FINAL REPORT BRIEFING

Framing the Challenge of Urban Flooding in the United States

Chad Berginnis, Committee Member

21 June 2019

URBAN FLOODING IN THE UNITED STATES

Scope of Study

An ad hoc committee will organize a series of regional workshops or case studies to explore the issue of urban flooding in 3 to 8 metropolitan areas (locations to be determined). These case study/information gathering sessions will provide information from federal, state, and local government agencies, and other relevant stakeholders responsible for flood control, flood response, recovery, or mitigation on questions related to urban flooding *both outside and inside the floodplain*, such as:

- How big is the problem of flooding in each metropolitan area; i.e., how bad can floods be or have floods been and how much do floods cost?
- What causes the worst impacts of flooding, *including structural and human impacts*?
- How could the worst impacts be avoided or mitigated?
- Who is affected most by floods in the metropolitan area?
- Which regions of the metropolitan areas see the longest lasting or most costly effects of flooding?

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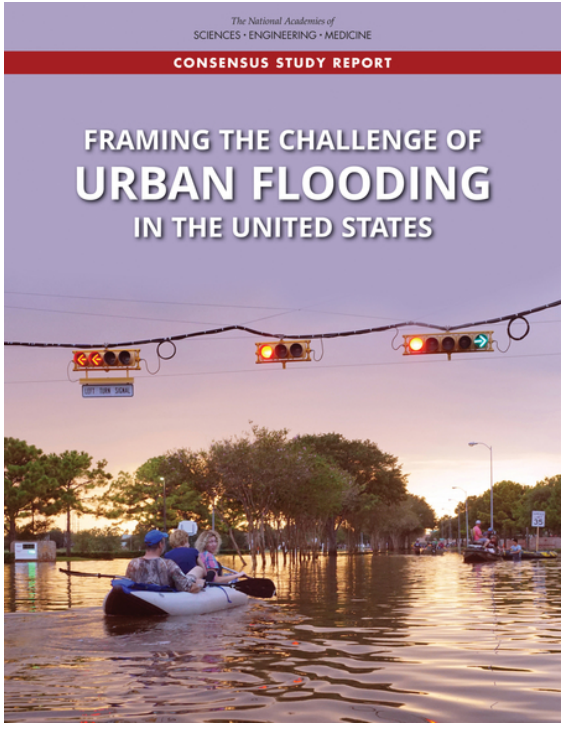
Study Overview

The Committee conducted workshops in 4 metropolitan areas to gain an initial understanding of the causes and impacts of urban flooding and to help address 3 tasks:

1. Identify commonalities and differences among the case study areas
2. Estimate of the size or importance of flooding in those urban areas
3. Relate the causes and actions of urban flooding to existing federal resources or policies



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Committee Members

David Maidment, *Chair*, University of Texas at Austin

Chad Berginnis, Association of State Flood Plain Managers

Lt. Gen. (Ret.) Thomas P. Bostick, Intrexon

Samuel Brody, Texas A&M University

Jeffrey Czajkowski, University of Pennsylvania and National Association of Insurance Commissioners

Dara Entekhabi, Massachusetts Institute of Technology

Harriet Festing, Anthropocene Associates

Katherine Greig, University of Pennsylvania

Jo Ann Howard, H2O Partners Inc.

Conor Jensen, Renegade Science

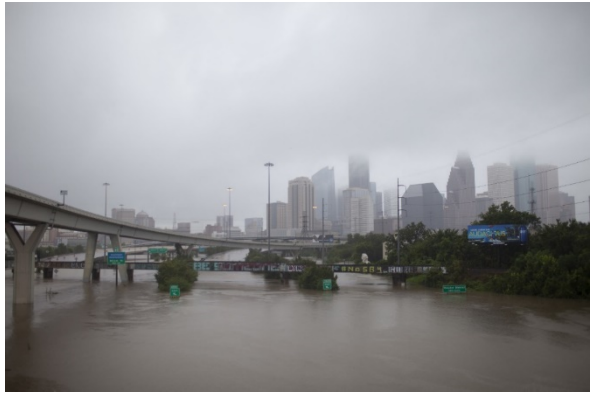
Eric Tate, University of Iowa

Claire Welty, University of Maryland, Baltimore County

James Wescoat, Massachusetts Institute of Technology

Flooding in Urban Areas

- Flooding is the natural hazard with the greatest economic and social impact in the United States
- Within cities, flood damage can occur anywhere
  - 280 million people in urban areas are potentially affected
  - impacts can be highly localized
- Flood problems reflect the history of a city and generally increase with urbanization



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Flood Waters Come From …

Direct impact of rainfall (or pluvial flooding, critical for urban areas)

Inundation from rivers

Coastal storm surge

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What is Urban Flooding?

