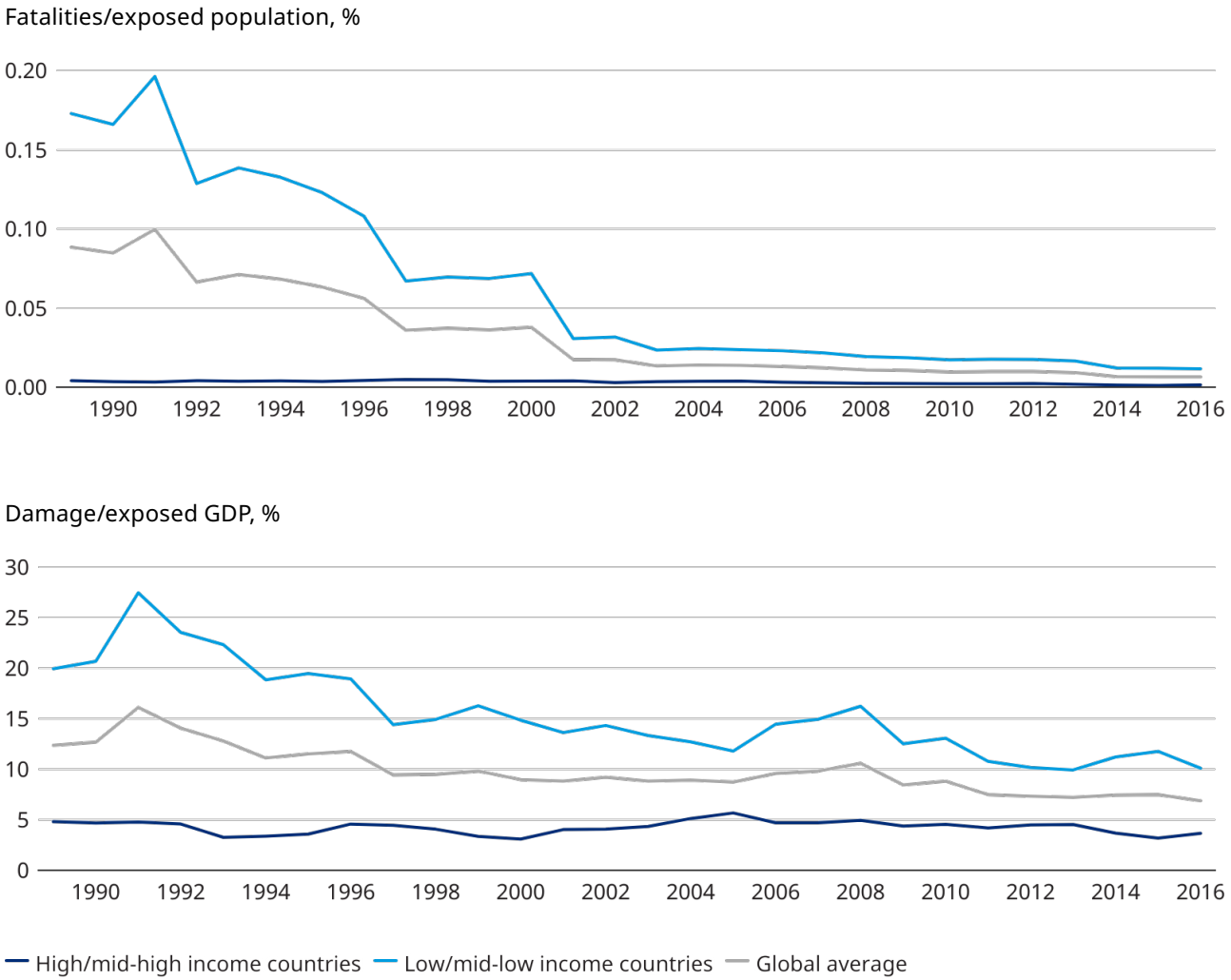
41 Rufat, S., et al. (2015). *Social vulnerability to floods: Review of case studies and implications for measurement.* International Journal of Disaster Risk Reduction. Volume 14, Part 4, Pages 470-486.

42 Formetta, G. & Feyen, L. (2019). *Empirical evidence of declining global vulnerability to climate-related hazards.* Global Environmental Change, Volume 57. ISSN 0959-3780.

However, progress has been uneven, and regions of extreme vulnerability remain. And despite the development gains of recent decades, a significant vulnerability gap between developed and developing countries still remains (see Exhibit 3).[43]

Even in wealthy countries, economic and social inequality creates pockets of severe vulnerability. For example, in England, flood risk is greatest in socioeconomically disadvantaged areas, with the greatest disparities occurring in rural and coastal regions,[44] in the US, rural communities, racial minorities, and mobile-home occupants comprise some of the most at-risk groups.[45]

Exhibit 3: Fatalities as percentage of exposed population and damage as percentage of exposed GDP from coastal flooding



Note: Graphs represent 10-year moving averages of the median values of fatalities as percentage of exposed population and damage as percentage of exposed GDP caused by coastal flooding. Exposed population and GDP estimated using a 50 km radius around the centroid of each event. Similar downward trends are observed for other types of flooding.

Source: Formetta and Feyen (2019)

43 Ibid.

44 UK Environment Agency. (2021). *Evidence: Social deprivation and the likelihood of flooding.*

45 Tate, E., Rahman, M.A., Emrich, C.T. et al. (2021). *Flood exposure and social vulnerability in the United States*. Nat Hazards 106, 435-457.

THE COSTS OF FLOODING

Increasing flood risk threatens national prosperity and societal wellbeing. The cost of flood damages is rising rapidly but the full impact of flooding is significantly greater than material damage alone: it includes losses from business interruption, environmental degradation, and a significant toll on mental health.

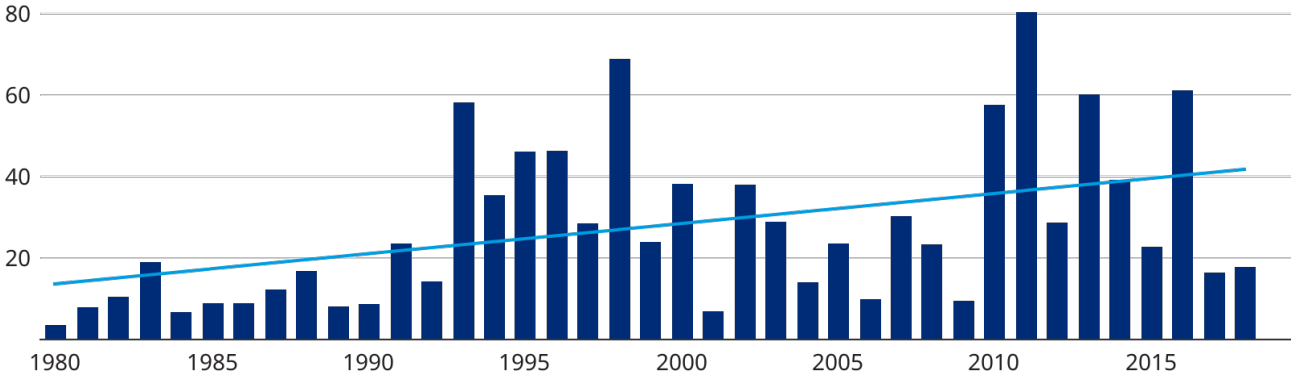
Increasing flood risk is a threat to prosperity, economic security, and societal well-being. Economic losses from damage to assets and business interruption are rising with hazard and exposure trends. Floods are also a major cause of environmental pollution and exact a significant toll on mental health, the scale of which is only starting to become apparent.

