Tools and Strategies for Hazard Planning

E. NANCE

Outline

Introduction

Flood Risk

Green/Gray Infrastructure

Land Use Planning

Conclusions and Take-Home Points

Introduction

The objective of the presentation is to discuss best practices in flood hazard planning for our region.

This field is currently in transition so I will present both the old and new paradigms that are guiding practice.

The content is designed for public officials with a general familiarity of the subject, but who seek a deeper understanding that is relevant to practice.

Introduction

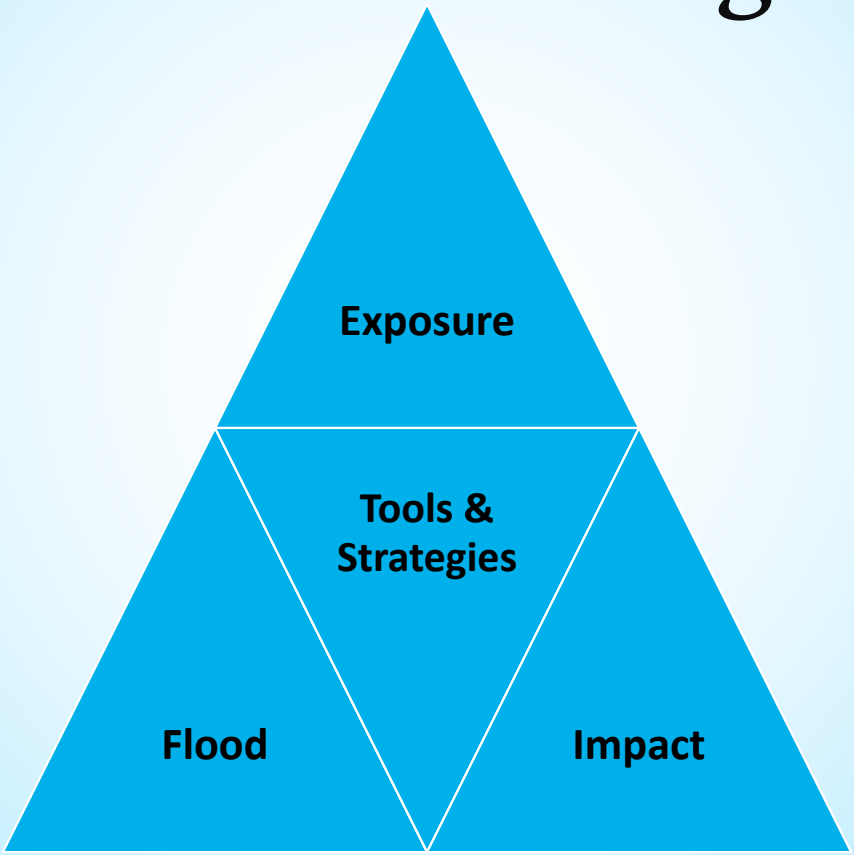
Recent documents by the Flood Mitigation Consortium are a helpful supplement to the lecture (note: I am a co-author).

"The Flood Next Time: What We Can Do Now" (May 2019)

"Development Regulations" (April 2019)

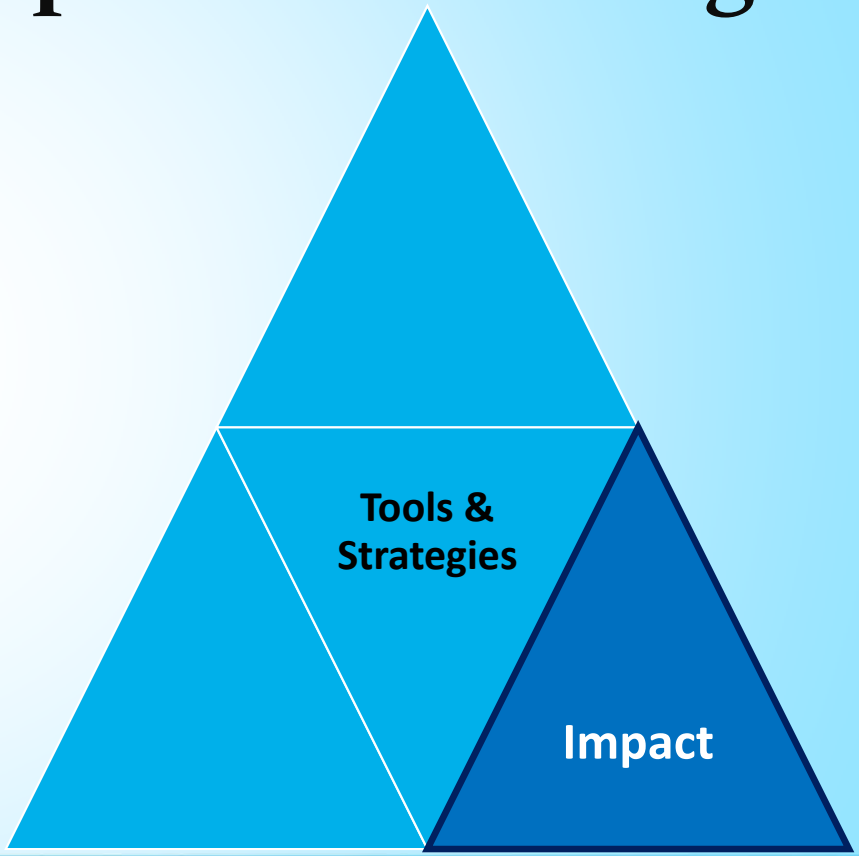
available at: https://www.houstonconsortium.com

Flood Hazard Planning Framework



Tools to Modify the Impact of Flooding

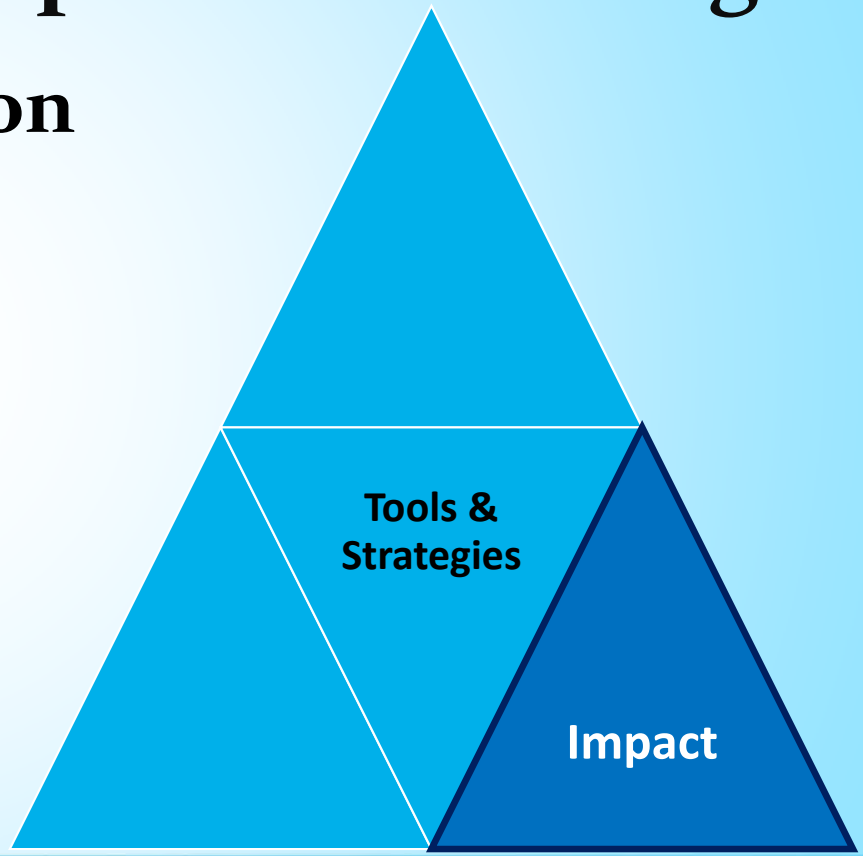
- Information and Education
- Flood Insurance
- Tax Adjustments
- Flood Emergency Measures
- Post-Flood Recovery



FEMA, Flood Damage Reduction Strategies and Tools, Ch. 7.

Tools to Modify the Impact of Flooding

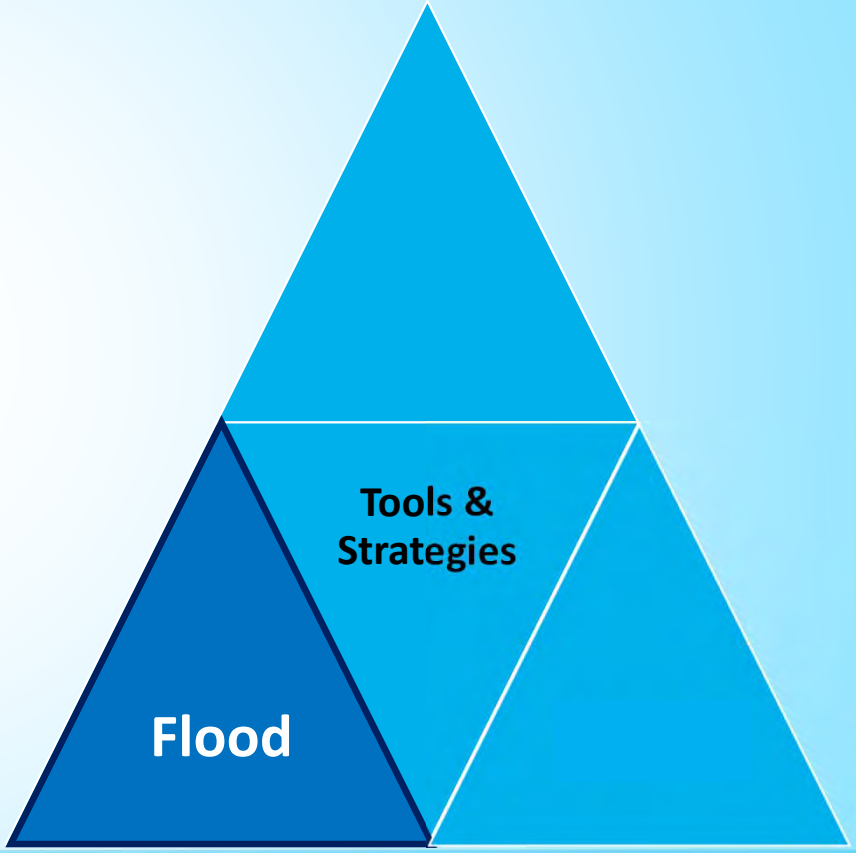
- **Information and Education**
- Flood Insurance
- Tax Adjustments
- Flood Emergency Measures
- Post-Flood Recovery



FEMA, Flood Damage Reduction Strategies and Tools, Ch. 7.

