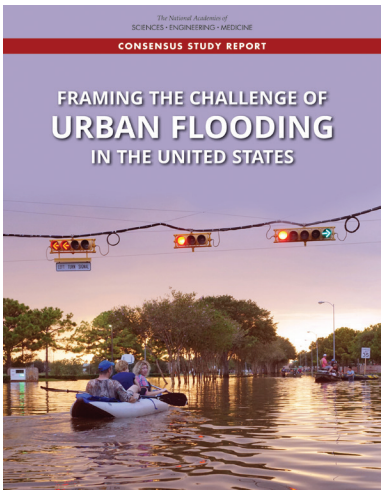
Consensus Study Report

APRIL 2019

HIGHLIGHTS

Framing the Challenge of Urban Flooding in the United States



Flooding is the natural hazard with the greatest economic and social impact on the population of the United States. It causes significant loss of life, incurs tens of billions of dollars in property damage, adversely affects millions of people, and delivers a heavy toll on the economic well-being of major metropolitan areas. The costs and impacts of urban flooding are growing more severe as development and population growth continue in urban areas and as sea level rises and heavy precipitation events become more frequent due to climate change.

The flood hazard analysis and mapping conducted by the Federal Emergency Management Agency (FEMA) focus on inundation from riverine and coastal flooding, but within cities, flood damage can occur anywhere, not just in floodplains along rivers and coasts. To better understand urban flooding, FEMA asked the National Academies to:

1. Identify commonalities and differences in the causes and impacts of urban flooding in selected metropolitan areas;
2. Estimate the size or importance of flooding in those urban areas; and
3. Relate causes and actions of urban flooding to existing federal resources or policies.

The study's objective was to contribute to existing knowledge by providing some real-world examples in specific places and not to provide a comprehensive overview of urban flooding in the United States.

WHAT IS URBAN FLOODING?

Urban flooding is caused when storm water in urban areas from heavy rainfall, stom surge, or high tides exceeds the capacity of drainage systems to infiltrate storm water into the soil or carry it away. Flood water inundation and movement are influenced by land development, which disturbs natural drainage patterns and creates hardened surfaces that inhibit infiltration of storm water; and storm water systems that are undersized for current needs.

COMMONALITIES AND DIFFERENCES IN FOUR METROPOLITAN AREAS

To examine urban flooding in different parts of the United States, the committee conducted case studies in four disparate metropolitan areas: Baltimore City and Baltimore County in Maryland, the City of Chicago and Cook County in Illinois, the City of Houston and Harris County in Texas, and the City of Phoenix and Maricopa County in Arizona. Discussions were organized around four dimensions of urban flooding:

1. **Physical Dimensions (built and natural environments).** Each area had a unique flood hazard defined by its natural environment history and pattern of land development and type of storm water and sewage systems. The case study areas also differed by the source of flooding: riverine, coastal, flash, or pluvial flooding, as well as sewer backups.

2. **Social Dimensions (impacts on people)**. Flooding crossed the economic spectrum, but the poor, racial and ethnic minorities, the elderly, renters, non-native English speakers, and those with mobility challenges were disproportionately affected by floods in each area. A major difference across the metropolitan areas was the level of citizen empowerment.
3. **Information Dimensions (data used to communicate flood events)**. Stakeholders in all four areas lamented a lack of data on urban flood hazard, flooding at local scales, or the economic costs and social impacts of flooding. Without better information, managers were using FEMA's Flood Insurance Rate Maps to estimate where flooding would occur.
4. **Actions and Decision-Making Dimensions (steps for managing flooding)**. People in each metropolitan area wanted ongoing urban flood management efforts (e.g., buyouts of chronically flooded properties), and they noted the importance and the challenges of working towards solutions for urban flooding across jurisdictional divides.

Finding: Each of the study areas (Baltimore, Houston, Chicago, and Phoenix) has a unique flood hazard and manages urban flooding in its own way, using a tailored mix of federal, state, local, and nongovernmental financial and information resources. In each metropolitan area visited, the impacts of flooding are particularly felt by disenfranchised populations. All four dimensions (physical, social, information, and actions and decision making) are needed to understand and manage urban flooding.

Historical Estimates of Urban Flood Losses

FEMA collects the most complete, consistent, and accessible data on historical flood losses, which include claims for property losses insured by the National Flood Insurance Program, loans for Small Business Assistance, and grants to cover immediate unmet recovery needs of individuals (Individual Assistance), assistance for publicly owned facilities (Public Assistance), and hazard mitigation projects and buyouts (Hazard Mitigation Grant Program).