Economic losses

Since 1980, inflation-adjusted global economic losses from flooding have averaged around $26 billion a year, but this number masks a rising trend, as economic development and urbanization have compounded exposure.[46] Measured in constant dollars, average annual economic losses recorded in the EM-DAT database are now more than four times what they were in the 1980s (see Exhibit 4).[47]

Floods do not simply damage assets, they also suspend economic activity. Floods may shut down facilities, cut off power transmission, or interrupt water supplies. Supply chains or sales and distribution may be disrupted; staff may be prevented from getting to work. The World Bank has conservatively estimated the value of economic activity exposed to significant flood risk at $5.3 trillion globally.[48] Losses from business interruption can approach, or even exceed, those from damage to property and assets, as data from a number of recent large-scale flood events reveals (see Exhibit 5 on next page).[49]

Exhibit 4: Global damage costs from flood events
$Billion



Note: Data has been adjusted for inflation using $US CPI values. Trend line in light blue.

Source: EM-DAT, Our World in Data

46 Ritchie, H. & Rose, M. (2019). *Natural Disasters.* OurWorldInData.org. Data from EM-DAT: OFDA/CRED International Disaster Database, Université catholique de Louvain — Brussels — Belgium. Retrieved March 10, 2021.

47 Ibid.

48 This is likely to be an underestimate as it excludes China and other countries. See World Bank Group. (2020). *People in Harm's Way: Flood Exposure and Poverty in 189 Countries.* The World Bank.

49 Vilier, J., et al. (2014). *Assessment of the losses due to business interruption caused by large-scale floods.* Safety, Reliability and Risk Analysis: Beyond the Horizon — Steenbergen et al. (Eds). Taylor & Francis Group, London. 978-1-138-00123-7

Exhibit 5: Losses[1] from material damage and business interruption in large-scale flood events

Event	Material damage $Billion	Business interruption $Billion	Percentage of total GDP[2]
Japan 2011 tsunami	205	97	5.3%
Thailand 2011	21	26	13.4%
Superstorm Sandy 2012	70	26	5.1%
Hurricane Katrina 2005	30	9	20.0%

1. First order economic losses.

2. GDP in the year of the flood; based on the states of New York and New Jersey for Sandy, and the state of Louisiana for Katrina.

Source: Vilier at al (2014) and Marsh McLennan Advantage analysis

In the most serious events, suspension of business activity can lead to widespread bankruptcies among small and medium-size enterprises with low levels of working capital and no business interruption coverage. In the US, between 40 percent and 60 percent of small businesses shut down by disasters remain closed indefinitely; in the wake of catastrophic flooding caused by Hurricane Harvey, 13.5 percent of businesses had vanished from the disaster area by the following quarter.[50, 51] This has obvious knock-on consequences for employment, and Houston lost almost 25,000 jobs in the immediate aftermath.[52]

Below we outline how flood risk affects different sectors and some of the implications for economic and resource security.

Manufacturing

Recent events have revealed the extent to which complex global supply chains are vulnerable to flooding at key chokepoints such as production sites, storage facilities, or ports. The 2011 Thai floods dislocated automotive, computer, and electronics supply chains, halting manufacturing at assembly sites thousands of miles away and generating business interruption losses that exceeded material damages (see Exhibit 5). As a result, global industrial output shrank 2.5 percent.[53] Meanwhile, Thai exports fell by almost $8 billion and government tax revenues by 3.7 percent.[54] In 2015, floods in Chennai disrupted supply chains and forced the shutdown of automotive plants, affecting up to 15 percent of Indian car production,[55] and in 2018, catastrophic flooding in the west of Japan forced the suspension of production at automotive plants.[56] More recently, the 2020 floods in China disrupted international supply chains of critical personal protective equipment during the coronavirus pandemic.[57]

50 Brooks, C. (2021). *From COVID-19 to Hurricane Season: Disaster Preparedness for Small Business.* Business.com. Retrieved March 10, 2021.

51 South Texas Economic Development Center. (2018). *The Economic Aftermath of Harvey.* Retrieved March 10, 2021.

52 Sixel, L.M. (2017, October 20). *Houston sheds 25,000 jobs in wake of Harvey.* Houston Chronicle. Retrieved March 10, 2021.

53 Schanz, K.U. & Wang, S. (2015). *Insuring Flood Risk in Asia's High-Growth Markets.* Geneva Association.

54 World Bank (2012). Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning.

55 Thakkar, K. (2015, December 15). *Chennai floods: Carmakers like Ford and BMW struggle to restart work after screeching halt.* The Economic Times. Retrieved March 10, 2021.

56 Williams, M. (2018, July 10). *Japanese floods disrupt automotive supply chain.* Automotive Logistics.

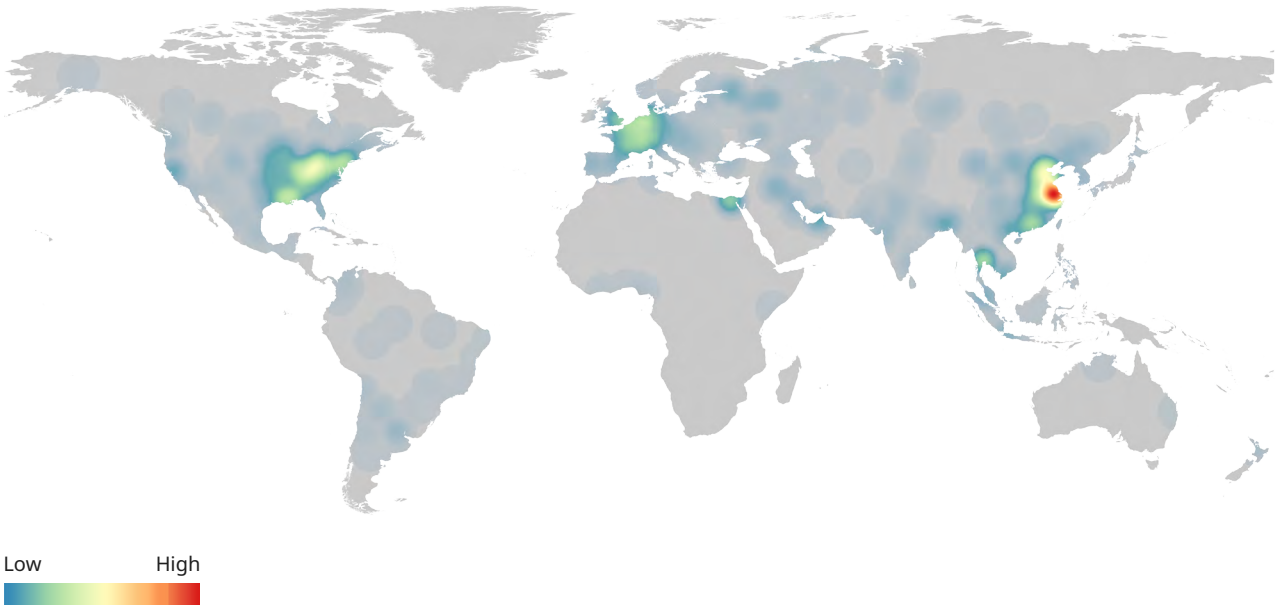
57 Stanway, D. (2020, July 17). *Red alerts in China as floods maroon equipment to fight coronavirus.* Reuters. Retrieved April 22, 2021.

Energy and power

Energy and power infrastructure is often sited near water for good reasons: Thermoelectric generators such as nuclear, coal- and gas-fired plants rely on water for cooling, while logistical considerations dictate that hydrocarbon storage and refining assets are often located along coasts. As a consequence, energy and power infrastructure is disproportionately exposed to flood risk (see Exhibit 6). When the US Nuclear Regulatory Commission directed operators of the country's nuclear fleet to undertake flood risk assessments in the wake of the 2011 Fukushima crisis, it found 54 plants (out of 58) faced flood risk that exceeded their design.[58]

Floods at coal or gas plants do not have the same catastrophic potential as they do at nuclear plants, but they can still result in outages. For example, North Carolina flooding after Hurricane Florence forced the shutdown of a major gas-fired power plant in 2018.[59] Hurricane Harvey forced the shutdown of some Texan coal plants — not because the units were flooded, but because their coal piles were.