Tools to Modify the Flood Itself

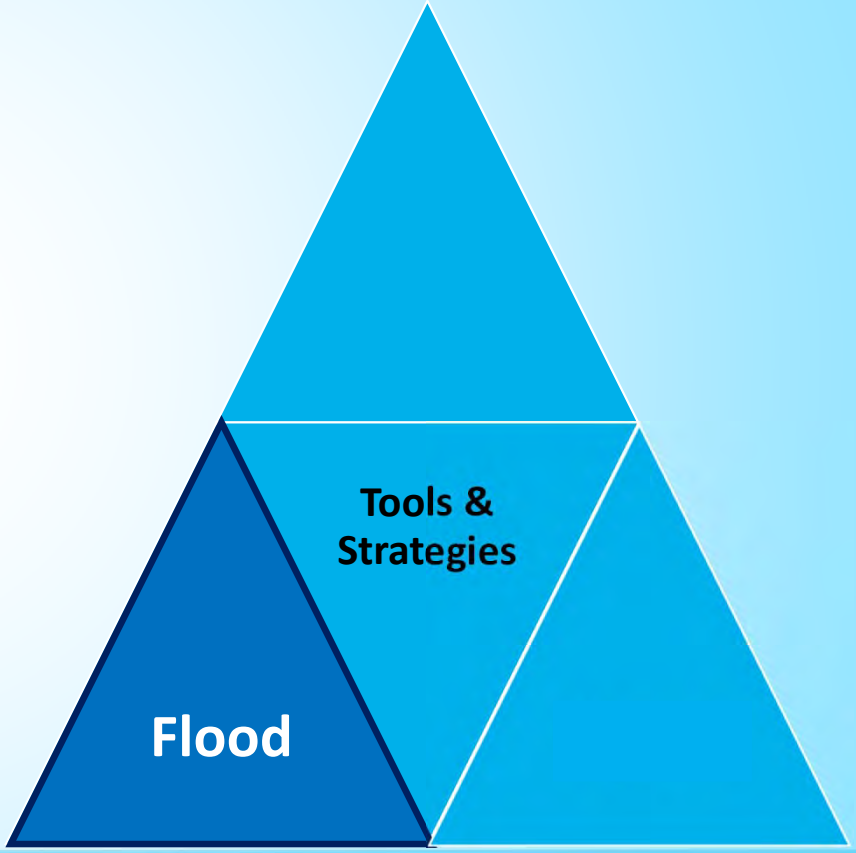
- Dams, Reservoirs
- Dikes, Levees, Floodwalls
- Channels, Canals
- Diversions, Spillways
- Onsite Detention
- Shoreline Protection
- Local Drainage Systems



FEMA, Flood Damage Reduction Strategies and Tools, Ch. 7.

Tools to Modify the Flood Itself

- Dams, Reservoirs
- Dikes, Levees, Floodwalls
- Channels, Canals
- Diversions, Spillways
- Onsite Detention
- Shoreline Protection
- Local Drainage Systems
- **Green Infrastructure/LID**

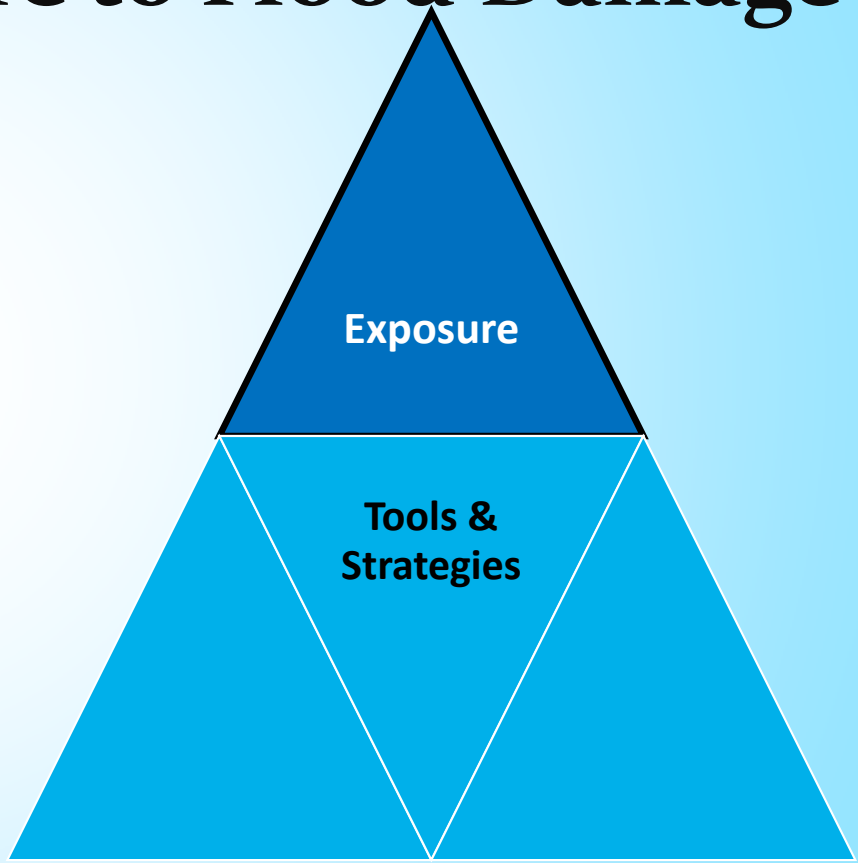


GRAY + GREEN

FEMA, Flood Damage Reduction Strategies and Tools, Ch. 7.

Tools to Modify Exposure to Flood Damage

- Development Regulations
- Development Policies
- Disaster Preparedness
- Floodproofing
- Flood Warning Systems
- Green Infrastructure/LID

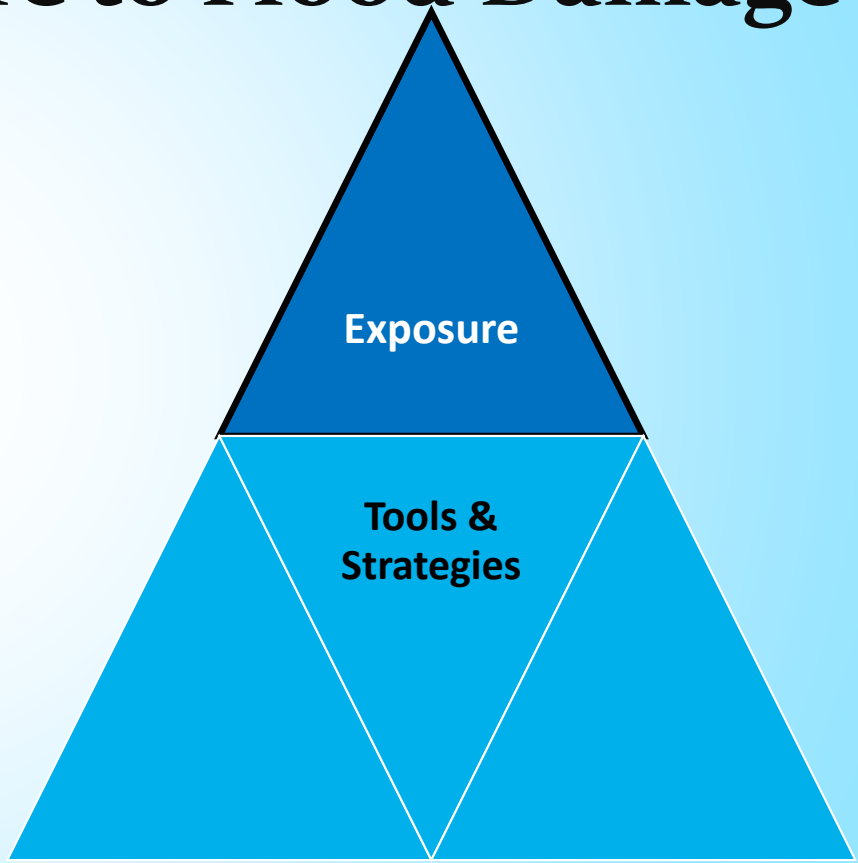


FEMA, Flood Damage Reduction Strategies and Tools, Ch. 7.

Tools to Modify Exposure to Flood Damage

LAND USE

- Development Regulations
- Development Policies
- Disaster Preparedness
- Floodproofing
- Flood Warning Systems
- Green Infrastructure/LID



FEMA, Flood Damage Reduction Strategies and Tools, Ch. 7.