Caused when the *inflow of storm water* in urban areas *exceeds the capacity of drainage systems* to infiltrate storm water into the soil or to carry it away

Heavy rainfall and riverine flooding

Complex urban environment impedes flow

Storm surge, high tides

Inadequate storm water systems

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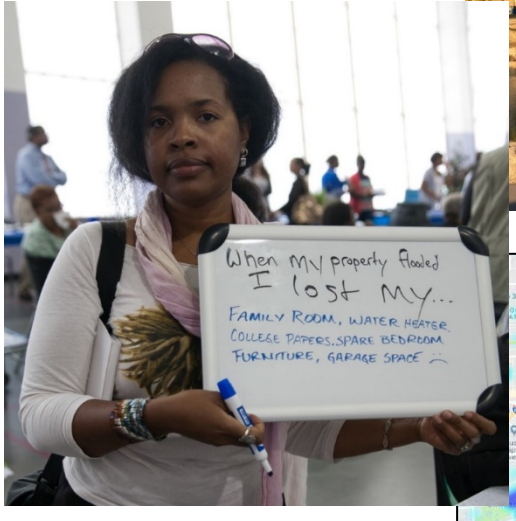
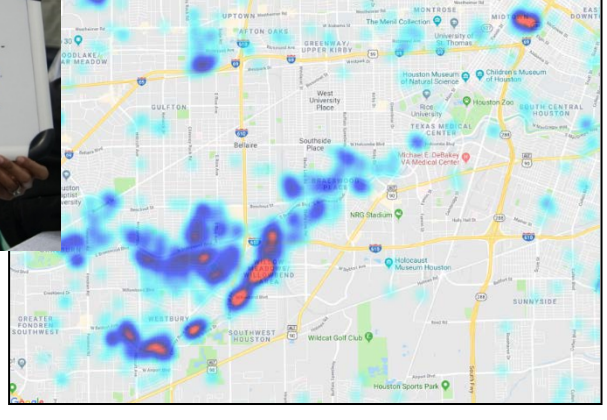
Dimensions of Urban Flooding

1. Physical—the built and natural environments
2. Social—impacts on people
3. Information—data used to understand or communicate flood events
4. Actions and decision making—steps and policies for managing flooding





Four groups for each workshop

Tom Bostick to provide comment

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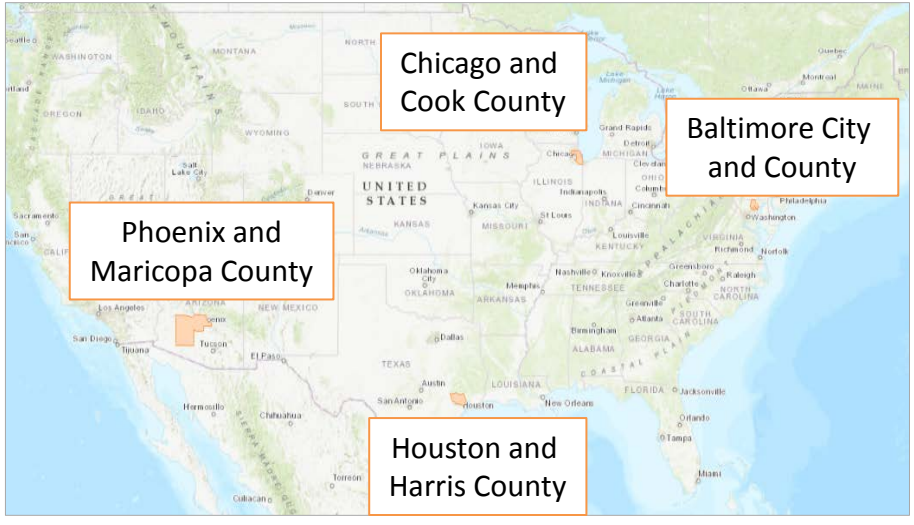
Four Case Studies



- Workshops
- Stakeholder meetings & interviews
- Field trips

Two older cities from Northeast and Midwest
Two younger cities from South and West

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76 Participating Organizations

Local Government

Arizona Department of Transportation
Baltimore City, Office of Sustainability
Baltimore County Public Works
Chicago Metropolitan Agency for Planning
Chicago Metropolitan Agency for Planning
City of Baltimore, Department of Public Works
City of Baltimore, Department of Public Works
City of Chicago, Department of Planning and Development
City of Chicago, Department of Water Management
City of Houston
City of Houston, Mayor's Office
City of Phoenix
City of Scottsdale
Community and Environmental Planning/Houston-Galveston Area Council
Cook County Bureau of Economic Development
Flood Control District of Maricopa County
Harris County
Howard County Office of Community Sustainability
Metropolitan Planning Council (Chicago region)
Metropolitan Water Reclamation District of Greater Chicago
North Houston District
Transportation and Drainage Operations

Non-Governmental Organizations/Non-Profit Organizations

American Planning Association
American Red Cross
Association of Baltimore Area Grantmakers
Catholic Charities
Center for Neighborhood Technology
Center for Progressive Reform
Community Health Resilience for Baltimore
Frostwood Flood Committee
Houston Habitat for Humanity
Houston Wilderness
Jewish Family Service
League of Women Voters
Leonard and Helen R. Stulman Foundation
Lone Star Legal Aid
Maryland Environmental Health Network
Midwestern Regional Climate Center
Mission for Wellness
Operation HOPE
Parks and People Foundation
RainReady
Residents Against Flooding
The Nature Conservancy
United Way of Greater Houston
West Monroe Partners

State and Federal Agencies

Atkins Global
Department of Natural Resources
Dewberry
DHS, Flood APEX Program
FEMA, Insurance Analytics and Policy Branch
FEMA, Office of Environmental Planning and Historic Preservation
FEMA, Risk Analysis Branch
Illinois Office of Water Resources
Maryland Department of Planning
Maryland Department of the Environment
Maryland Department of Transportation
Maryland Emergency Management Agency
Maryland Port Administration
NAFSMA
NOAA
NOAA, National Weather Service
U.S. Army Corps of Engineers
U.S. Geological Survey

Congressional Offices

Office of Congressman Mike Quigley
Office of Senator Durbin

Industry/ For Profit Organizations

AECOM
Allstate Insurance Company
Beth Wolff Realtors
Hanson Professional Services, Inc.
Kaiser Permanente
Mahan Rykiel Associates
OptiRTC
Zurich North America