Exhibit 6: Density of power plants located in flood zones



Note: Density has been weighted by installed electrical capacity.

Source: World Resources Institute, European Commission, GFDDR, Marsh McLennan Advantage analysis

58 Flavelle, C. & Lin, J. (2019, April 18). *U.S Nuclear Power Plants Weren't Built for Climate Change.* Bloomberg. Retrieved March 10, 2021.

59 Maher, K. & Ailworth, E. (2018). *Flood Shuts Down N.C. Power Plant, Sweeps Waste Into River.* The Wall Street Journal. Retrieved March 10, 2021.

Food and agriculture

Flooding has an enormous impact on agriculture. The UN Food and Agriculture Organization estimates that floods are the source of almost two-thirds of all damages and losses of crops.[60] The implications for developing countries, where agriculture provides up to 40 percent of GDP and employment, can be particularly severe. A review of UN food security monitoring documents indicates that flooding adversely affected 35 developing countries' food security in 2020.[61]

Nor do floods spare developed countries' agriculture. Spring flooding in 2019 prevented planting on almost 20 million acres of US farmland, while in the UK only 40 percent of the spring wheat crop was planted due to flooding. In January 2019, extensive flooding in Argentina impacted over 2 million hectares of soybeans and other crops. This was the country's second most expensive flood on record and caused $2.2 billion in economic losses,[62] amounting to 0.5 percent of the country's GDP.

Transportation

Floods regularly disrupt critical transportation infrastructure such as roads, railways, waterways, ports, and airports, interrupting economic activity and creating risk cascades that ripple through supply chains and across markets.

Flooding of coastal roads in the US is estimated to cause 100 million vehicle hours in delays each year.[63] The inundation of roads in Brazil periodically prevents exports of soybeans from the world's largest exporter. Flooding of inland waterways in another global breadbasket — the US — sporadically hinders exports of grain. Most recently, flooding of the Mississippi in 2019 stranded almost $1 billion of grain destined for overseas markets.[64]

Airports are particularly exposed to flooding as they are often built on floodplains and reclaimed wetlands or close to the sea — usually where the flattest land can be found. Globally, over 1,200 airports are located in a low-elevation coastal zone (LECZ, defined as the contiguous coastal area less than 10 meters above sea level), including many of strategic importance; just 20 from this list handle around 18 percent of global passengers and 25 percent of all air freight. Modelling has identified 269 airports within the global LECZ at risk of coastal flooding, placing 8.5 percent of all flight routes at risk of disruption.[65]

Flooding adversely affected 35 developing countries' food security in 2020.

60 Food and Agriculture Organization of the United Nations (FAO). (2017). *The impact of disasters and crises on agriculture and food security.* Based on data for 2006 to 2016. The impact of disasters and crises on agriculture and food security.

61 Food and Agriculture Organization of the United Nations (FAO). (2020). *Crop prospects and food situation: Quarterly Global Report.*

62 Confederación Intercooperativa Agropecuaria Limitada. (2019, January 16). *Crítica situación por inundaciones. Coninagro solicita obras en el campo y ley de seguro multiriesgo.*

63 University of New Hampshire. (2018, March 28). *Research Finds Dramatic Increase in Flooding on Coastal Roads.* Phys.org.; more on this topic can be found at Jacobs, J. M., et al. (2018). *Recent and Future Outlooks for Nuisance Flooding Impacts on Roadways on the US East Coast.* Transportation Research Record: The Journal of the Transportation Research Board. DOI: 10.1177/0361198118756366.

64 United States Coast Guard. (2019). *Impacts of the 2019 Upper Mississippi River Flooding on Barge Movements in the Upper Midwest Region.* Retrieved March 10, 2021.

65 ScienceDaily. (2021, January 21). *Climate change puts hundreds of coastal airports at risk of flooding.* Retrieved March 10, 2021.

Ports — and their dense ecosystems of warehouses, processing plants, and inland transport network connections — are critical junctures for global trade. These chokepoints are exposed to storm surges and sea-level rise. A study of the world's largest port cities estimated they have assets worth around 5 percent of global GDP exposed to 1-in-100 year coastal flooding, with the 10 most exposed ports all located in the US, Netherlands or Japan.[66]

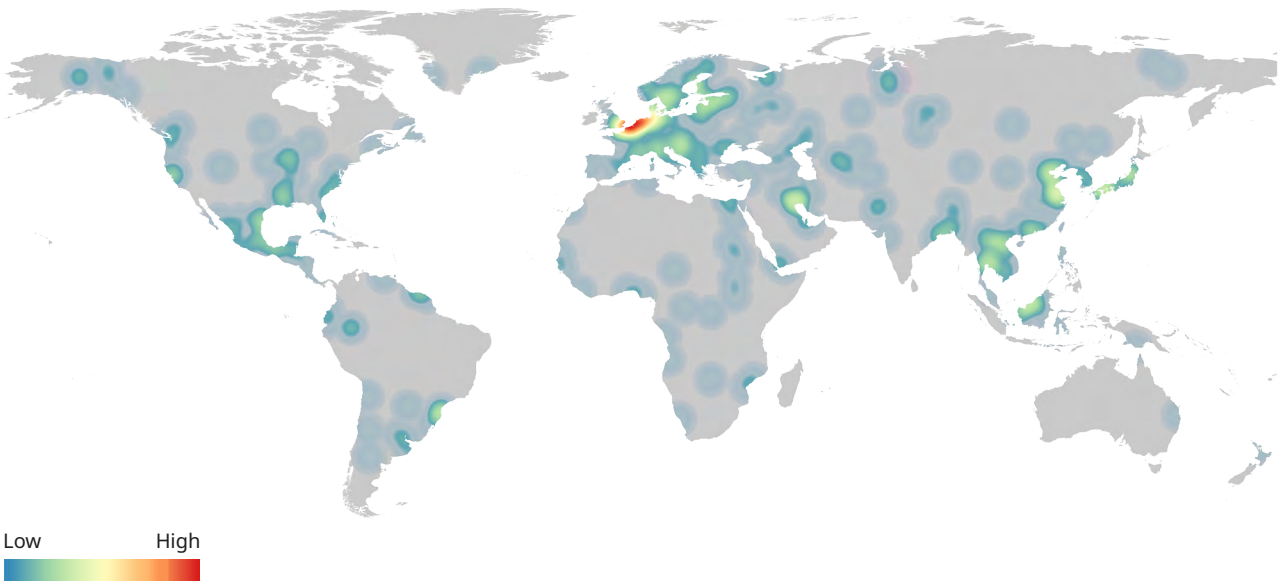
Critical vulnerabilities on rail networks are common where lines pass through cuttings and tunnels that are lower than the surrounding areas or where lines sit on flat, low-lying land. Union Pacific railroad experienced 13-day outages in service in parts of the Midwest during the flood of 2019, interrupting grain transport and necessitating contingency measures to ensure continued coal supplies for power generators.[67]

Geographic information systems (GIS) heat maps reveal the extent to which critical transport hubs (ports and airports) are exposed to flooding around the world (see Exhibit 7).

Tourism and cultural heritage

Floods may disrupt tourism and dissuade potential tourists from future visits. For example, the 2011 floods in Thailand cost an estimated $3 billion in lost tourism revenues.[68] More recently, the flooding of Venice in 2019 led to widespread cancellations, with hotels reporting bookings down by 45 percent and leading to concerns that the city could lose its place on the UNESCO World Heritage List.[69, 70]

Exhibit 7: Density of airports and ports located in flood zones



Source: The World Bank, European Commission, GFDDR, Marsh McLennan Advantage analysis

66 Nicholls, R., et al. (2008). *Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates.* OECD Environment Working Papers, No. 1, OECD Publishing, Paris.

67 Potter, E. (2019, May 19). *Midwest flooding may affect utility coal shipments, stockpiles for months.* S&P Global Market Intelligence. Retrieved March 10, 2021.