part 1. Flood Risk

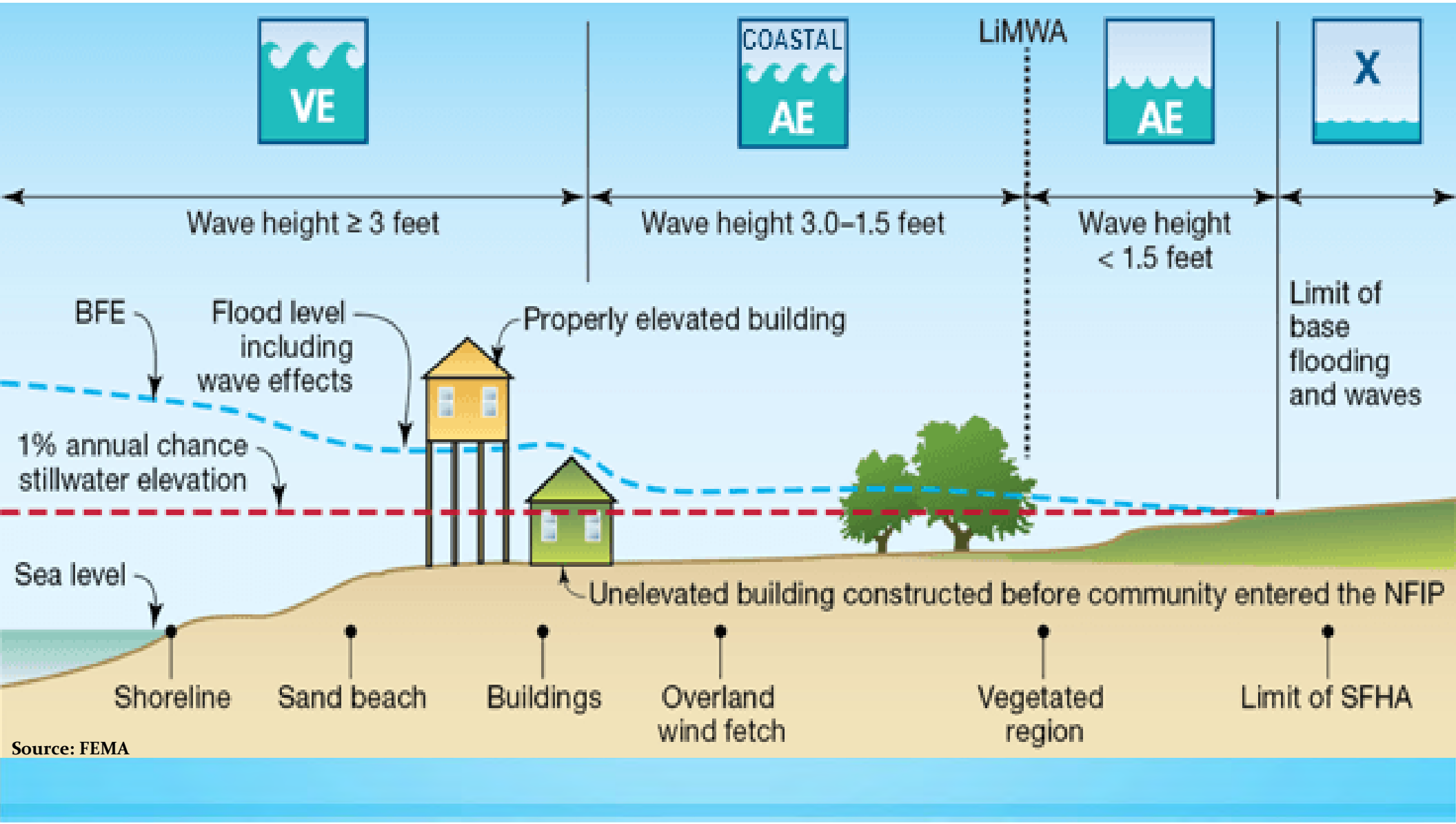
Basic Terms

- Probability = chance of occurrence of a flood
- Frequency = how often a flood occurs
- 1% AEP = one-percent annual exceedance probability, or 1% chance, or 100-year flood
- Exposure = number of people and value of property subject to damage
- Consequences = quantifiable impacts of the disaster in terms of expected lives lost and dollar damages

Types of Flooding

- Slow Onset –vs– Rapid Onset Flooding

Slow	Rapid
Includes riverine floods, excess rainfall, insufficient drainage	Includes flash floods, storm surge, levee/dam/channel failure
Less intense, slow flow	More intense, fast flow
Longer duration, able to escape	Shorter duration, no escape time
Less damage, soaking	More damage, velocity waves
Less risk to life and property	Greater risk to life and property


VE
COASTAL
AE
LiMWA
AE
X
Wave height ≥ 3 feet
Wave height 3.0–1.5 feet
Wave height
< 1.5 feet
BFE
Flood level
including
wave effects
Properly elevated building
Limit of
base
flooding
and waves
1% annual chance
stillwater elevation
Sea level
Unelevated building constructed before community entered the NFIP
Shoreline
Sand beach
Buildings
Overland
wind fetch
Vegetated
region
Limit of SFHA

Source: FEMA

Types of Flood Risk

- High Frequency –vs– High Consequence

High Frequency	High Consequence
Annual spring floods, snow melt	Extreme weather, catastrophic flooding
Conventional	Also known as residual risk
Rainfall intensity & duration	Exposure & system performance
Repetitive damage	Extraordinary damage
Frequent exposure	Infrequent exposure
Risk is broadly perceived	Risk is not perceived

Resilience strategies must address both types of risk.

UNIVERSITIES COUNCIL ON WATER RESOURCES
JOURNAL OF CONTEMPORARY WATER RESEARCH & EDUCATION
ISSUE 141, PAGES 21-30, MARCH 2009

Responding to Risk: The Making of Hazard Mitigation Strategy in Post-Katrina New Orleans

Earthea Nance

Director of Disaster Mitigation Planning, City of New Orleans

New Orleans faces unique types of catastrophic risk resulting from a combination of factors that include potential levee failure, land subsidence, coastal erosion, rising sea level, and stronger and more frequent storm activity. A comprehensive hazard mitigation strategy would address these unique types of catastrophic risks in addition to addressing the standard types of repetitive risk already covered by conventional approaches. Diverse actors are engaged in the making of this new strategy. This paper introduces New Orleans' response to its emerging risk profile, with emphasis on the risk of flooding.

Background

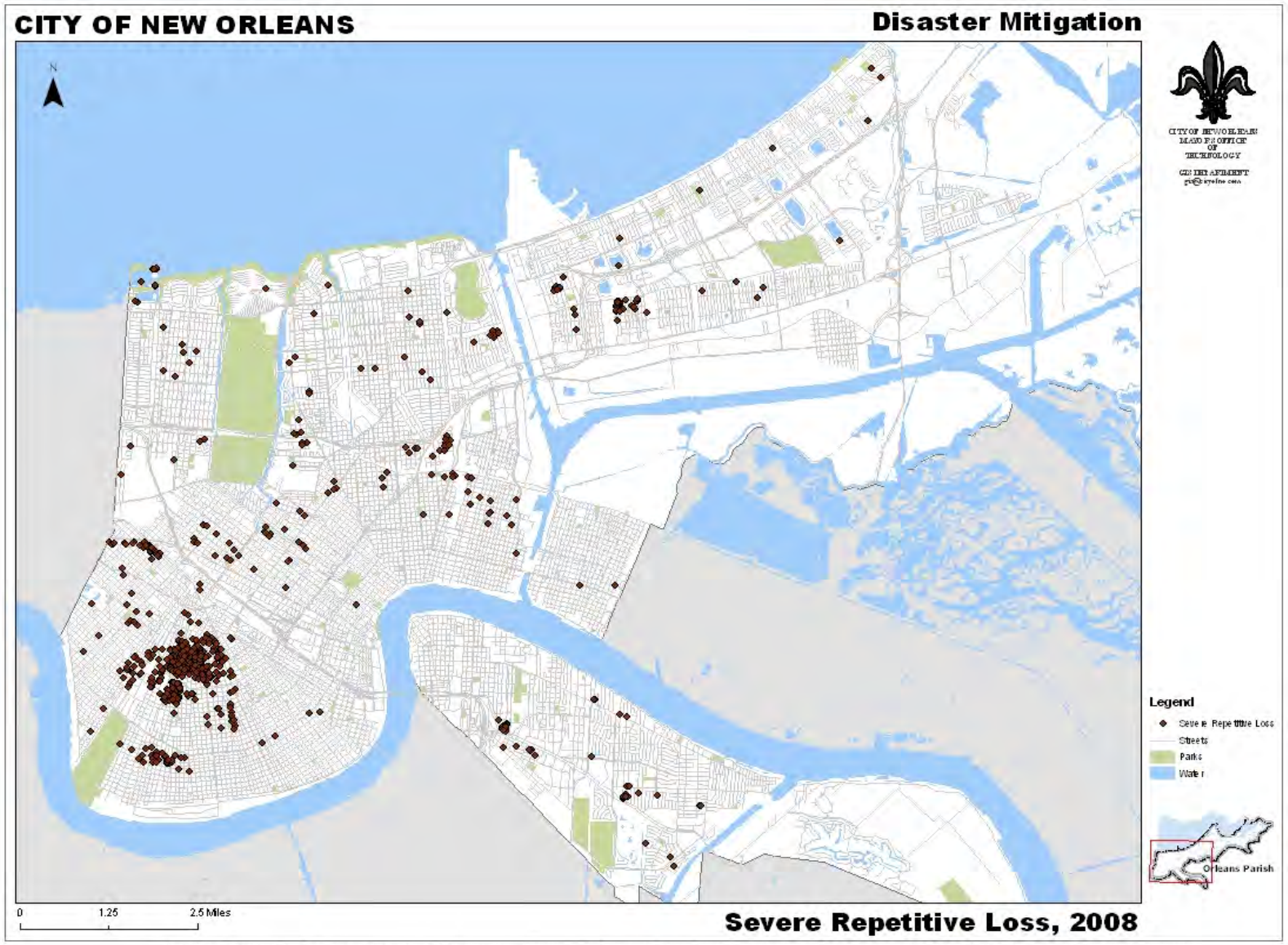
The premise underlying the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program is that future claims covered by the National Flood Insurance Program (NFIP) must be reduced. Such claims arise as a result of flood damage to homes insured under NFIP. Flood insurance for homeowners is federally subsidized and shared across the U.S. In the case of Louisiana, most claims are covered by payments from outside the Southeast region (FEMA 2008). Naturally, the federal government has an interest in reducing overall program costs, and for this reason it operates a national hazard mitigation program comprised of several types of grants to mitigate against flood risk and to reduce the cost of claims. Only those homes that have already filed numerous flood damage claims are eligible for these grants. FEMA keeps track of these repetitively damaged homes by identifying them as Repetitive Loss and Severe Repetitive Loss properties[1].

To meet the goal of reducing the overall cost of claims paid, the primary objective of the Hazard Mitigation Grant Program is to provide grants for mitigating Repetitive Loss and Severe Repetitive Loss properties (e.g., by elevation, reconstruction, acquisition, etc.) when the cost of the mitigation is less than the cumulative cost of NFIP claims. Only NFIP-insured property owners are eligible, and only those property owners that filed enough past claims to warrant inclusion on the Repetitive Loss and Severe Repetitive Loss lists can receive mitigation grant money. Therefore, these criteria prioritize properties with a documented history of flood damage, and they direct hazard mitigation funds to properties that were the subject of past flood risk. While necessary in its own right, this hazard mitigation strategy is insufficient on several grounds. Most fundamental of these is that the strategy manages risk as if it were a static phenomenon. In truth, risk is a changing phenomenon. The risks of the past are not the same as the risks of the future. Moreover, our understanding of risk continues to change over time. As a result, the conventional hazard mitigation strategy as performed under FEMA's Hazard Mitigation Grant Program contains gaps that preclude a focus on the elimination of future flood risk, which is considerable.