Academic and Research Institutions

HARC Research
Iowa State University
Maryland Institute College of Art
Rice University
Texas A&M University
University of Chicago
Ph.D. Student

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Baltimore City and County

- City and County are geographically distinct
- Strong influence of water quality management in Chesapeake Bay
- Sinkholes from collapsing storm sewers in city
- Historical buildings in steeply sloping floodways
- Low annual flood losses
- Limited flood management

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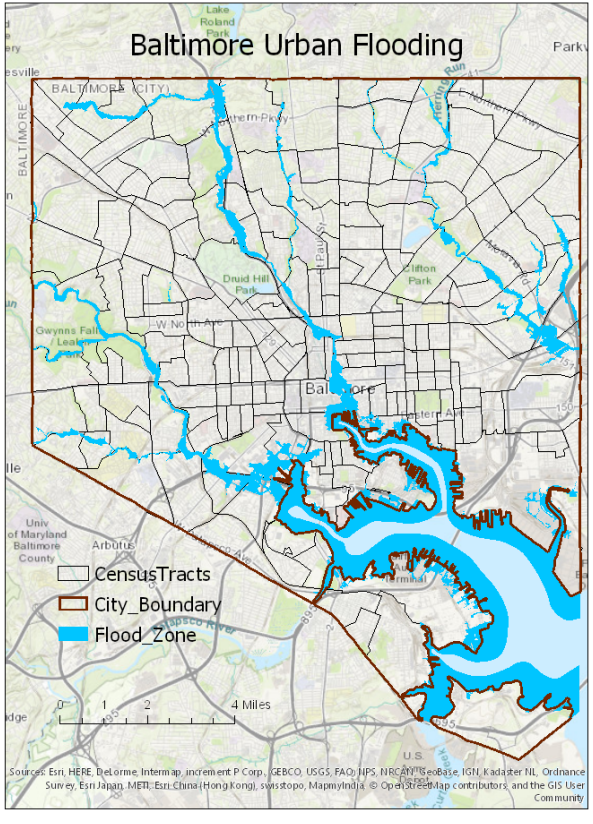
Flooding in Baltimore



Buildings in floodway with flood gates

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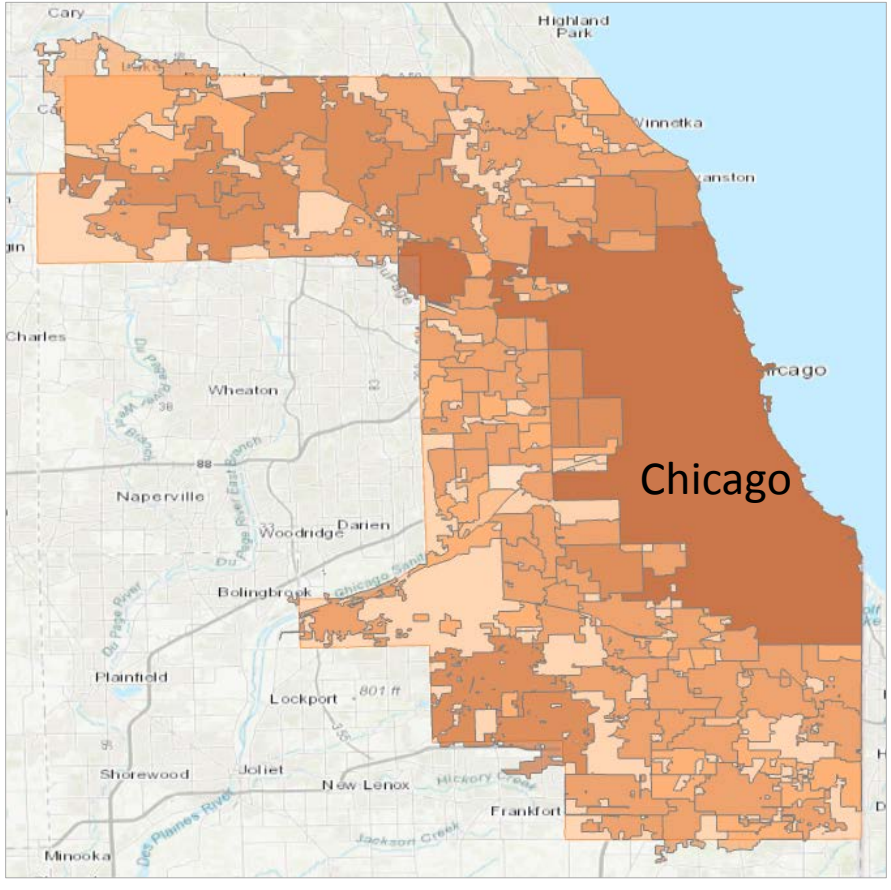
City of Chicago and Cook County



- Combined storm and sanitary sewage system
- Overwhelmed in large storms leading to sewage backups flowing into basements
- Huge Tunnel And Reservoir Plan (TARP) to convey and store stormwater flow
- Marked geographic response differences across city
- High annual flood losses