68 World Bank and Thai Ministry of Finance. (2012). Rapid Assessment for Resilient Recovery and Reconstruction Planning. World Bank, Bangkok.

69 Agence France-Presse. (2019, December 21). *Venice hotel bookings drop by nearly half following November's historic flood.* The Guardian. Retrieved March 10, 2021.

70 Scholz-Carlson, A. (2019, November 21). *Without better flood protection, Venice risks loss of heritage status.* Reuters. Retrieved March 10, 2021.

Around the world, World Heritage Sites (WHS) are at risk of flooding. A study of low-lying coastal sites in the Mediterranean concluded that 37 of 49 cultural WHS are already at risk of flood, with the risk level set to increase 50 percent over the course of the century.[71]

Real estate and financial risk

Flood risk can have a big impact on property values. An analysis of housing data in the US between 2007 and 2017 revealed that price rises in areas of low flood risk far outpaced the broader market, while average prices in high risk zones declined in value.[72] A detailed analysis of New York real estate data following Superstorm Sandy revealed an 8 percent price discount for properties located in flood zones.[73] Falls in value have knock-on consequences for mortgage lenders, where a high loan-to-value ratio is a sign of increasing default risk. For a typical mortgage with an 80 percent loan-to-value ratio, an 8 percent depreciation as seen in the wake of Sandy represents a 40 percent reduction in equity.

In areas with high property values and high exposure to flood — as is often the case with coastal real estate — these risks add up. Between 2005 and 2017, coastal flooding erased an estimated $5.4 billion in value in homes in Florida and $4.5 billion in the New Jersey residential market. For 18 states along the East Coast and Gulf Coast, the total loss in property values was almost $16 billion.[74]

There may be additional corrections in US property prices, once the Federal Emergency Management Agency (FEMA) introduces more granular and accurate flood-risk ratings, increasing the transparency of risks and premiums in high-risk areas (see page 25).

Unsurprisingly, for financial institutions with property exposure, be it mortgage lenders, insurers, or real estate investors, flood risk is a growing concern. One analysis of 350 listed real estate investment trusts (REITs) found 17 percent of properties in their portfolios exposed to inland flood risk, 6 percent to coastal flooding, and 12 percent to hurricanes or typhoons.[75]

In many parts of the world, such financial risks will increase due to climate change and continued building on floodplains. For example, in the UK, where already 10 percent of banks' mortgage exposure is to properties in flood-risk zones,[76] the number of homes on the floodplain is set to double over the next 50 years. Meanwhile, the frequency and severity of flooding is expected to increase significantly. The implications of flood risk for financial stability have not been lost on the Bank of England, which will require banks and insurers to quantify the impacts of potential flooding scenarios on their balance sheets in its forthcoming climate-stress tests.[77]

---

71 Reimann, L., Vafeidis, A.T., Brown, S. et al. (2018). *Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise.* Nat Commun 9, 4161.

72 Flavelle, C. & McCartney, A. (2018, June 18). *Climate Change May Already Be Hitting the Housing Market.* Bloomberg. Retrieved March 10, 2021

73 Ortega, F. & Taspinar, S. (2017). *Rising Sea Levels and Sinking Property Values: The Effects of Hurricane Sandy on New York's Housing Market.* SSRN.

74 First Street Foundation. (2019). *State by State Analysis: Property Value Loss from Sea Level Rise.*

75 427 & GEOPHY. (2018). *Climate Risk, Real Estate, and the Bottom Line.*

76 The Bank of England. (2019). T*he 2021 biennial exploratory scenario on the financial risks from climate change.* Financial Policy Committee & Prudential Regulation Committee.

77 Ibid.

Environmental and societal costs

Flooding results in considerable unpriced costs for societies and the environment, which we explore below.

Pollution

Floods overrun sewage systems and spread pollutants from damaged buildings and infrastructure. Runoff can contaminate property, food production, soils, and water sources or result in airborne pollution, necessitating decontamination and cleanup efforts and creating potential liabilities for businesses responsible for the pollutants. An analysis of sites listed in the Toxics Release Inventory in the US found 2,500 toxic chemical facilities to be in areas at risk of flooding, including 1,400 in areas of high risk.[78] Flooding caused by Hurricane Harvey led to multiple pollution events. In the week Harvey made landfall, more than 40 sites released dangerous levels of airborne pollutants, while at least 14 toxic waste sites were damaged and nearly 100 spills of hazardous chemicals were reported.[79]

Harvey floodwaters also led to the release of toxic dioxins from the San Jacinto River Waste Pits — a Superfund site, where contamination levels are so high that that the site has been placed on a National Priorities List by the Environmental Protection Agency (EPA). Dioxin pollution nearby was later found to be more than 2,000 times the EPA's acceptable level. Other Superfund sites are exposed to flood risk. A report by the Government Audit Office identified 828 sites at risk of flood, storm surge, or sea-level rise — representing more than half of the total.[80]

Biodiversity

The implications of flooding for biodiversity are complex and context specific. In many ecosystems, floods are part of the natural cycle and play an important role in soil formation, water body replenishment, and providing conditions for breeding. However, in certain areas, climate change may be increasing the frequency of severe flooding faster than species can adapt. Biodiversity hotspots such as river ecosystems and wetlands are particularly vulnerable to these changes.[81]

Fatalities

Causes of death from floods include drowning and trauma from debris during the event, and exposure to waterborne disease in the aftermath. Globally, floods are estimated to have killed over 170,000 people between 1995 and 2019, although the average annual death toll has been falling as vulnerability declines in developing countries (see Exhibit 8 on next page).[82] However, the overwhelming burden of mortality is still borne by the developing world: More than 97 percent of recorded fatalities from floods occur in low- and middle-income countries.[83]

---

78 Tabuchi, H., et al. (2018). *Floods Are Getting Worse, and 2,500 Chemical Sites Lie in the Water's Path.* The New York Times. Retrieved March 10, 2021.

79 Griggs, T., et al. (2017). *More Than 40 Sites Released Hazardous Pollutants Because of Hurricane Harvey.* The New York Times. Retrieved March 10, 2021.

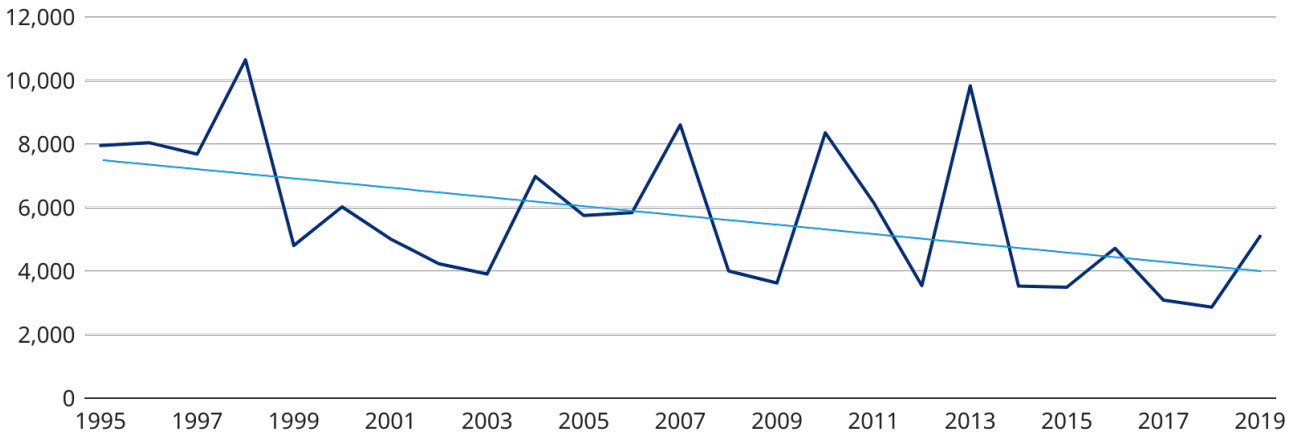
80 The report identifies 828 sites exposed to coastal hazard (flood, storm surge or sea-level rise), flood hazard, coastal and wildfire hazards, and flood and wildfire hazards. United States Government Accountability Office (GAO). 2019. *SUPERFUND: EPA Should Take Additional Actions to Manage Risks from Climate Change.* Report to Congressional Requesters.