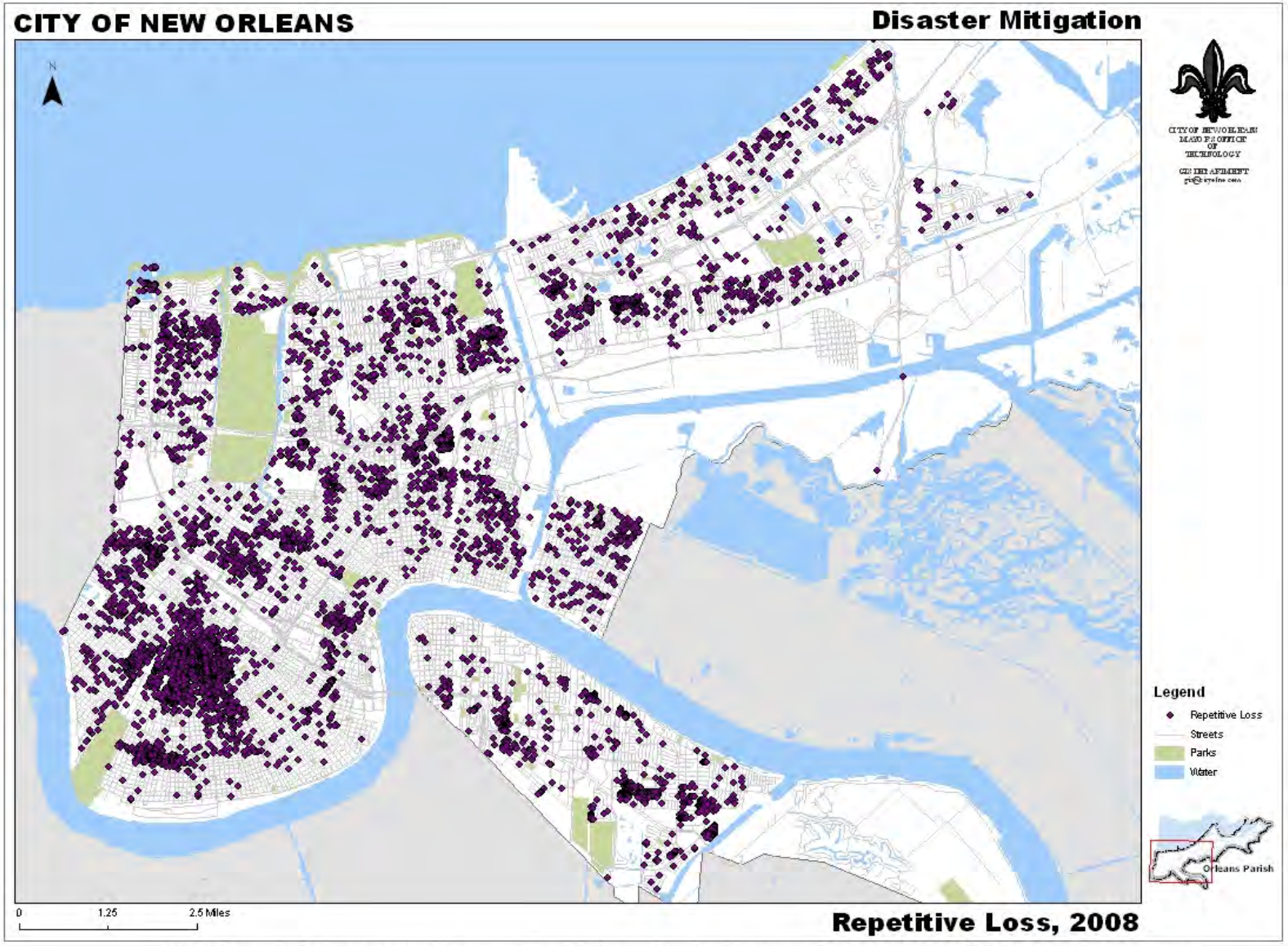
How Mitigation Funds are Prioritized

What does this mean in New Orleans? Figure 1 is a map of the properties on FEMA's 2008 Severe Repetitive Loss list for New Orleans. The most severely damaged properties are concentrated in the lowest lying area of the city, known as the bottom