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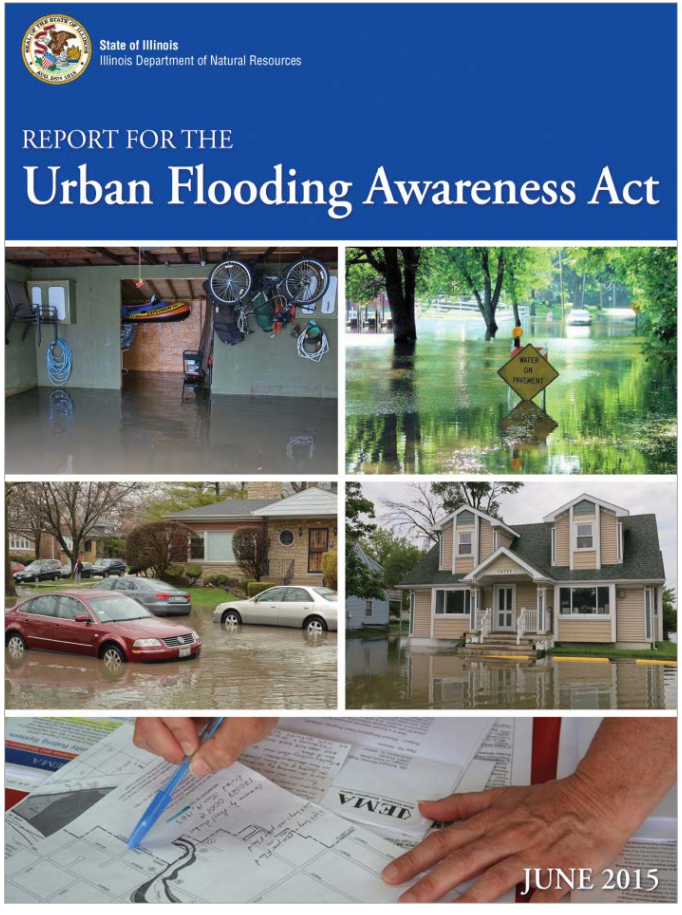
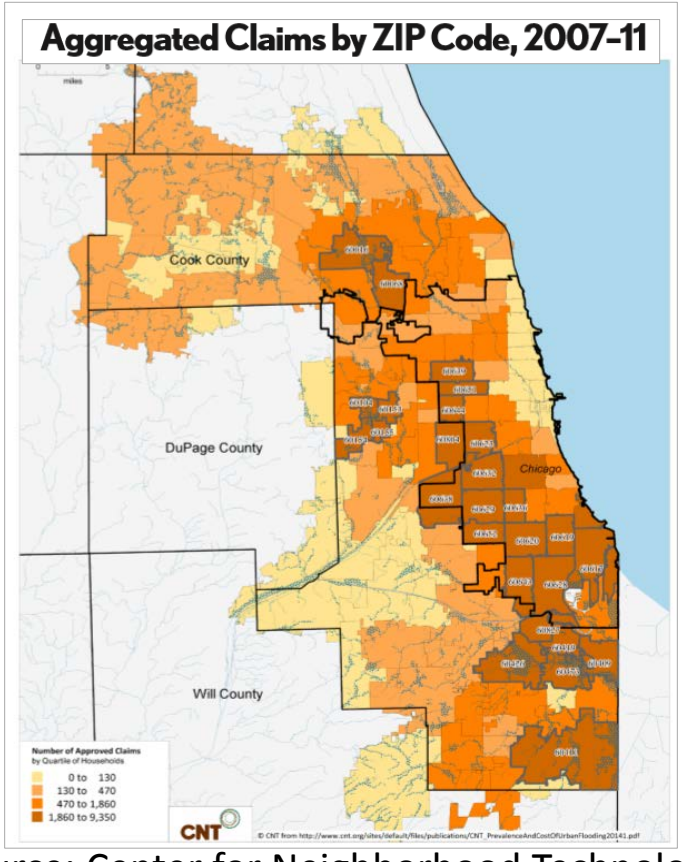
State Concern in Illinois



Widely distributed flood damage across city



Source: Center for Neighborhood Technology

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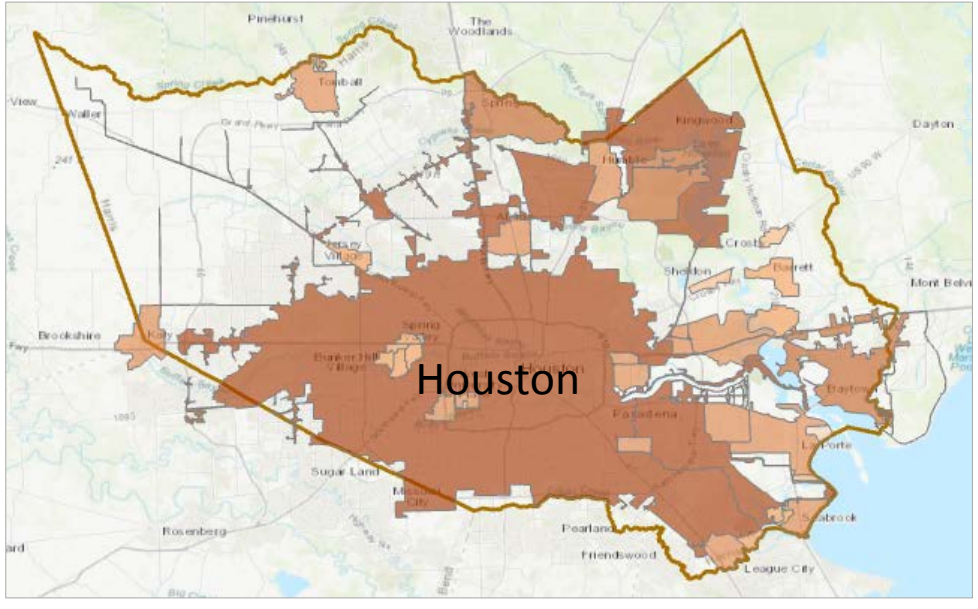
City of Houston and Harris County