81 See, for example:
i) Wheston, P. (2020, April 1). *The losses could be profound: How floods are wreaking havoc on wildlife.* The Guardian. Retrieved April 22, 2021.
ii) European Commission. (2016, February 18). *Science for Environment Policy.* Issue 447. Environment News Alert Service, edited by SCU, The University of the West of England, Bristol.

82 United Nations Office for Disaster Risk Reduction (UNDDR) & Centre for Research on the Epidemiology of Disasters (CRED). (2016). *The Human Cost of Weather Related Disasters, 1995-2015.*

83 United Nations Office for Disaster Risk Reduction (UNDDR) & Centre for Research on the Epidemiology of Disasters (CRED). (2016). *Poverty & Death: Disaster and Mortality 1996-2015.*

Exhibit 8: Global fatalities from flood events



Note: Adjusted for 30,000 deaths associated with landslides in Venezuela in 1999.[1] Trend line in light blue.

1. Intergovernmental Panel on Climate Change. (2007). *IPCC Fourth Assessment Report: Climate Change 2007.*

Source: EM-DAT, Our World in Data

Public health

Floods create both acute and chronic public health problems. Floodwaters can harbor and transmit pathogens, contributing to outbreaks of waterborne diseases such as typhoid, cholera, leptospirosis, and hepatitis A if drinking water facilities are contaminated. Flooding may also lead to increases in vector-borne disease such as dengue, malaria, and West Nile fever.[84]

Flooding can also impose a significant toll on mental health. Floods destroy livelihoods, kill, and wreck homes and ruin possessions, turning lives upside down and disrupting communities. Increases in depression, post-traumatic stress disorder (PTSD), and substance abuse are well documented in the aftermath of floods and can persist for years afterward. An estimated 19 percent of people affected by Hurricane Katrina suffered PTSD.[85] Research in Canada has shown flood victims experience elevated and prolonged levels of stress and increased absenteeism from work.[86] In the UK — where mental ill health is estimated to cost more than £100 billion a year — flood survivors are nine times more likely to suffer long-term mental health problems than the general population.[87]

The unpriced social costs of floods are therefore significant. The average mental health cost of a flooding event in the UK ranges from £1,878 to £4,136 per adult, according to a study,[88] indicating the mental health toll of flooding could be as much as 20 percent of the cost of physical damage to homes and possessions.[89] This finding implies the mental health burden of flooding represents a sizable share of residential damages.

---

84 World Health Organization (WHO). (n.d.). *Flooding and communicable diseases fact sheet.* Retrieved March 10, 2021.

85 DeSalvo, K. B, et al. (2007). *Symptoms of posttraumatic stress disorder in a New Orleans workforce following Hurricane Katrina.* Journal of urban health: bulletin of the New York Academy of Medicine, 84(2), 142-152.

86 Decent, D. & Feltmate, B. (2018). *After the Flood: The Impact of Climate Change on Mental Health and Lost Time from Work.* Intact Centre on Climate Adaptation, University of Waterloo.

87 Cruz, J., et al. (2020). *Effect of Extreme Weather Events on Mental Health: A Narrative Synthesis and Meta-Analysis for the UK.* International Journal of Environmental Research and Public Health, 17(22), 8581. MDPI AG.

88 Viavattene, C. & Priest, S. (2020). *Delivering benefits through evidence: A method for monetising the mental health costs of flooding.* UK Environment Agency.

89 Assuming an average mental health cost of £3,000 per adult, an average of 1.9 adults per household and average flood damages of ~£30,000 per home.

PROTECTING THE MOST VULNERABLE

Flooding is a social justice issue because it disproportionately affects disadvantaged groups which are typically more vulnerable and more exposed to flooding. Extending affordable insurance to these populations can help break the link between rising flood risk and increasing inequality.

Given the threat to prosperity posed by flood risk, governments should be making resilience to flooding a national priority. Strategies for building resilience will be the focus of a later paper. Here our focus is on one critical element: increasing protection among society's most vulnerable. In the wake of the coronavirus pandemic and concerns over ever-widening social and economic disparities, this is arguably governments' greatest challenge, because it is typically the poorest and most marginalized communities that bear the brunt of flooding. Unchecked, flood risk will deepen inequality.

Disadvantaged communities typically face a double whammy of greater vulnerability and heightened exposure. Wealthy communities tend to situate themselves in less risky areas, making properties in the riskier parts more affordable for poorer (and more vulnerable) households. Hurricane Harvey disproportionately affected Houston's lower-income population because these families were concentrated in flood prone areas.[90]

Because flooding hits those groups least able to recover, it deepens pre-existing inequality. And these disparities are likely to worsen as climate change spurs the frequency of floods, raising the prospect of ever-deepening vulnerability as communities struggle to recover fully before the next event. The most vulnerable populations may be sucked inexorably into a vicious cycle in the housing market, enticed by the affordability of homes in flood prone areas. Data for the US shows that wealthy people are more likely to leave an area affected by flooding, while lower-income households are more likely to remain or move in.[91]

Vulnerable groups are distinguished not only by lower incomes, but other social and demographic factors. In the US, vulnerability and exposure are greatest among racial minorities and mobile-home occupants in rural areas and across the South, with other determinants including household earnings, employment status, and education.[92] In Canada, almost 22 percent of indigenous peoples' homes on reserve lands are in the 100-year floodplain.[93] These patterns repeat across the world: Poorer and more marginalized communities are most likely to undergo flooding and suffer serious consequences in the event.[94]

---

90 Krause, E. & Reeves, R.V. (2017, September 18). *Hurricanes hit the poor the hardest.* Brookings.

91 Platt Boustan, L., Lucia Yanguas, M., et al. (2017, July 2). *Natural Disasters by Location: Rich Leave and Poor Get Poorer.* The Conversation. Scientific American. Retrieved March 10, 2021.

92 Tate, E., Rahman, M.A., Emrich, C.T. et al. (2021). *Flood exposure and social vulnerability in the United States*. Nat Hazards 106, 435-457.

93 Thistlethwaite, J., et al. (2020). Indigenous Reserve Lands in Canada Face High Flood Risk. Centre for International Governance Innovation. DOI:10.2307/resrep24941.

94 For a 1-in-100 year return period. Rentschler, J., & Salhab, M. (2020). *People in Harm's Way: Flood Exposure and Poverty in 189 Countries.* The World Bank.

It is typically the poorest and most marginalized communities that bear the brunt of flooding. Unchecked, flood risk will deepen inequality.

Increasing insurance penetration among at-risk communities

Clearly, the reasons for why flood vulnerability and exposure play out along the socioeconomic and demographic divide are multiple, complex, and inextricably linked to wider structural inequalities within societies and economies. Nevertheless, absent more fundamental reforms to address these problems, insurance coverage can transfer risks and aid recovery. Data shows that greater insurance penetration enhances recovery from flood,[95] indicating that insurance can help to break the vicious cycle of increasing vulnerability and rising inequality.

But increasing insurance coverage among vulnerable populations is not as simple as selling more private insurance, since premiums in at-risk areas are often prohibitively expensive. This may be exacerbated by the problem of adverse selection, whereby a lack of demand for flood insurance among low-risk households concentrates insurers' exposure among high-risk households, forcing insurers to charge higher premiums. Data and modelling limitations may also constrain insurers' ability to assess and price flood risk in some countries, placing limits on the availability of insurance.