4 claims >$5k each or
2 claims >FMV and insured

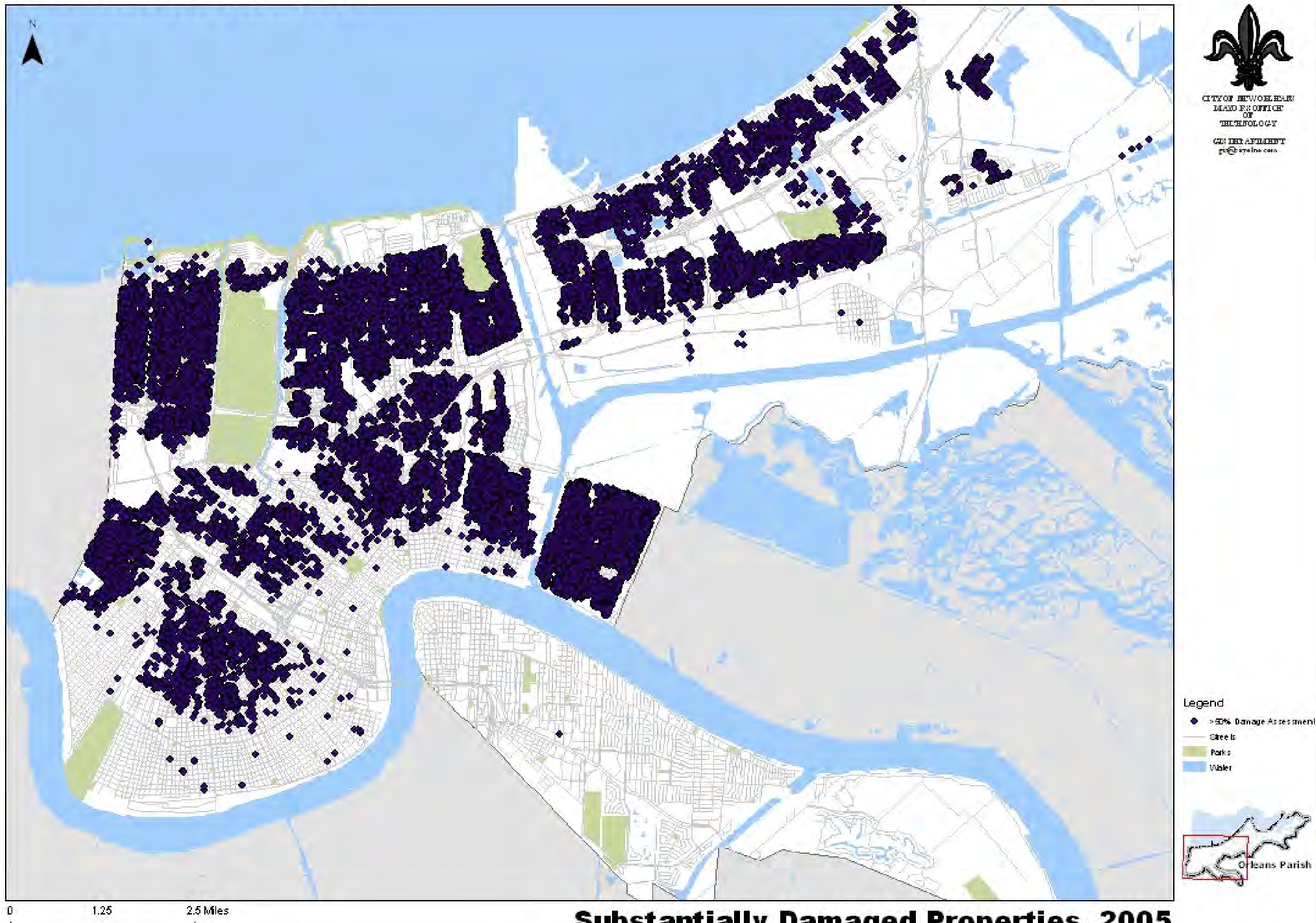


2 claims > $1k each over 10 years, insured

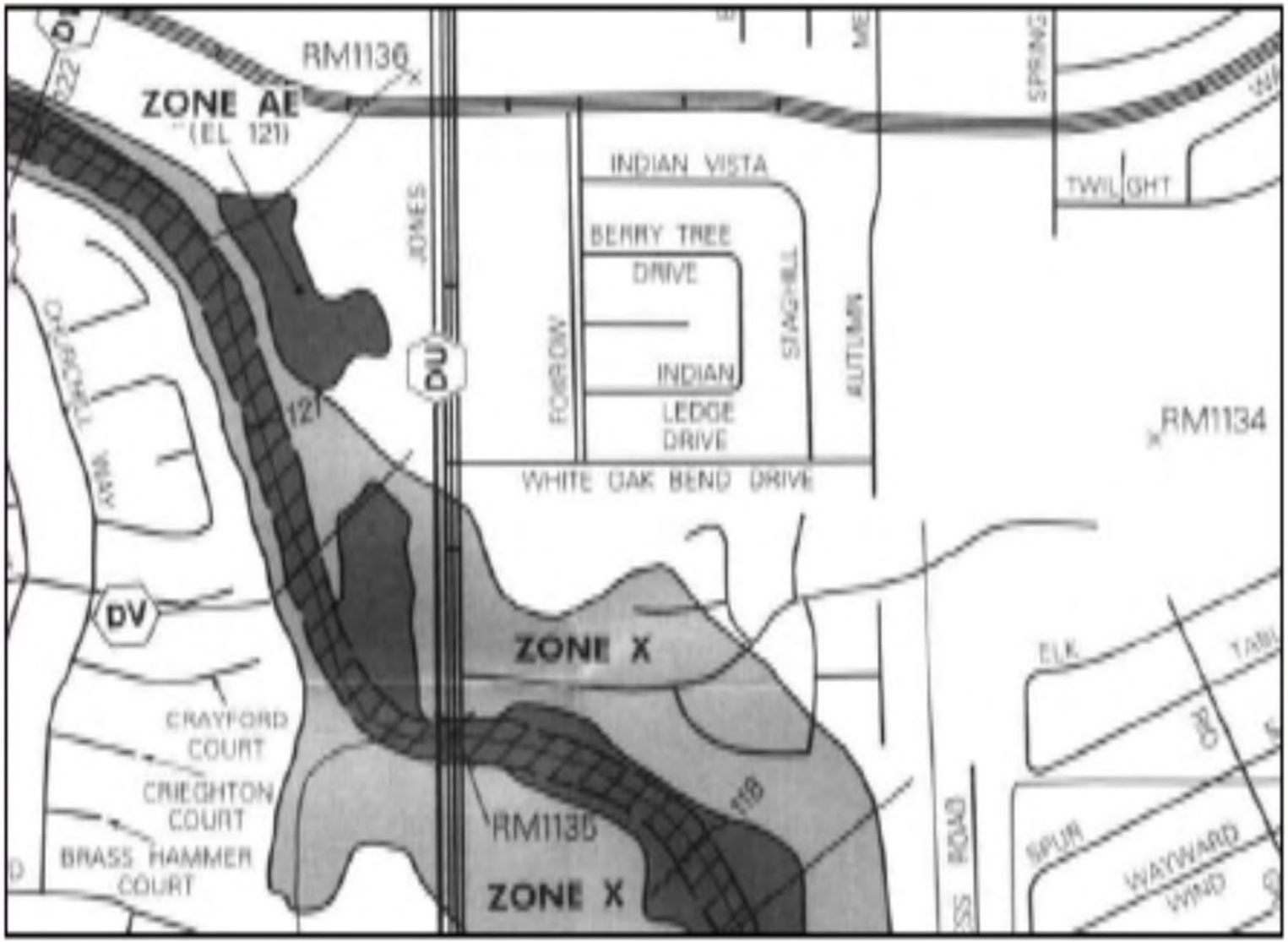


CITY OF NEW ORLEANS

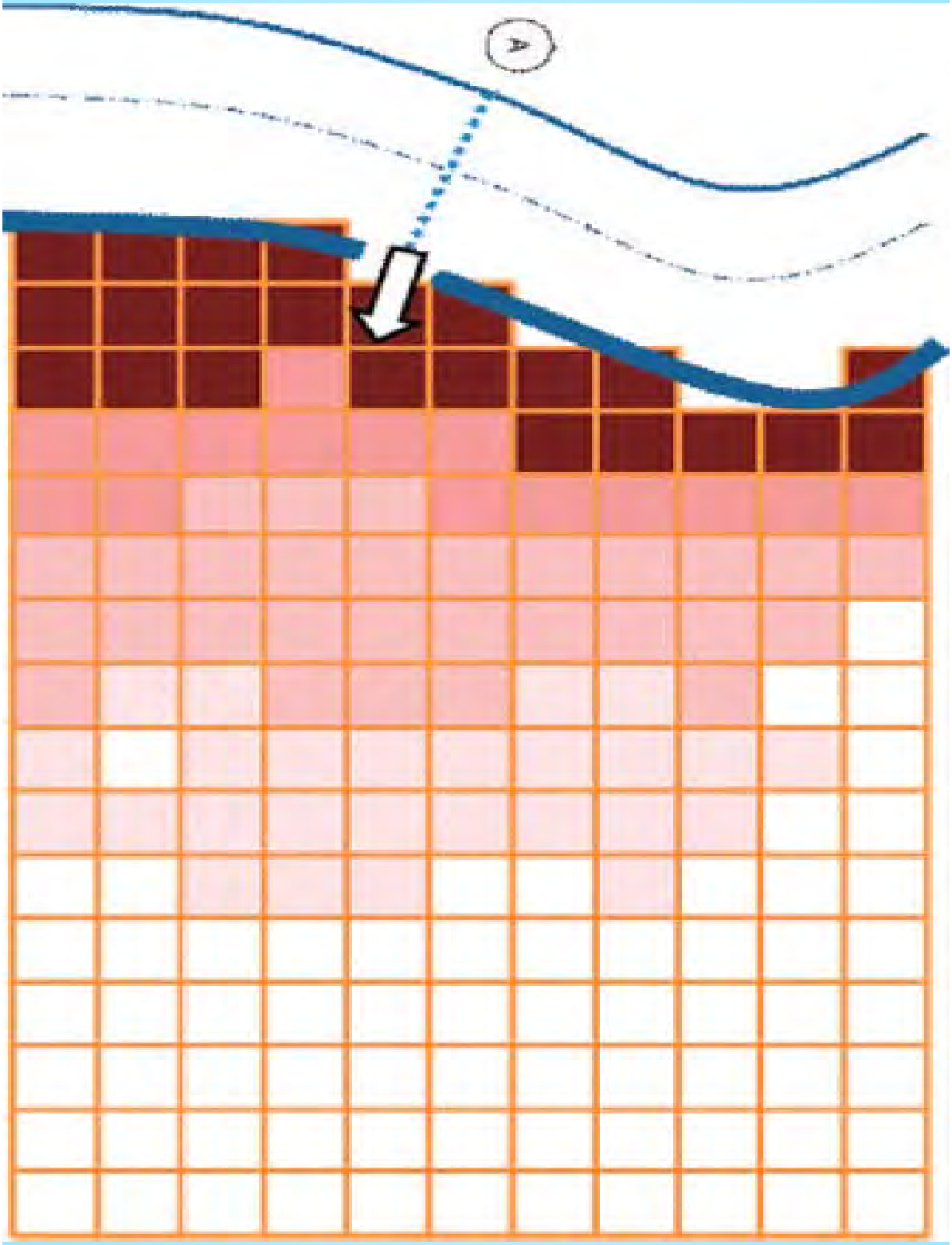
Disaster Mitigation



Substantially Damaged Properties, 2005

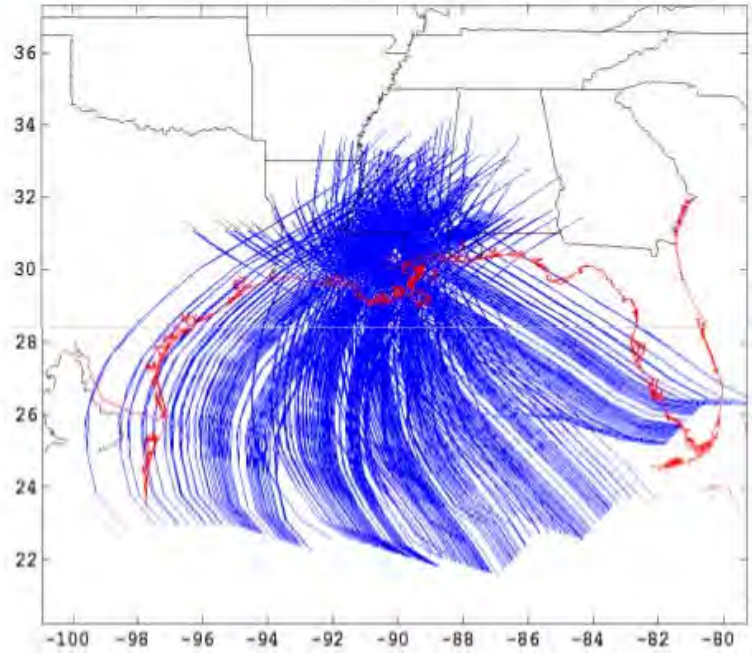

RM1136
ZONE AE
(EL 121)
INDIAN VISTA
BERRY TREE
DRIVE
INDIAN
LEDGE
DRIVE
WHITE OAK BEND DRIVE
JONES
FOREDOW
STAGHILL
AUTUMN
SPRING
TWILIGHT
RM1134
DU
DV
121
ZONE X
CRAYFORD
COURT
CREIGHTON
COURT
BRASS HAMMER
COURT
RM1135
ZONE X
118
ELK
SPUR
WAYWARD
WIND

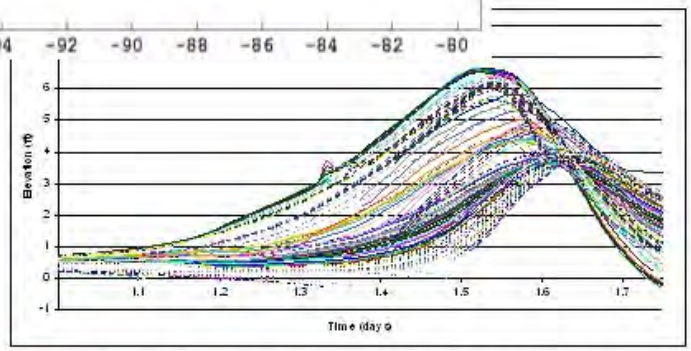
Source: National Research Council. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices.*



Hurricane Paths Considered in the Risk Analysis

US Army Corps of Engineers



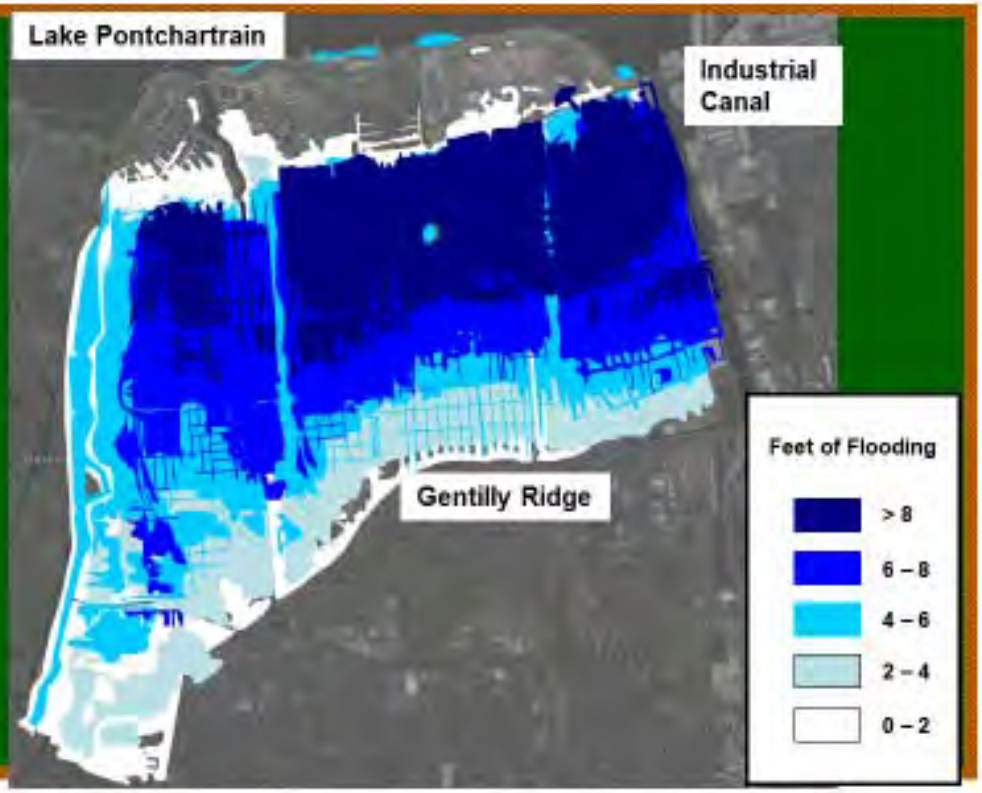


- *3 HPS Geometries*
  - *Pre-Katrina*
  - *Current (1 June 07)*
  - *100-year LOP (~2011)*
- *152 storm hydrographs*
- *350+ features*
  - *Floodwalls*
  - *Levees*
  - *Pumps Stations*