- Flat terrain with almost all surface water drainage
- Large engineering commitment to flood mitigation
- Vulnerability to storm surge, riverine, and pluvial flooding
- High annual flood losses
- Catastrophic impact of Hurricane Harvey
- Committee visited Houston one month before Harvey occurred

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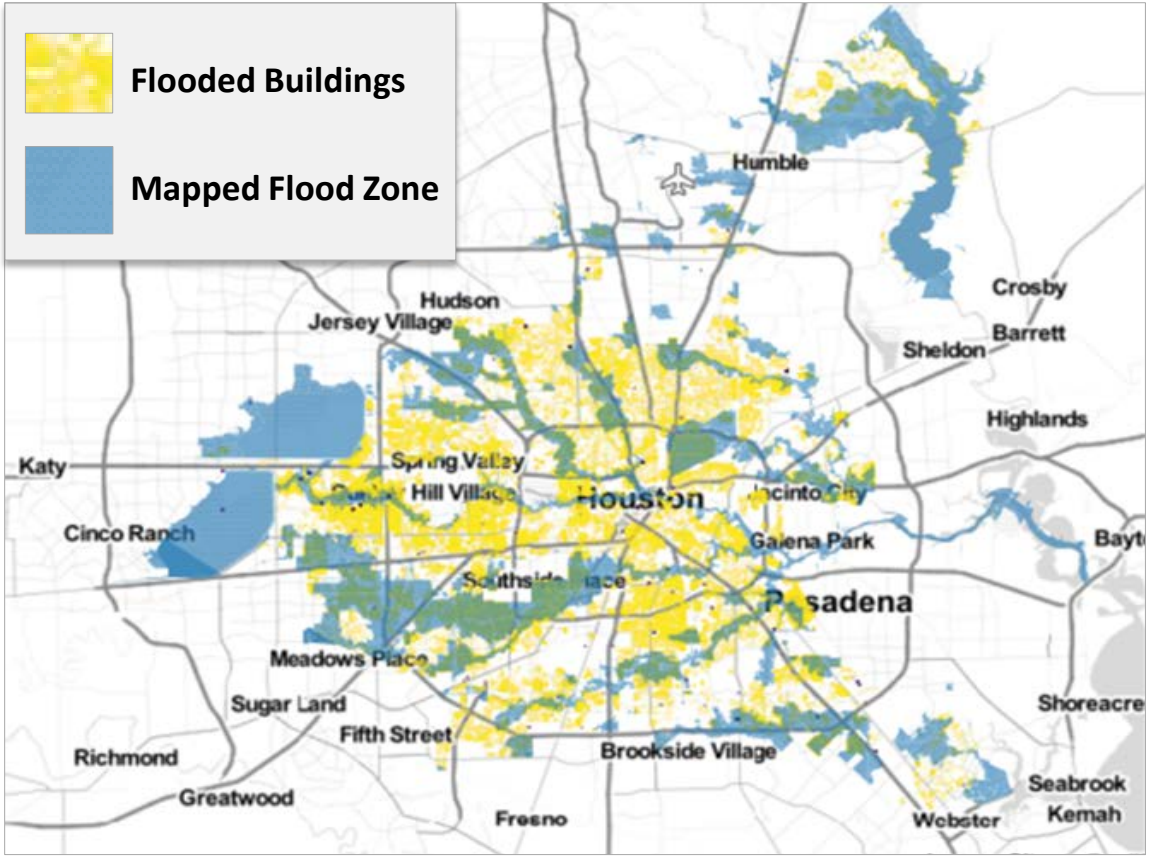
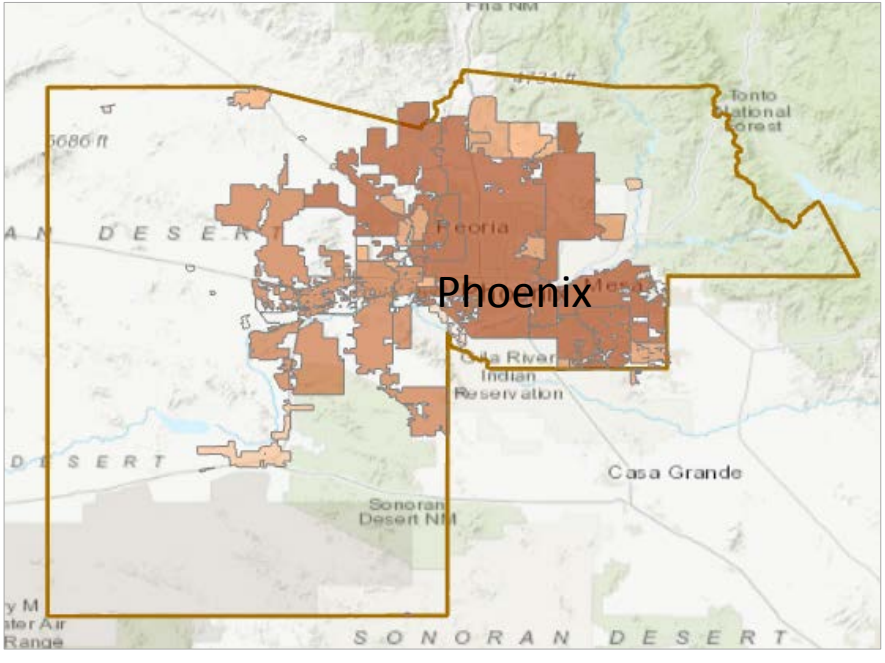
Flooded Buildings in Harvey