National flood insurance schemes

Many governments intervene in insurance markets to help extend cover to households in high risk areas and avoid a spiral of increasing inequality. In Iceland, for example, a public insurer provides compulsory natural catastrophe insurance, including flood cover, for all buildings. France and Spain have implemented mandatory government-backed schemes where the purchase of private insurance includes a compulsory, flat-rate government surcharge to cover flood and other natural hazards (which are reinsured by the state). Programs such as these can achieve near universal cover.

The US National Flood Insurance Program (NFIP) provides a different model of government intervention, offering federally backed flood insurance administered through participating private insurers (see page 25). However, the NFIP has struggled to achieve high levels of coverage because unlike the French and Spanish schemes where flood coverage is mandatory, property insurance in the US excludes flood cover, making it optional.[96]

95 See, for example, Cambridge Centre for Risk Studies and AXA XL. (2020). *Optimising Disaster Recovery: The Role of Insurance Capital in Improving Economic Resilience.* Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School.

96 The exception being property owners with federally backed mortgages in FEMA designated high-risk zones who are required to have flood policies.

The US National Flood Insurance Program and Societal Discounting of Flood Risk

The US National Flood Insurance Program (NFIP) was established in 1968 to compensate for the absence of a private market, offering federally backed insurance to communities that adopt floodplain management regulations. Although a private flood insurance market has emerged, it is miniscule next to NFIP, which accounts for more than 95 percent of household policies purchased.[97] However, despite NFIP's market dominance, low rates of insurance penetration show a significant number of Americans still lack flood cover — as much as 85 percent of households.[98]

Various factors explain the poor uptake of flood insurance. There is some evidence that expectations of government relief reduce demand for flood insurance. More fundamentally, property owners do not understand their flood risk, making a binary assessment of risk based on whether they are "inside or out" a FEMA-designated Special Flood Hazard Area (SFHA) — a zone with a greater than 1 percent annual probability of flooding. Those outside SFHAs often consider themselves safe, but this is a fallacy: Flooding is by no means confined to SFHAs — almost three-quarters of Houston properties flooded during Hurricane Harvey were outside SFHAs for example.[99] Plus, SFHAs are outdated: Recent modelling estimated that the number of properties facing a 1 percent annual probability of flood to be 14.6 million — 68 percent more than currently listed in SFHAs.[100]

Low uptake among households outside SFHAs does not fully explain the US flood protection gap, however, because even inside SFHAs, only 30 percent of homeowners have flood insurance, despite a requirement that flood insurance be in place for federally backed mortgages in these areas.[101] In other words, flood risk is underestimated inside *and* out.

Another factor for low flood insurance uptake is the misperception that it's expensive. The average NFIP premium of $743, while not inconsequential, is small compared to the average flood insurance claim of $43,000. The problem is not that NFIP cover is too expensive, but that it is too cheap — at least for those properties at highest risk. A recent analysis estimated that the average premium for homes with a 1 percent annual probability of flooding would need to more than quadruple to cover the true risk.[102]

---

97 Wharton Risk Management and Decision Processes Center. (2018). *The Emerging Private Residential Flood Insurance Market in the United States.* University of Pennsylvania.

98 Moorcraft, B. (2018, July 18). *Private insurers and NFIP must work together to close gap.* Insurance Business America. Retrieved March 10, 2021.

99 Dempsey, M., et al. (2018, March 30). *Harvey's floods.* The Houston Chronicle. Retrieved March 10, 2021.

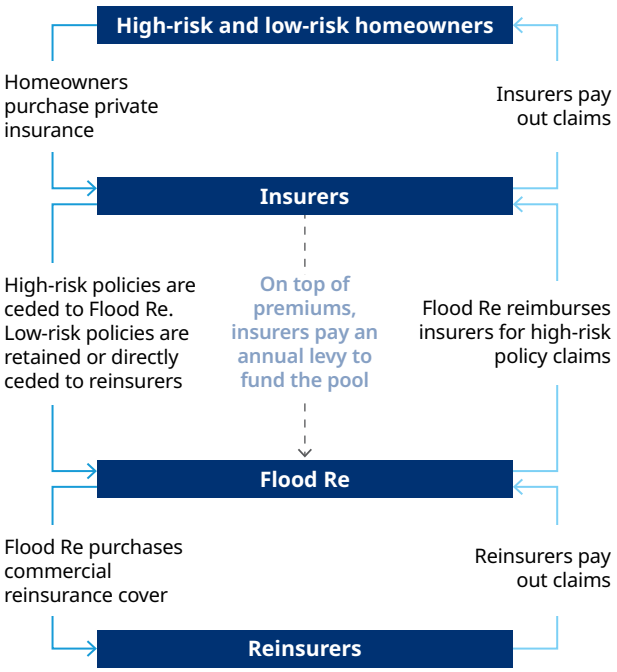
100 First Street Foundation. (2020, June 29). *Highlights From "The First National Flood Risk Assessment."* Retrieved March 10, 2021.

101 Dempsey, M., et al. (2018, March 30). *Harvey's floods.* The Houston Chronicle. Retrieved March 10, 2021.

102 First Street Foundation. (2021, February 22). *Highlights From "The Cost of Climate: America's Growing Flood Risk."* Retrieved March 10, 2021.

In the UK, about 70% of households purchase home insurance, and almost all these policies include flood coverage. This has been achieved by including flood in standard household policies alongside a requirement from mortgage lenders that homebuyers have insurance in place. The UK model for extending insurance to the most vulnerable targets private insurers rather than property owners and thus does not result in the state providing insurance or reinsurance. The UK has established Flood Re — a flood reinsurance pool — to which private insurers can cede high risk policies in return for a levy and fixed premium that is independent of risk (see Exhibit 9). This allows insurers to provide affordable cover in areas where risk-reflective pricing would be prohibitively expensive, diversifying risks across the pool and spreading the cost of insurance for a relatively small number of high-risk homes.

Exhibit 9: Flood Re operations in the UK's flood insurance market



Source: Flood Re

The degree of government intervention is also comparatively light. Flood Re is not a government entity but a joint initiative of the government and the insurance industry, a public body funded by insurers and accountable to Parliament. Because the state is not providing insurance or reinsurance, it faces no direct financial liability — Flood Re purchases reinsurance to secure protection up to a 1-in-200 year loss level and is subject to the Bank of England's solvency regulations.

Flood Re has made insurance available and affordable for high-risk homes through private markets.[103] The scheme is intended to run until 2039, when it is hoped the market will have reverted to risk-based pricing. Significant progress in flood-risk reduction and resilience will be required if risk-reflective premiums are to be universally affordable when the scheme ends, particularly given how climate change is expected to increase the frequency and severity of flooding in the UK.

Community-based flood insurance

In certain contexts, there may be opportunities to close localized protection gaps through community-based flood insurance. In this model, a local authority or other local entity arranges flood cover for properties within a community.

Community-based models have applications in developing countries, where rates of private insurance penetration are low and where fiscal and administrative constraints may preclude national programs. The potential of community-based models for flood insurance remains largely unexplored, and could be extended so as to complement existing private or public insurance through the provision of supplemental cover or providing a more affordable alternative in high-risk areas.[104]

103 Flood Re. (2020). *Annual Report and Financial Statements.* Among households with previous flood claims, 98 percent can get quotes from 5 or more insurers and 80 percent have seen quotes decline by 50 percent or more.

104 Bernhardt, A., Kousky, C., et al. (2021). *Community-Based Catastrophe Insurance: A model for closing the disaster protection gap.* Marsh McLennan Advantage & Wharton Risk Management and Decision Processes Center.