→ **62,928 Hurricane Hydrographs**

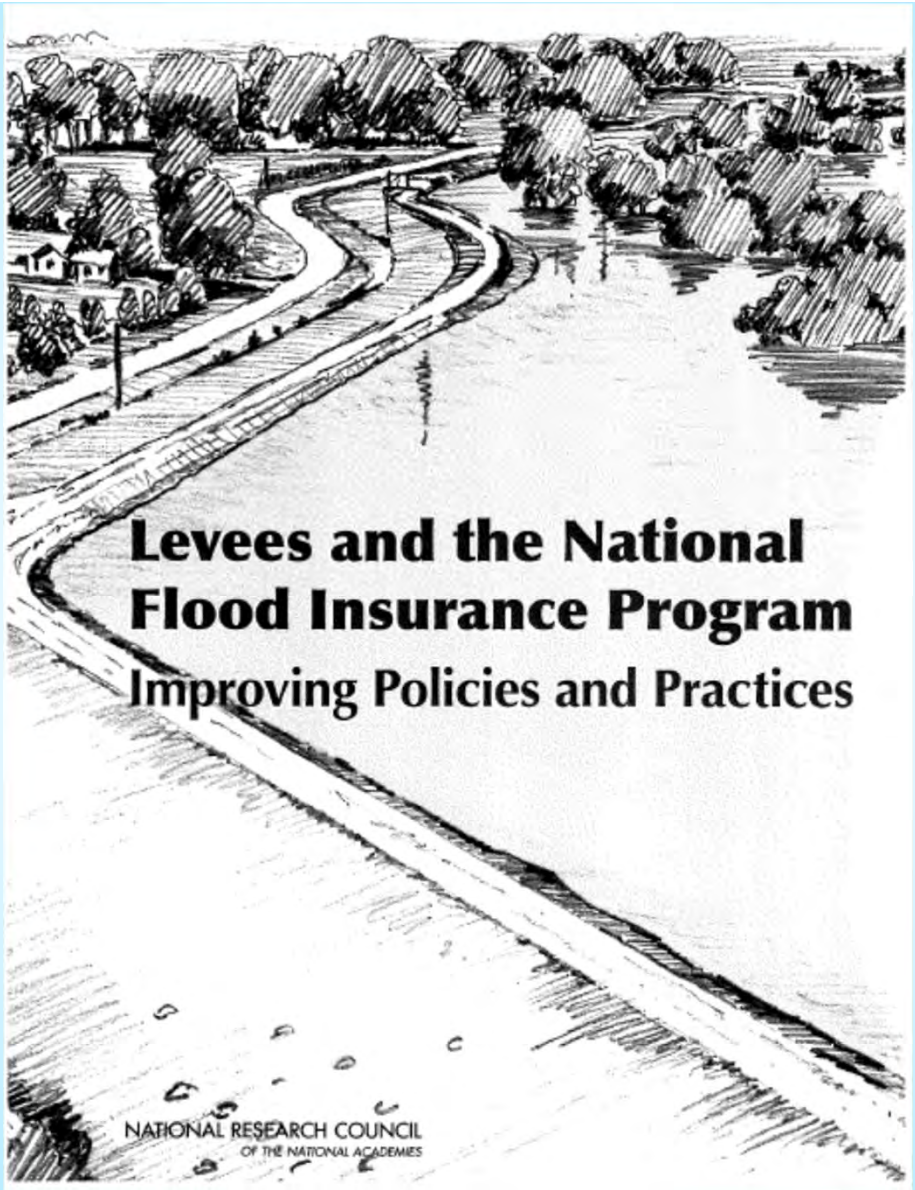
Risk Assessment Flood Maps

The Risk Maps are color- coded to indicate how deep the water is.



US Army Corps of Engineers

Source: US Army Corps of Engineers.


Levees and the National
Flood Insurance Program
Improving Policies and Practices
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Flood Risk Analysis

- Probabilistic analysis –vs- Deterministic analysis
- Deterministic = outcome can be determined by the initial conditions(observational record)
- Probabilistic = outcome is random but likelihood can be ascertained (predictive models)
- Researchers conclude that probabilistic flood mapping is the best approach (NRC, 2013; Baldassarre, et al, 2010).

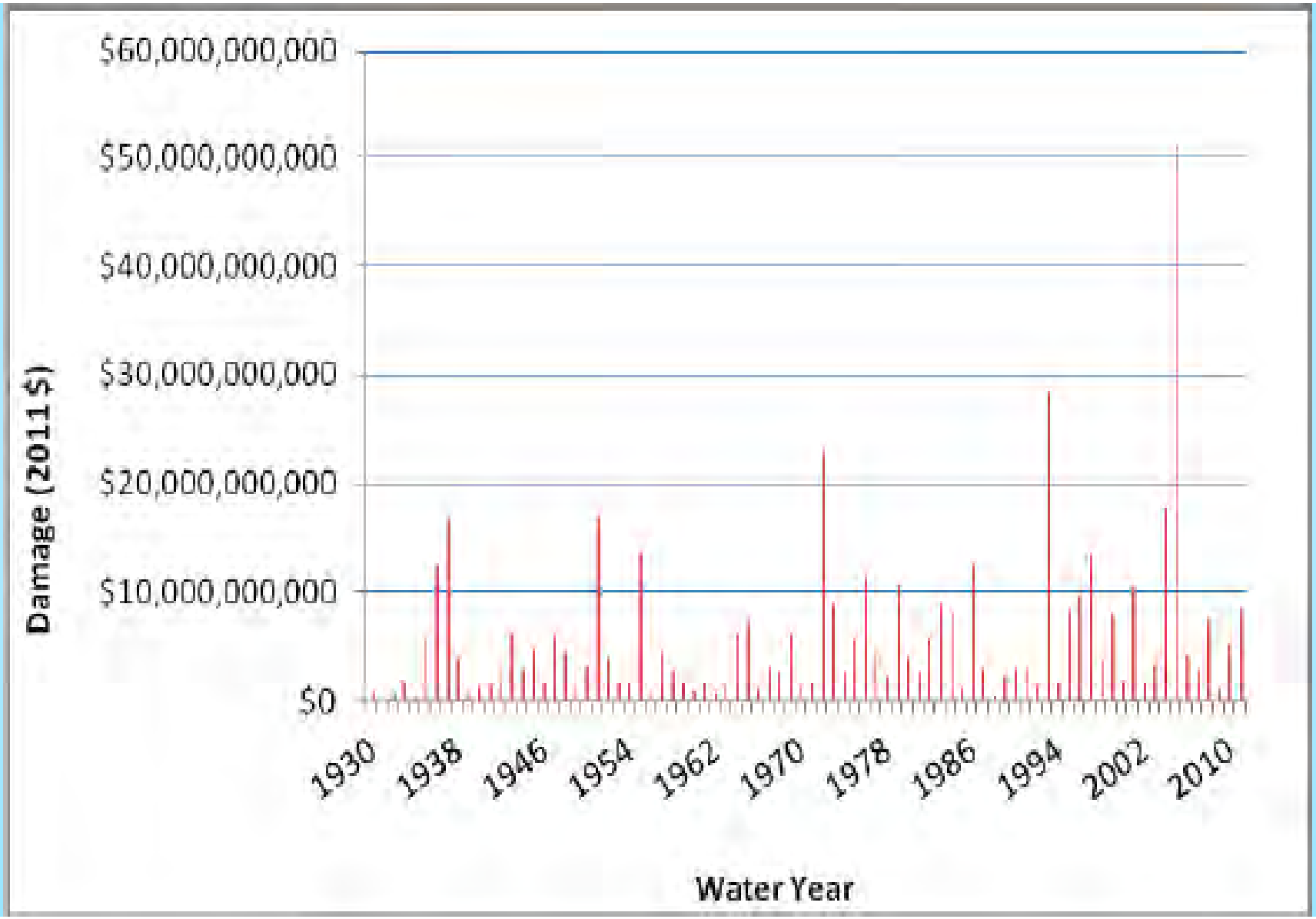
Flood Risk Analysis

- Stationarity –vs- Non-Stationarity
- Stationarity = the assumption that annual maximum floods conform to a stationary, independent, identically distributed random process.
- This assumption underlies conventional flood risk assessment.