Half flooded buildings outside mapped flood zones

Source: City of Houston, Housing Department

City of Phoenix and Maricopa County



- Flat terrain in city with sloping hills outside
- Flood irrigation used to water landscape in older areas (ponded yards)
- Sophisticated 2D flood modeling of sheet flow
- Extensive use of green infrastructure to infiltrate stormwater
- Low flood losses

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Flooding in Phoenix

River park for flood control

Green infrastructure

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Task 1: Similarities and Differences Among Study Cities

Similarities

- Multiple sources of flood water
  - river overflow, storm surge, flash floods, pluvial floods, sewer backups
- Disenfranchised groups disproportionally affected by flooding
  - Poor, minority, elderly, non-native English speakers, low mobility
- Lack of data on flood hazard, social impacts, and economic costs
- Desire for improved urban flood management

Differences

- Natural environment, development, storm water and sewer infrastructure
- Level of citizen empowerment
- Capability to fill data gaps
- Ability to forge cross-jurisdictional agreements for major mitigation

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Finding: Similarities and Differences in Case Study Areas

- Each metropolitan area 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, 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

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Task 2: Magnitude of Urban Flooding

- Methods for estimating magnitude:
  - Evaluation of historical flood impact data (retrospective estimate)
  - Urban flood risk assessment (prospective estimate)
- Types of data available:
  - Direct impacts — Immediate effect of the disaster (e.g., loss of life; damage to buildings, roads, agriculture, and infrastructure; monetary loss)
  - Tangible impacts—Impacts that have a market value and can generally be measured in monetary terms (e.g., structural losses)

Committee made an exhaustive study of available data sources

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Historical Estimates of Urban Flood Losses

Available Data (FEMA)

- NFIP claims
- Small Business Assistance loans
- Individual Assistance grants (immediate unmet recovery needs)
- Public Assistance grants (publicly owned facilities)
- Hazard Mitigation Grants (projects and buyouts)

Data Limitations

- Exclude uninsured property
- Major flood events (presidential disaster declarations)
  - ➢ miss less extreme, more frequent events

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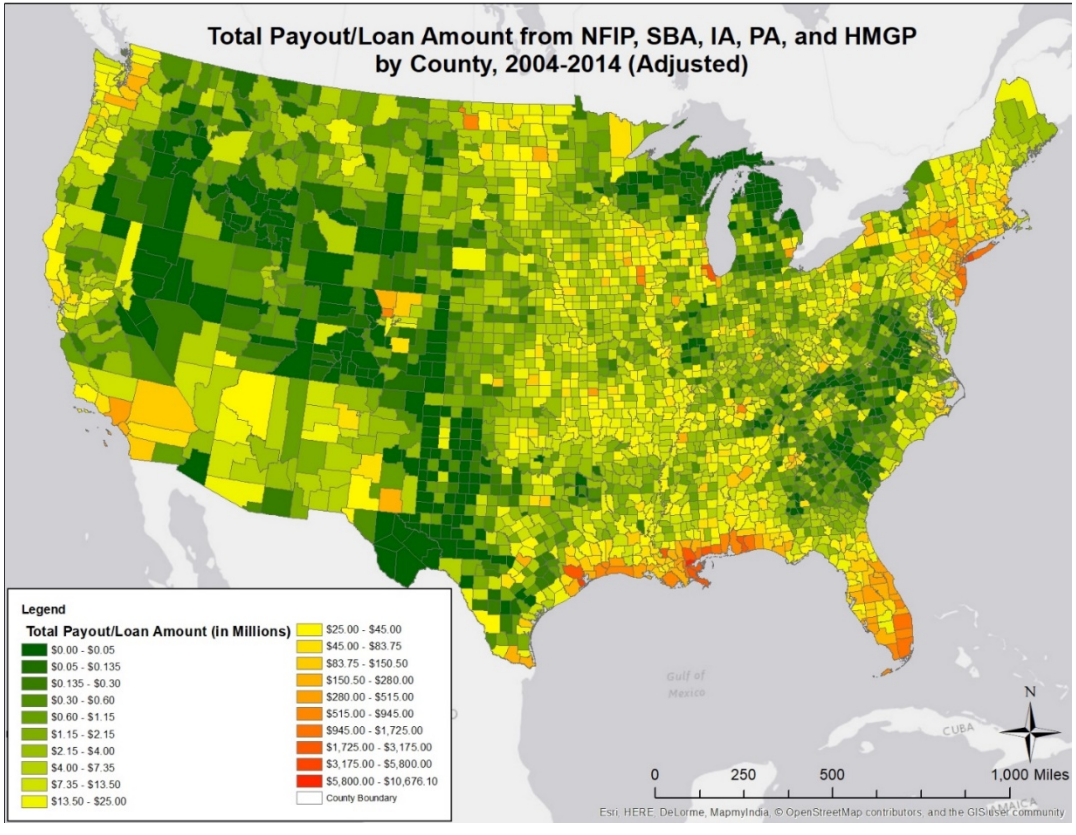
Historical flood losses highest in populous coastal counties



Losses in Harris and Cook counties are 2 orders of magnitude higher than losses in Baltimore and Maricopa counties

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Flood Risk Assessments

- More comprehensive picture of urban flooding
  - Flood hazard—probability and magnitude of the urban flood hazard
  - Exposure—population and economic assets at risk
  - Vulnerability—damage relationship between hazard and exposure
  - Performance—accounts for flood mitigation measures such as levees
- Yield much higher estimates of flood losses and population affected
- Limitations
  - Relatively few flood risk assessments, often black box or missing pluvial flood hazard
  - Insufficient historical data for calibration