To estimate urban flood losses, the committee summed the dollar amounts from these five FEMA data sets over a 10-year period (2004–2014), then adjusted the figures to 2014 prices. For the ten analyzed years, the total payouts, grants, and loans for case study counties were $2.7 billion for Harris County (excluding Hurricane Harvey), $1.8 billion for Cook County, $38 million for Baltimore County, and $11 million for Maricopa County. Flood losses are greatest in heavily populated coastal counties; for example, the significant flood events of Hurricane Katrina and Superstorm Sandy drove the urban flood losses for New York and Louisiana, which received payouts, loans, and grants on the order of $10 billion from 2004 to 2014.

Flood Risk Assessments

Flood risk assessments offer a more comprehensive picture of urban flooding than historical estimates because they include a wider range of flood probabilities and some non-property damages. Such assessments include: (1) flood hazard—the probability and magnitude of the hazard, (2) exposure—the population and economic assets at risk, (3) vulnerability—the damage relationship between hazard and exposure, and (4) performance—flood mitigation measures such as levees. The few published risk assessments for the case study areas found that 2.8 million people are exposed to flooding, more than triple the number estimated by FEMA. In addition, studies estimate that average annual losses are $3.3 billion for both Chicago and Houston and $76 million for Baltimore, more than 20 times higher than historical estimates.

Both historical estimates and flood risk assessments likely underestimate flood losses. Much of the historical data is derived only from presidentially-declared flood events, and it also excludes uninsured property and indirect losses. Many flood risk assessments do not consider pluvial flooding include only a few non-property damages.

Finding: Existing data are inadequate to provide an accurate monetary estimate of the magnitude of urban flooding. Historical loss estimates for each of the counties that include Chicago and Houston average $200 million per year (for 2004–2014). However, losses likely far exceed these estimates—possibly on the order of a few billion dollars per year—when pluvial flooding, uninsured property and indirect losses, declines in gross domestic product, and the millions of residents exposed to flooding are considered. While historical flood losses are lower in the counties that include Baltimore and Phoenix (few million dollars per year), actual losses are likely much higher when the other contributing factors are considered.

CONNECTION OF FEDERAL RESOURCES TO URBAN FLOODING

Urban Flood Hazard

One need identified in the case study areas was a better understanding of urban flood hazard. FEMA has established methods for analyzing riverine or coastal flood hazard, but methods for analyzing urban flood hazard will have to incorporate urban components, such as the capacity of storm water systems, topographic variations, local drainage patterns, and site-specific

structural designs that drive the granular nature urban flood impacts.

Finding: An established method for analyzing urban flood hazard is needed. FEMA is well positioned to take a leading role in guiding this development effort by virtue of its mission and expertise in analyzing various types of flood hazards. Important partners include local government agencies, which know their storm water systems and local land characteristics, and organizations developing hydrologic or hydraulic models that account for pluvial flooding and other factors. Urban flood hazard analyses would also contribute to urban flood risk assessments being developed by academic researchers and private companies.

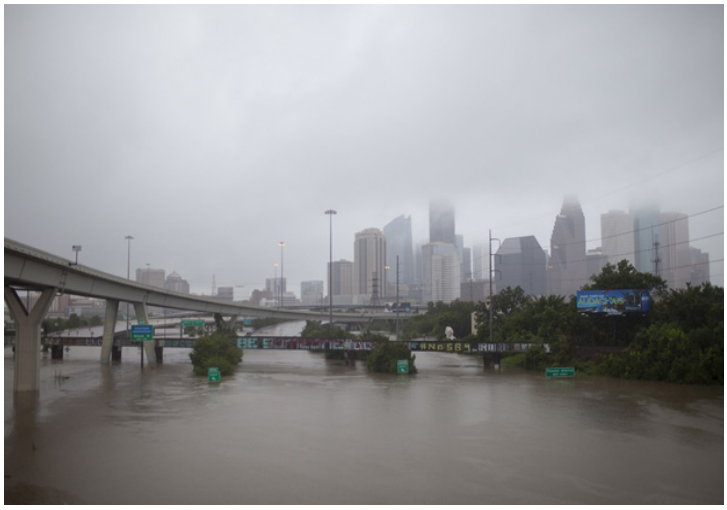


FIGURE 2.1.1 Inundation of Houston in August/September 2017, when more than 33 inches of rain fell over 4 days during Hurricane Harvey.
SOURCE: Photo courtesy of Katie Luke Hayes.

Socially Vulnerable Populations

While severe storms fall on the rich and poor alike, the capacity to respond to and recover from flooding is much lower in socially vulnerable populations that even in the best of times are struggling to function. This point is supported by research, but the social dimensions of urban flooding are far less studied than the physical dimensions. Data on intangible impacts (e.g., health or community cohesion), indirect impacts (e.g., unemployment due to business interruption), and additional vulnerability drivers (e.g., risk perception and social capital) would help improve urban flood risk assessments.