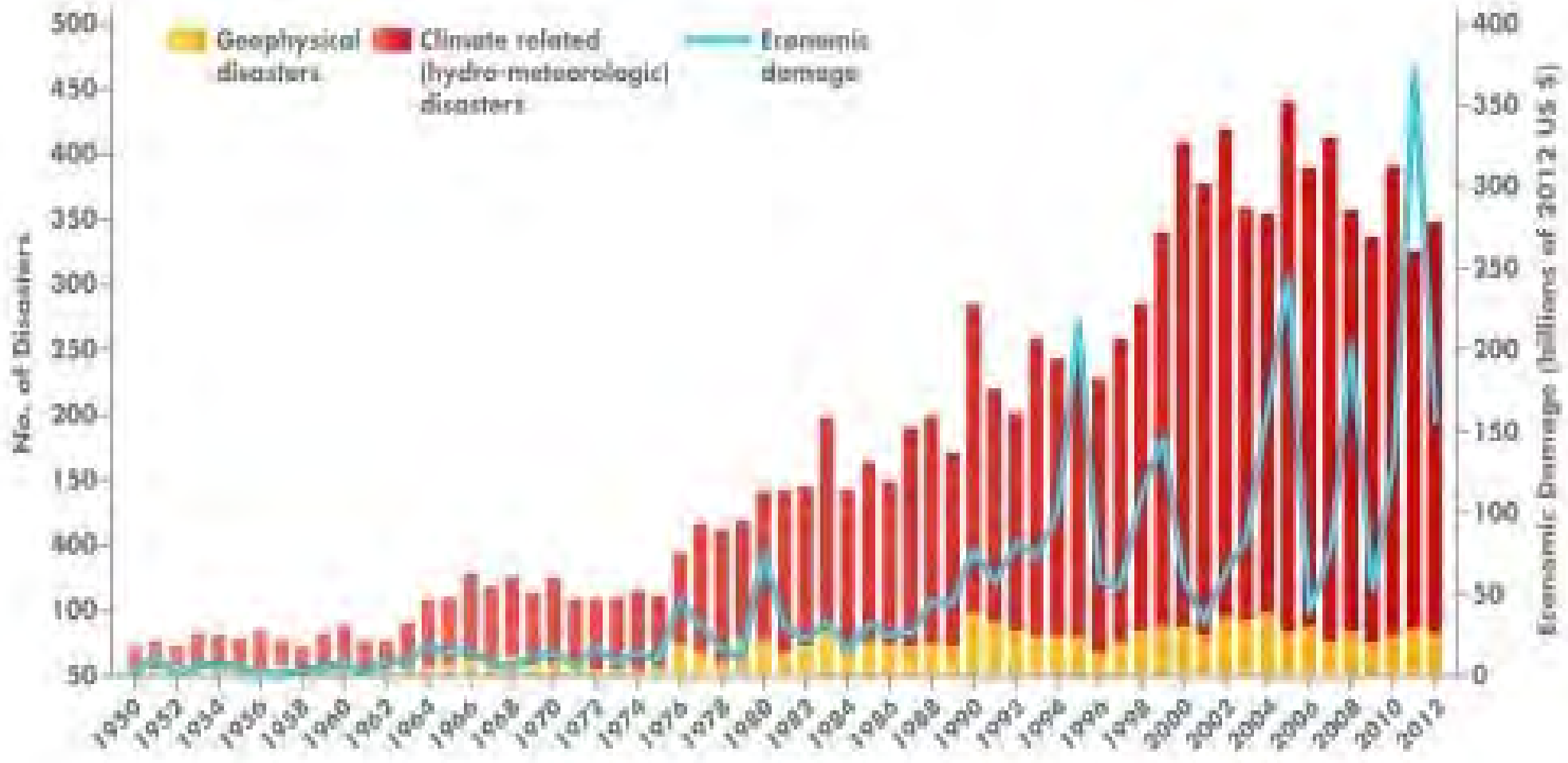
Improving American River Flood Frequency Analysis, Ch.4, National Academies Press, 1999.

Flood Risk Analysis

- Non-stationarity = lack of physical constancy in the regimes of precipitation, evaporation, geomorphology, meteorology, and other hydrologic and atmospheric variables (e.g., long-term mean, variance, and autocorrelation structure).
- Researchers conclude that flood risk is best evaluated with the assumption of non-stationarity. (Galloway, 2009; Milly, 2008; Klemes, 1989)

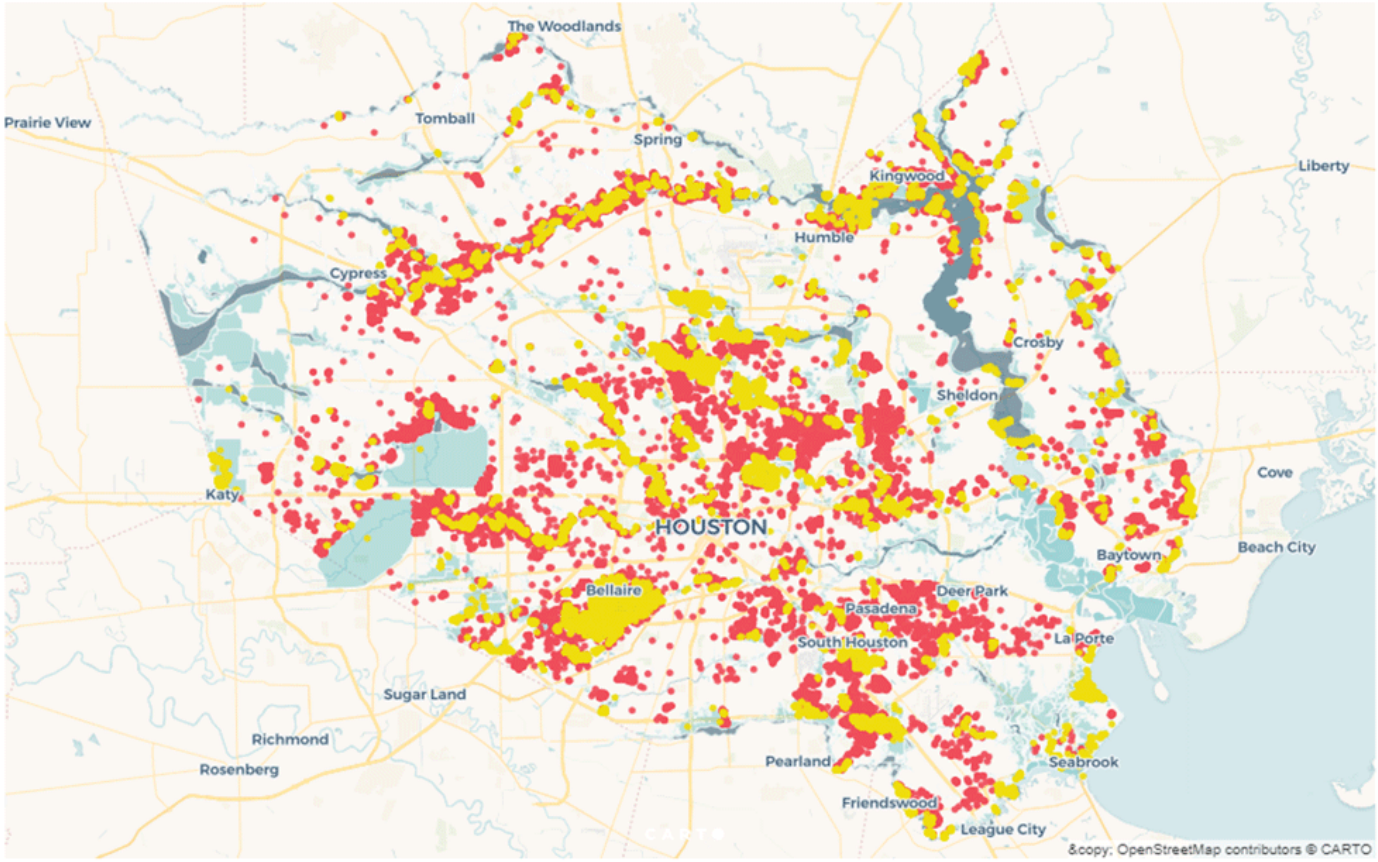


Source: National Research Council. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices.*



Source: https://owlcation.com/stem/Worlds-worst-natural-disasters

Total flooded structures



What is Modern Flood Risk Analysis?

A modern flood risk analysis is defined as a risk analysis using the best available science and analytical methods to evaluate flood risk.

This is more precisely defined as an analysis where the likelihood of adverse consequence (loss of life and property) is quantitatively evaluated and takes into account the following:

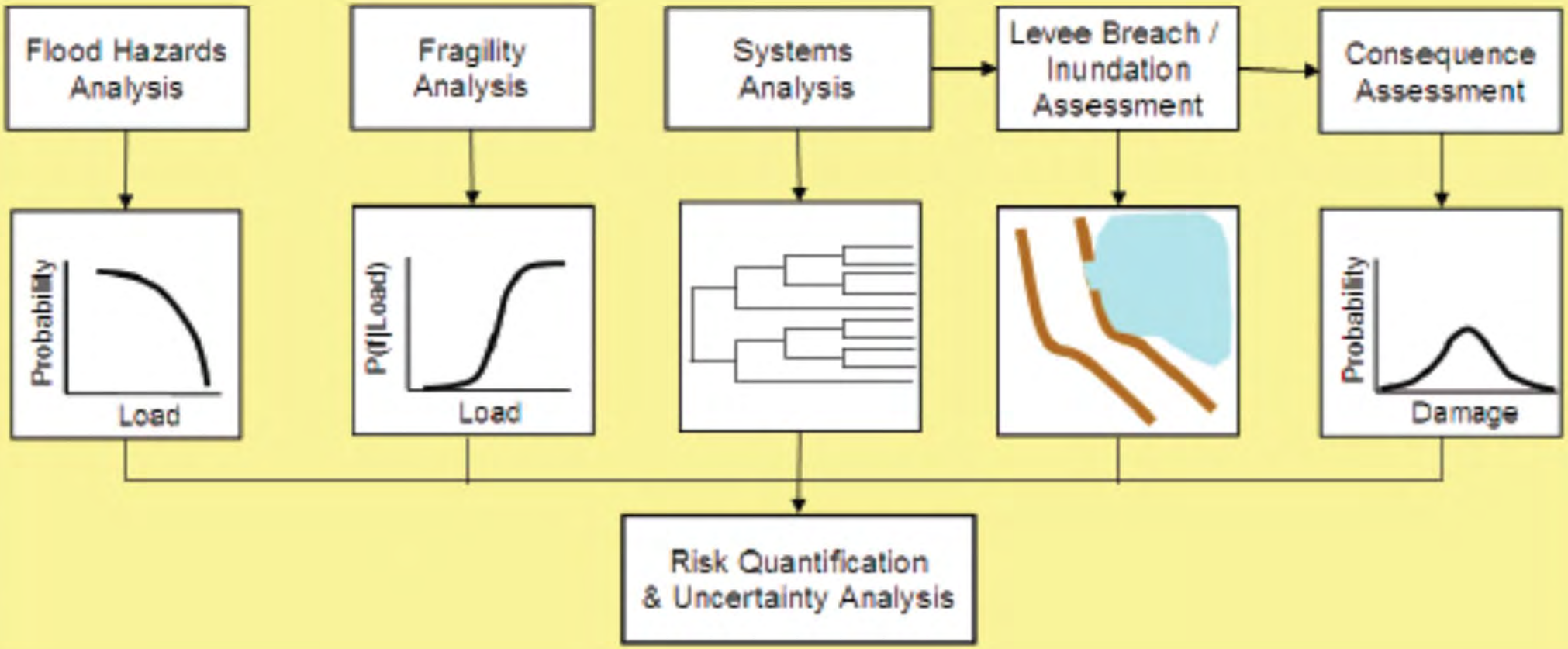
Source: National Research Council. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices.*

What is Modern Flood Risk Analysis?