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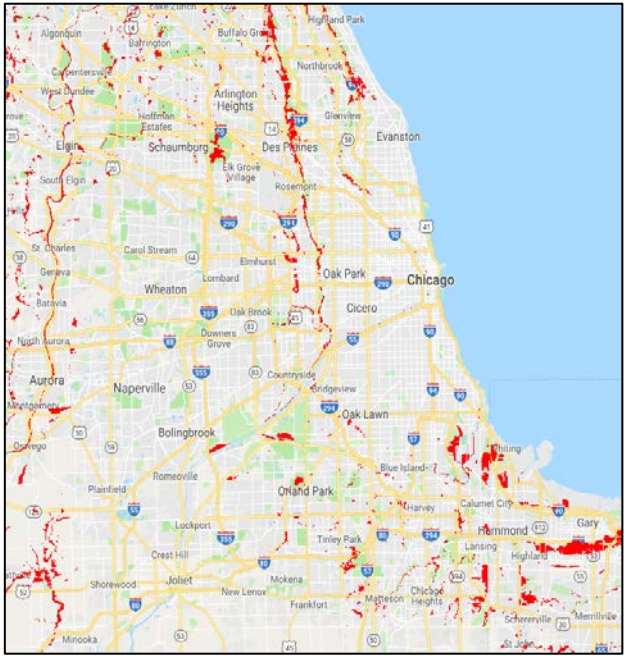
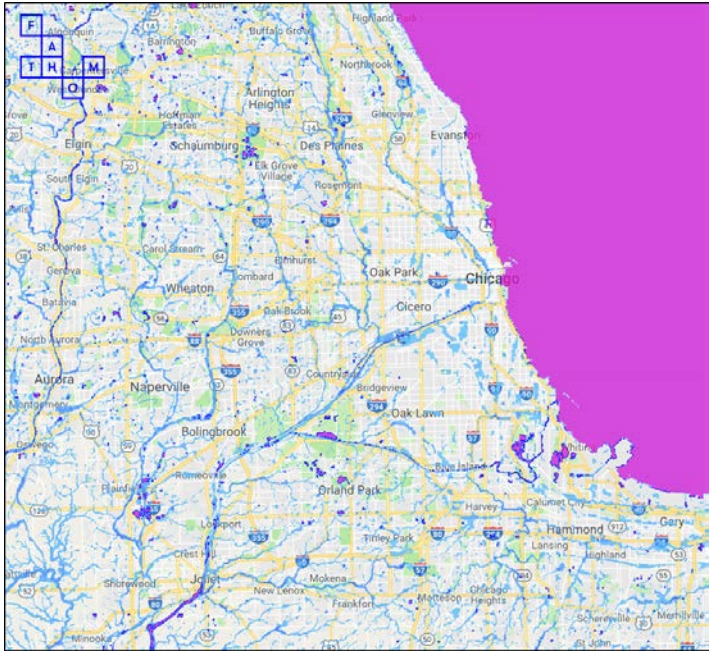
Comparison of Chicago Floodplains (1% annual chance)



FEMA riverine flood study
Population exposed: 135,000 (1%)



Wing et al. (2018) riverine & pluvial flood model
Population exposed: 945,000 (10%)

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Finding: Magnitude of Urban Flooding

- Existing data are inadequate to provide an accurate monetary estimate of the magnitude of urban flooding.
- Historical loss estimates for the counties that include Chicago and Houston average $200 million per year (for 2004–2014) in each county.
- 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 GDP, and the millions of urban residents exposed to flooding are considered in a flood risk assessment.
- Historical flood losses are lower in the counties that include Baltimore and Phoenix (few million dollars per year), but actual losses are likely much higher when the other contributing factors are considered.

Task 3: Connect Federal Resources to Urban Flooding

Key needs with a strong federal connection:

- Understanding and communicating urban flood hazard and risk
- Understanding and mitigating social impacts
- Coordinating organizations with a role in managing urban flooding

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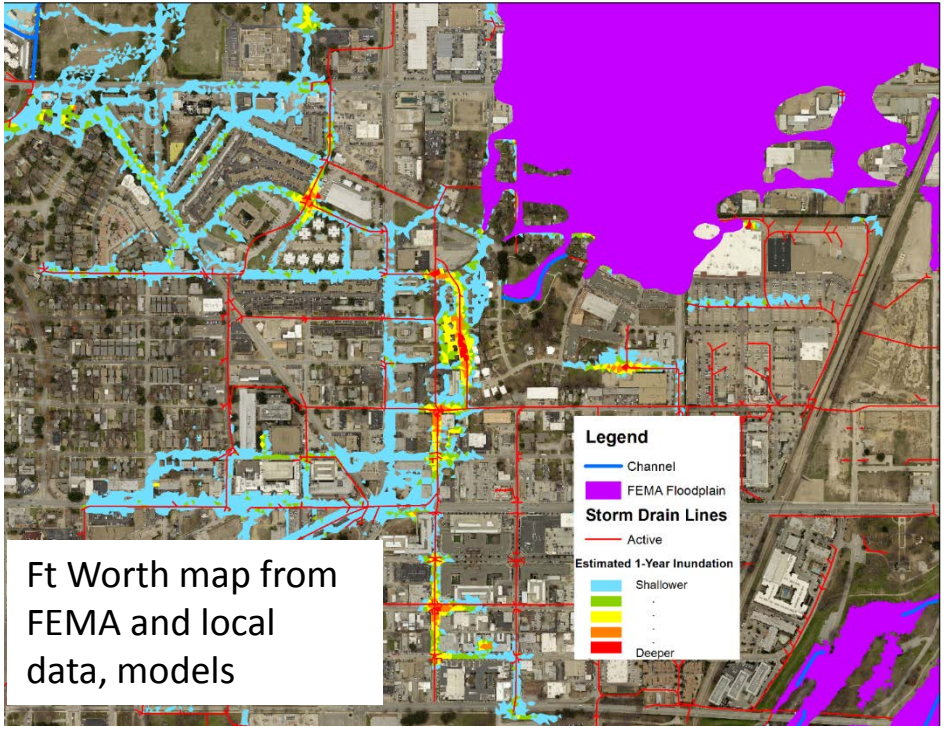
Urban Flood Hazard