Managing fiscal costs

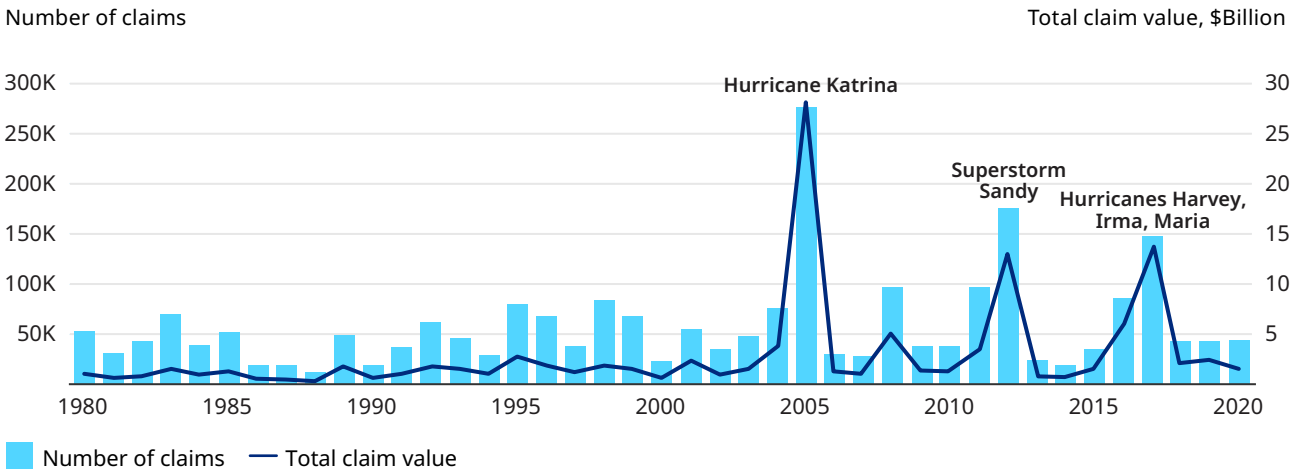
Public flood insurance schemes create contingent liabilities for governments when insured losses exceed accumulated reserves. This has happened with the NFIP, which has borrowed heavily from the US Treasury to cover losses. To a great extent, NFIP's indebtedness is the result of design: Premiums were set to cover expected annual payouts based on historical losses, with extraordinary loss events to be funded by borrowing from the Treasury.

However, the frequency and severity of hurricanes in recent years saw NFIP's borrowing become unsustainable (see Exhibit 10). This culminated in the cancellation of $16 billion of debt by Congress in 2017 so NFIP could pay claims arising from Hurricanes Harvey, Irma, and Maria that year. Its current debt stands at around $20 billion.

With heavy rainfall events such as Harvey becoming more frequent,[105] premiums based on historical losses are unlikely to sustain the NFIP in the long term. It is expected that the NFIP's Risk Rating 2.0 reforms will lead to more accurate and sustainable pricing of risks[106] by introducing updated flood maps and new risk models to provide more accurate pricing. Risk Rating 2.0 may also increase penetration by providing homeowners with better information about their flood risk and by supporting a more robust private insurance market.

In countries with higher rates of insurance coverage, public schemes are generally self-sustaining, provided that aggregate premiums cover risk. For example, Spain's unlimited guarantee of the public natural catastrophe reinsurance scheme has never been triggered in 70 years of operation; however, in 1999, France's scheme required a government injection and premium hike after a period of dwindling reserves.[107]

Exhibit 10: Total number of claims and claim value from NFIP policies



Source: OpenFEMA Data Initiative. FEMA and the Federal Government cannot vouch for the data or analyses derived from these data after the data have been retrieved from the Agency's website(s) and/or Data.gov.

105 Emanuel, K. (2017). *Assessing the present and future probability of Hurricane Harvey's rainfall.* Proceedings of the National Academy of Sciences, 114(48), 12681-12684.

106 Risk Rating 2.0 will be phased in gradually, beginning in October 2021 with the first premium rises in April 2022 but with potentially 15 years of rising premiums for the highest risk homes. For more information, see Kaufman, L. (2021, April 5). *FEMA unveils first flood insurance update in 50 years. PropertyCasualty360.* Retrieved April 22, 2021.

107 Jametti, M. & von Ungern-Sternberg, T. (2006). *Risk Selection in Natural Disaster Insurance — the Case of France.* Cahiers de Recherches Economiques du Département d'économie 06.02, Université de Lausanne, Faculté des HEC, Département d'économie.

Government spending in the wake of flooding also creates contingent liabilities. Governments may offer emergency assistance, fund reconstruction, or provide compensation and financial assistance to local authorities, businesses, and households, amounting to significant unplanned expenditure. For example, supplemental federal funding for Superstorm Sandy exceeded $50 billion; Germany's 2013 floods cost $11 billion in emergency relief, requiring the government to set a new budget; and the 2011 floods in Pakistan forced the government to increase its deficit target by 50 percent.[108, 109, 110]

High levels of flood insurance coverage can reduce the need for government relief spending, although with only 12 percent of global flood losses insured since 1980, the political reality is that many governments find themselves faced with a significant bill one way or another.

Maximizing private insurance coverage is a first step towards reducing contingent liabilities, whether from public-backed flood insurance programs or from emergency relief. After this, governments should consider the following risk financing and risk-transfer options:

- Establish reserve funds and dedicated budgetary allocations to self-insure against fiscal costs. This strategy's feasibility depends upon budgetary headroom and the overall size of potential liabilities. In countries with high contingent liabilities and constrained public resources, additional or alternative measures are likely to be needed.
- Governments can also choose to finance flood costs through ex-post borrowing. Those with good access to capital markets may issue bonds through normal public borrowing. Others can seek to access contingent borrowing facilities from multilateral institutions.
- Catastrophe bonds enable governments to transfer flood risk to the capital markets. Issued in advance of potential flooding, the bonds pay out in the event and can be structured with an indemnity trigger (with payout tied to insured losses) or a parametric trigger (with payout tied to the physical characteristics of the flood event). For example, NFIP has issued catastrophe bonds with indemnity triggers, to transfer flood risks from the government balance sheet to the capital markets. Parametric triggers provide more rapid funding because they avoid the need for claims to be assessed and losses quantified; instead, payout happens "in real time," when the predefined flood threshold is reached. Another potential advantage of parametric catastrophe bonds is that they obviate the need for insured losses to occur, making them useful for governments or public authorities with liabilities related to recovery and relief costs rather than public insurance schemes. One such example was issued by New York's Metropolitan Transport Authority after Superstorm Sandy, with a trigger tied to storm surge depth as measured at specific stations around the bay.[111]
- Reinsurance allows for governments to transfer risk from a public flood insurance scheme. For example, the NFIP's reinsurance program, initiated in 2016/17, has been the principal channel through which the US federal government has reduced its contingent flood liabilities.
- Governments can also cooperate to pool flood and other natural catastrophe risks in sovereign risk pools. By diversifying flood risk across geographies, governments can reduce insurance costs. For example, the Southeast Asia Disaster Risk Insurance Facility (SEADRIF) has established a regional flood risk pool for Lao PDR and Myanmar, including a parametric insurance component to provide rapid payouts.

---

108 Painter, W.L. & Brown, J.T. (2017). *Congressional Action on the FY2013 Disaster Supplemental.* Congressional Research Service.