Finding: Greater investments are needed to research, understand, and develop interventions to mitigate the social impacts of urban flooding and their disparate effects across populations. Although the National Science Foundation is the primary funder of social science research, FEMA, the U.S. Army Corps of Engineers, and the Centers for Disease Control and Prevention have promoted accounting for and engaging socially vulnerable populations in the planning and response to hazard events.

COMMUNICATING URBAN FLOOD HAZARD AND FLOOD RISK

Maps and visualizations are a primary means of communicating flood risk. A comprehensive flood risk map would portray information on both the flood hazard and the consequences of flooding. Urban flood risk maps should also portray information such as land cover, the distribution of socially vulnerable and other populations, the location of previous flood problems, and the age, design capacity, and condition of storm water networks, drainage systems, and roads.

Finding: A new generation of flood maps and visualizations that integrate predictions and local observations of flood extent and impact is needed to communicate urban flood risk. Federal contributions for such an undertaking include flood hazard analysis and data on flood damage (FEMA), precipitation and climate change (NOAA), social vulnerability (NSF), population and demographics (Census Bureau), and information from community development grants (HUD). Other contributors include public and private organizations developing visualization techniques, especially for flood risk.

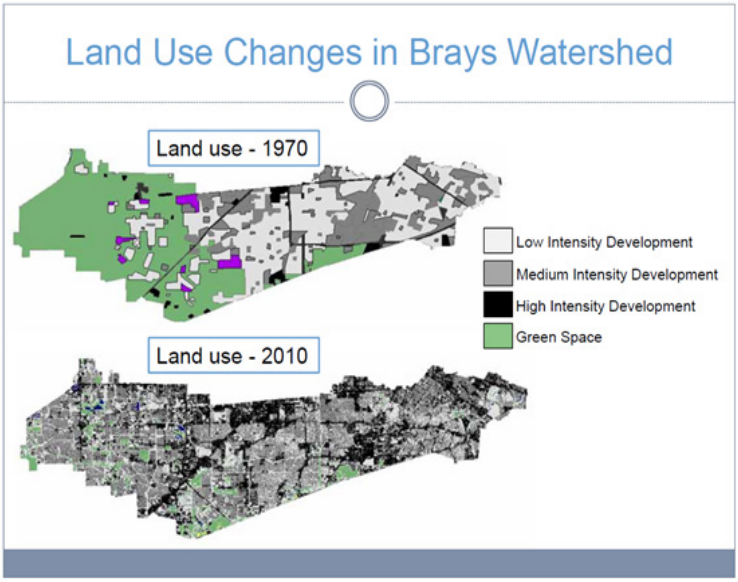


FIGURE 2.2 Changes in land use and high-density development in the Brays Watershed, Houston, from 1970 to 2010. Purple shading denotes large blocks of vacant land.
SOURCE: Philip Bedient, Rice University.

Coordination of Agencies Managing Urban Flooding

Depending on the area, more than a dozen organizations and agency departments may be involved in urban flood preparation, response, recovery, and mitigation. For major floods, FEMA is statutorily obligated to coordinate mitigation, response, and short-term recovery operations, but many urban floods are too small to trigger federal resources and are managed at the state or local level.

The coordination in FEMA's National Response Framework is intended to adapt to the unique needs, capabilities, and circumstances of affected communities. For example, agencies involved with floods in urban areas may include those responsible for storm water and sewer systems or for deploying tide gages to monitor tidal flooding and sea level rise. These differences complicate federal, state, and local coordination the high concentrations of people and assets at risk add urgency to the need to work together quickly and efficiently.

Finding: Stronger coordination is needed across agencies that have a role in managing small or large urban floods. Such coordination will be both vertical (e.g., federal, state, local) and horizontal (e.g., local agencies responsible for storm water systems, flood control, and removal of damaged property; federal agencies responsible for severe storm warnings, evacuation, community redevelopment, and urban flood mitigation).

CONCLUDING OBSERVATIONS

The current costs and impacts of urban flooding merit national attention. Further, flood problems are likely to get worse with continued urban development and population growth in urban areas, as well as with climate change, which is increasing sea-level rise and the frequency of heavy precipitation events. Multi-agency and cross-jurisdictional efforts are needed to analyze urban flood hazard, advance understanding of social impacts, and communicate urban flood hazard and flood risk.

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For More Information . . . This Consensus Study Report Highlights was prepared by the Resilient Amercia Progam based on the Consensus Study Report *Framing the Challenges of Urban Flooding in the United States* (2019). The study was sponsored by FEMA. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Resilient America Roundtable web page at http://www.nationalacademies.org/PGA/ResilientAmerica.

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