Finding: An established method for analyzing urban flood hazard is needed

- Incorporate urban components and small-scale effects
  - topography, drainage, building design
- FEMA lead due to mission and experience
- Partners
  - Local government agencies for storm water systems and land characteristics
  - Modelers accounting for pluvial flooding



Ft Worth map from FEMA and local data, models

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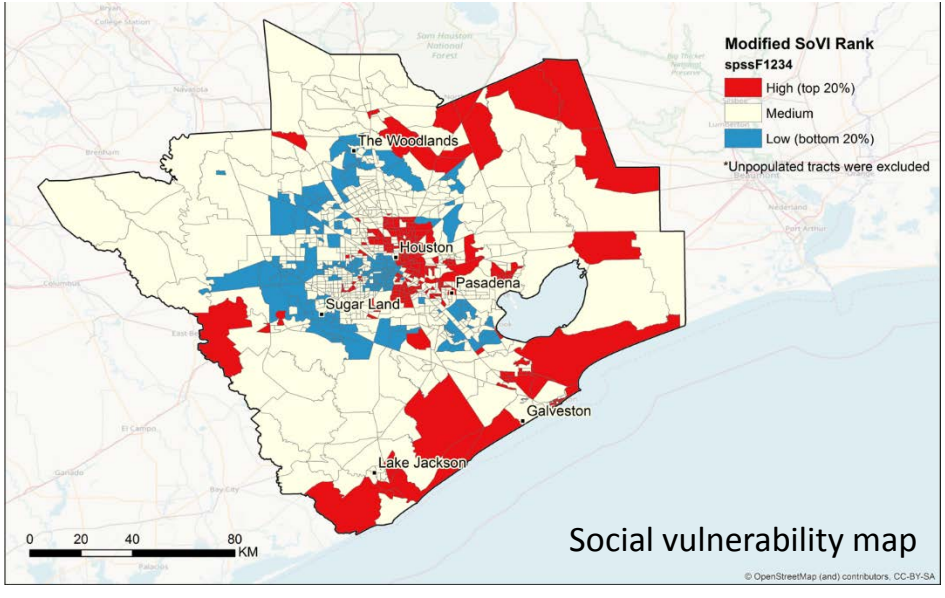
Socially Vulnerable Populations

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

- Research needs
  - Communities affected by urban floods
  - Indirect and intangible impacts (health, unemployment)
  - Building social networks and capacity
- NSF primary social science funder
- FEMA, USACE, CDC contribute experience with hazards and socially vulnerable groups



Social vulnerability map

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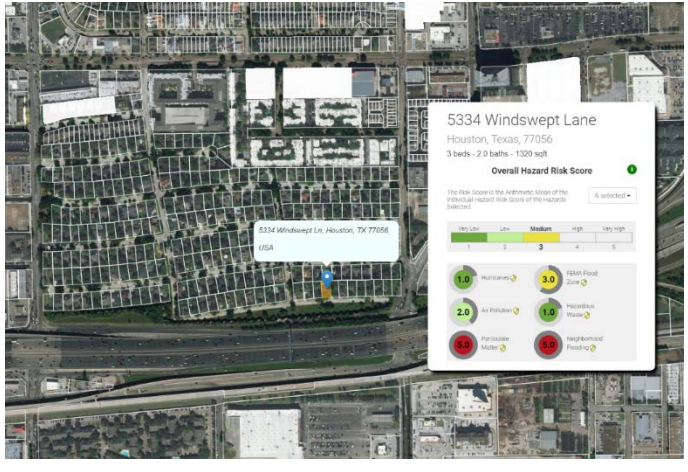
Communicating Flood Risk

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. Improved methods for updating the maps to keep pace with urbanization and climate change are also needed

- Flood risk maps & visualizations
  - Flood hazard (depth & extent of flooding for different scenarios)
  - Consequences of flooding (building damage, population exposure)
- Understandable to the public
  - relative risk, address lookup
- Contributors
  - FEMA, NOAA, NSF, Census, HUD



"Buyers B-Where"

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Agency Coordination

Finding: Stronger coordination is needed across agencies that have a role in managing small or large urban floods

- More than a dozen agencies may be involved
  - urban flood preparation, response, recovery, mitigation
- FEMA statutorily obligated to coordinate mitigation, response, and short-term recovery during major floods
- Floods too small to trigger federal resources are managed at state & local level
- Vertical (federal, state, local) and horizontal integration (local agencies) is needed

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Conclusions

- High costs and impacts of urban flooding merit national attention
- Flood problems will get worse with continued urban development and climate change
  - More people in harm's way, sea-level rise, more frequent heavy precipitation events
- Urban flooding is a complex problem that manifests across multiple dimensions
  - Requires multi-agency and multi-jurisdictional efforts to address