109 DW. (2013, June 19). *German states to share flood relief costs with federal government.* Retrieved March 10, 2021.

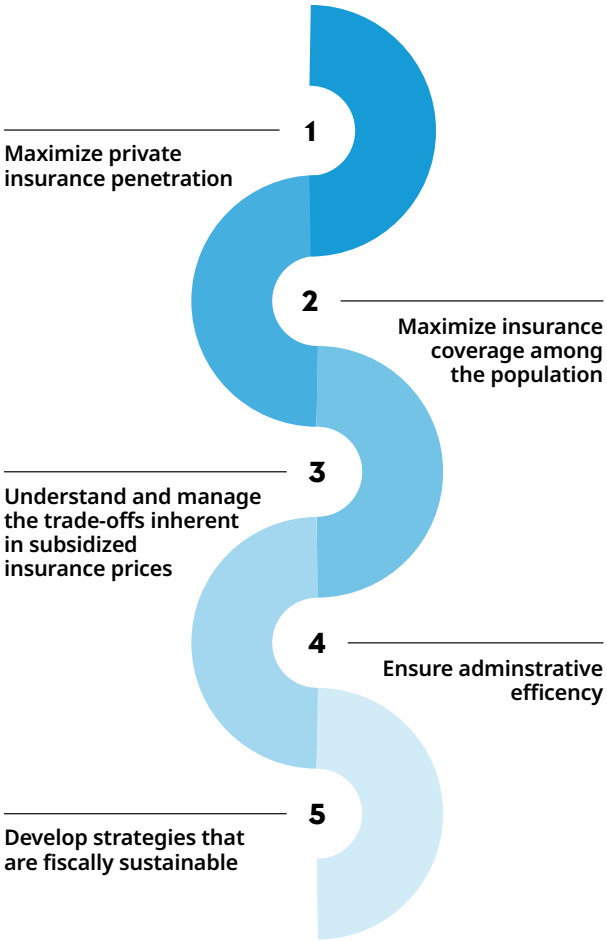
110 Bevan, D. & Cook, S. (2015). *Public Expenditure Following Disasters.* Policy Research Working Paper; No. 7355. The World Bank. Washington, DC.

111 Franco, G. (2020, August 19). *Parametric Insurance Can Boost Resilience for the Public Sector.* BRINK News. Retrieved March 10, 2021.

Principles for protecting the vulnerable

Marsh McLennan's experience in the management of flood risk and the preceding discussion highlight five general principles for designing effective strategies to close the flood protection gap among vulnerable populations (see Exhibit 11).

Exhibit 11: Five principles for protecting the vulnerable



Source: Marsh McLennan Advantage

Principle 1
Maximize private insurance penetration

Market-based insurance is risk reflective, with insurers seeking to charge actuarially sound premiums that cover the true risk. This creates incentives for risk-reducing behaviors among insured populations. It also reduces public contingent liabilities by transferring risk to the private sector.

Governments can maximize private insurance penetration through:

- Strategies to inform property owners of their risk, which may increase demand for insurance and encourage homeowner investments in flood resilience, making insurance more affordable.
- Public investments in flood protection and resilience to reduce flood risks, making coverage more affordable.
- Land-use and planning regulations to direct development to low-risk areas more easily served by insurers.
- A cautious approach to disaster relief spending to minimize public expectations of post-flood bailouts, which can deter insurance purchasing.

Principle 2
Maximize insurance coverage among the population

Rather than being an end in itself, universal coverage is a way to maximize diversification of flood risk and prevent adverse selection, making insurance more affordable for those in high-risk areas.

Flood insurance uptake can be increased through different strategies. Universal coverage can be achieved by mandating insurance for all buildings (as in Iceland), while near-universal coverage can be achieved by automatically including flood cover in general building insurance (as in UK, France, and Spain). Making mortgage lenders require that borrowers carry flood insurance will further drive acceptance. Generally, coverage rates are lowest in countries where flood insurance is an optional add-on and highest where it is mandatory or automatically included in property insurance.

Community-based flood insurance schemes may close localized gaps in protection or supplement a national program in high-risk areas.

Principle 3
Understand and manage the trade-offs inherent in subsidized insurance prices

Subsidized insurance prices result when homeowners are charged premiums that do not cover the true risk they face. This is an inevitable outcome of efforts to make insurance more affordable for at-risk properties. If properly managed, subsidized insurance may not become a problem. Subsidization can happen directly, where the government provides insurance or reinsurance (as in Iceland or France), or indirectly by affecting a transfer from low- to high-risk homeowners (as in the UK). That said, the disconnect between premiums and exposure dampens homeowner incentives to manage flood risk. Suppressed insurance costs create perverse incentives, such as encouraging construction in high-risk areas, and may crowd out private insurance if not targeted carefully. Holding premiums down in the face of rising risk makes it more difficult to move to risk-reflective pricing, because the adjustment for households becomes more painful and more likely to be rejected. In the UK, Flood Re manages these trade-offs by refusing cover to buildings built after a cut-off date and ensuring that its premium is higher than the market rate for low-risk properties.

Principle 4
Ensure adminstrative efficency

To be fiscally sustainable, a public insurance scheme's revenues must cover claims and expenses on an ongoing basis. Administrative costs can be significant, ranging from distribution and client onboarding, to underwriting, data handling and claims processing. Public-private partnerships may provide opportunities to manage costs, because private insurers are likely to be able to provide administrative services more efficiently than government bodies. For example, NFIP policies are distributed and serviced by private insurers through the Write-Your-Own program; Flood Re maintains the efficiency of private insurance markets by providing reinsurance to insurance companies, which write and administer policies. Private insurers may also be better at educating households on flood risk and coordinating cover of flood risk with that of other hazards. In circumstances where a national scheme is not desirable or may be too costly, community-based schemes — which are smaller and simpler to administer — may offer an efficient alternative.

Principle 5
Develop strategies that are fiscally sustainable

Government interventions, whether to provide subsidized insurance/reinsurance or establish public-private partnerships, can potentially create significant liabilities and result in budgetary pressures if they are not financially self-sustaining. Governments should ensure schemes can cover expected and extraordinary losses and that accompanying strategies are in place to reduce risk through building flood resilience and investing in protection. Strategies to finance or transfer risks, including reinsurance and catastrophe bonds, can smooth costs and help financial planning.

Conclusion

Increasing flood risk threatens prosperity and well-being in numerous countries, and demands a strategic response from governments. The problems arising are interrelated and systemic, ranging from business interruption and financial instability to a growing burden of public contingent liabilities. In the context of the novel coronavirus pandemic and mounting concerns about social and economic disparities, the potential for flood risk to deepen pre-existing inequalities represents a particularly urgent issue for many governments.

The wide-ranging and complex nature of these impacts indicates national flood risk strategies must be broad in scope, ensuring alignment across a variety of actors such as national governments, local authorities, businesses, financial regulators, and insurers. This in turn requires coherent policies and regulations, aligned incentives, and accessible, robust flood risk data.

Strategies must also be long term in their outlook, as climate change and increasing exposure mean risks in many countries will increase for the foreseeable future. In particular, plans must anticipate and manage the threat of potential tipping points, such as the emergence of uninsurable regions or financial market corrections.

These issues will be explored further in forthcoming publications.

Acknowledgements

Authors

Rob Bailey

Director, Marsh McLennan Advantage
rob.bailey@mmc.com

Claudio Saffioti

Research Manager, Marsh McLennan Advantage
claudio.saffioti@oliverwyman.com

Sumer Drall

Research Analyst, Marsh McLennan Advantage
sumer.drall@oliverwyman.com

Contributors

Marsh

Beverley Adams, Melissa Leuck

Guy Carpenter

Joseph F Becker, Ruth Lux, Andy Read, Christopher Sykes, Syzan Talo, Shilpa Pankaj

Marsh McLennan Advantage

Sydney Hedberg, Samuel Koh, Lucy Nottingham, Graeme Riddell, Richard Smith-Bingham

Designed by

Tezel Lim

Marsh McLennan (NYSE: MMC) is the world's leading professional services firm in the areas of risk, strategy and people. The Company's 76,000 colleagues advise clients in 130 countries. With annual revenue over $17 billion, Marsh McLennan helps clients navigate an increasingly dynamic and complex environment through four market-leading businesses. Marsh provides data driven risk advisory services and insurance solutions to commercial and consumer clients. Guy Carpenter develops advanced risk, reinsurance and capital strategies that help clients grow profitably and pursue emerging opportunities. Mercer delivers advice and technology-driven solutions that help organizations redefine the world of work, reshape retirement and investment outcomes, and unlock health and wellbeing for a changing workforce. Oliver Wyman serves as a critical strategic, economic and brand advisor to private sector and governmental clients.

For more information, visit mmc.com, follow us on LinkedIn and Twitter or subscribe to BRINK.