1. The likelihood of flood events occurring (the randomness of future events);
2. The likelihood that the capacity of structural flood protection systems may be overwhelmed by the flood (be overtopped) or fail (the randomness of structure performance for given levels of loading), leading to flooding of protected areas; and,
3. Given that flooding has occurred, an assessment of the consequences that occur.

Source: National Research Council. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices.*

Elements of Modern Flood Risk Analysis



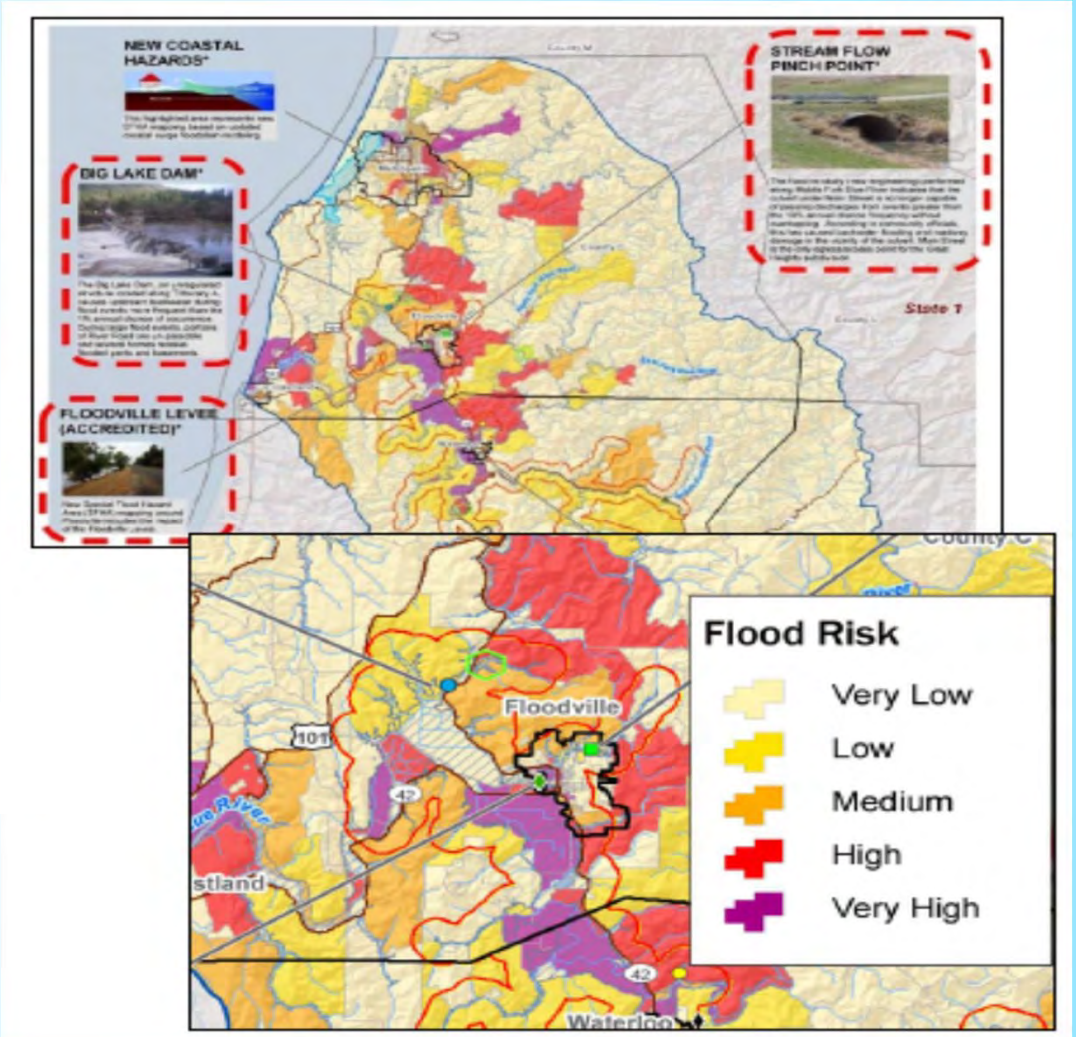
Source: National Research Council. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices.*

What is Modern Flood Risk Analysis?

Each element of the analysis is subject to uncertainty; neither the chance that different-size flood events can occur nor their magnitude can be estimated exactly—they are uncertain.

These uncertainties and the related implications to the estimate of risk are quantitatively evaluated in a modern risk-based analysis.

Source: National Research Council. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices.*



Source: National Research Council. (2013). *Levees and the National Flood Insurance Program: Improving Policies and Practices.*

Flood Risk Best Practices

- Renters and homeowners need outreach, education, and access to risk information.
- Local regulations, ordinances, and plans should be based on up-to-date risk maps.
- Risk maps should cover all types of flooding and use up-to-date rainfall and topography data.
- Risk maps should be reviewed and updated regularly.

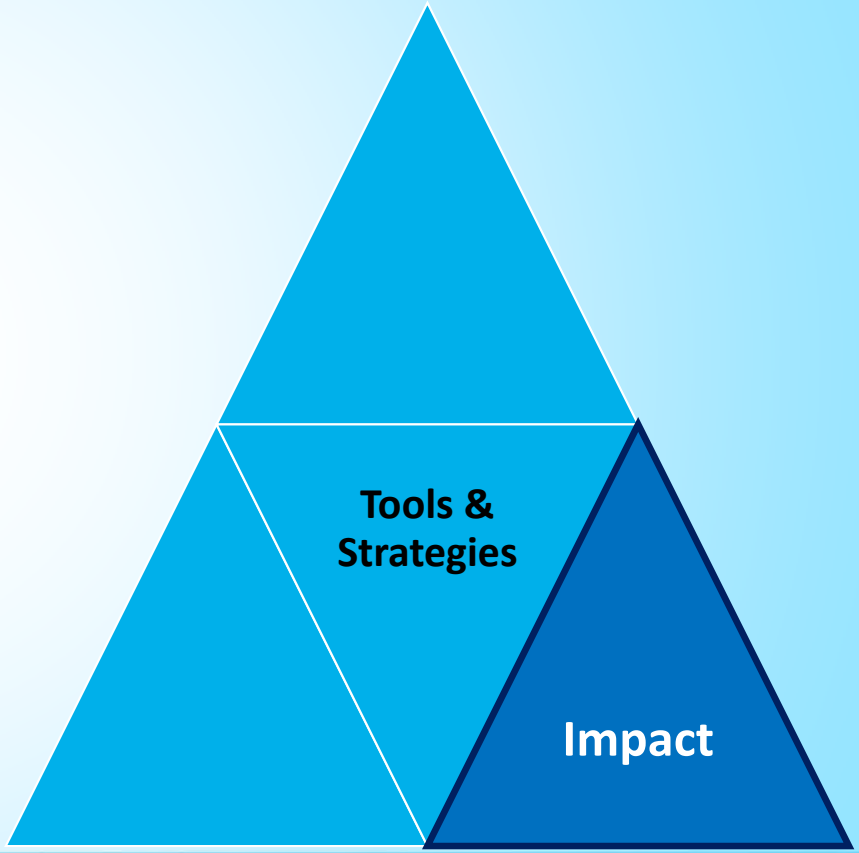
Flood Risk Best Practices

- Base local regulations on up-to-date risk maps that rely on the most current data about rainfall and topography and that account for all forms of flooding.
- Establish regular reviews of floodplain maps.
- Underpin all of this with adequate education and outreach to residents about the risks they face.

Model Cities for Flood Risk

- State of North Carolina
  - City of Charlotte
  - Mecklenburg County
- State of California
- City of Tulsa, OK

Modern flood risk analysis is an informational tool that modifies the impact of flooding.



part 2. Green/Gray Infrastructure

Gray Infrastructure

Gray infrastructure is the legacy substructure of all cities.

Most gray infrastructure has been poorly maintained, is aging, and is undersized for today's needs.

The existence of gray infrastructure induces development and increases flood exposure.

Gray/Green Infrastructure

- Gray Infrastructure Strategies
  - Structural mitigation (retain, block, convey)
  - Non-structural mitigation (avoid, modify)

- Green Infrastructure Strategies
  - Nature-based mitigation (slow, treat, infiltrate, evapotranspire, reuse)
  - Includes low-impact development (LID)

Gray/Green Infrastructure

- Recent disasters provide ample evidence that gray infrastructure alone is not enough to address today's flooding issues.
- Localized drainage facilities and larger scale conveyance and storage systems do not have the capacity to mitigate the massive deluges and hurricanes of this region.
- Gray infrastructure should be augmented with green infrastructure to maximize mitigation. Green infrastructure can mitigate small events.

Gray Paradigm

- Gray Paradigm - remove stormwater from the area as fast as possible. For example, concrete lined channels are preferred because the water flows faster.
- Includes large scale structures (channels, pipes, storage, pumps, levees, reservoirs, etc.) and small scale streets and drainage.

Green Paradigm

- Green Paradigm - mimic natural processes that slow down stormwater so it can soak into the ground or evaporate, prevent stormwater from leaving the site, maximize permeability.
- For example, unlined channels are preferred.

Green Paradigm, continued

- Preserve site hydrology
- Reduce impervious cover
- Reduce runoff volume
- Improve water quality/reuse water
- Retention/detention
- Prevent erosion
- Absorb/infiltrate/treat

What is Green Infrastructure?

Green infrastructure refers to ecological systems, both natural and engineered, that act as living infrastructure.

Green infrastructure elements are planned and managed primarily for regional stormwater control, but also exhibit social, economic and environmental benefits.

What is Low Impact Development?

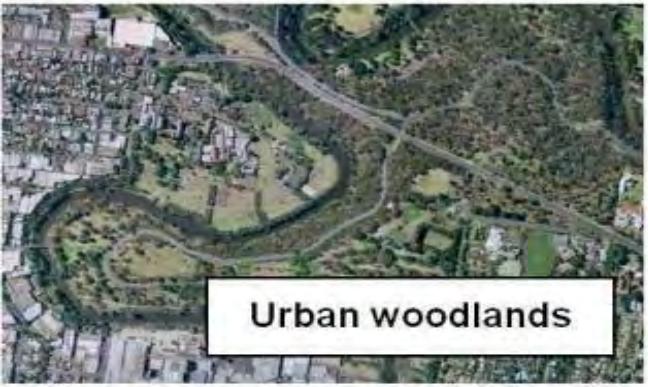
LID aims to return sites to their natural hydrologic state.

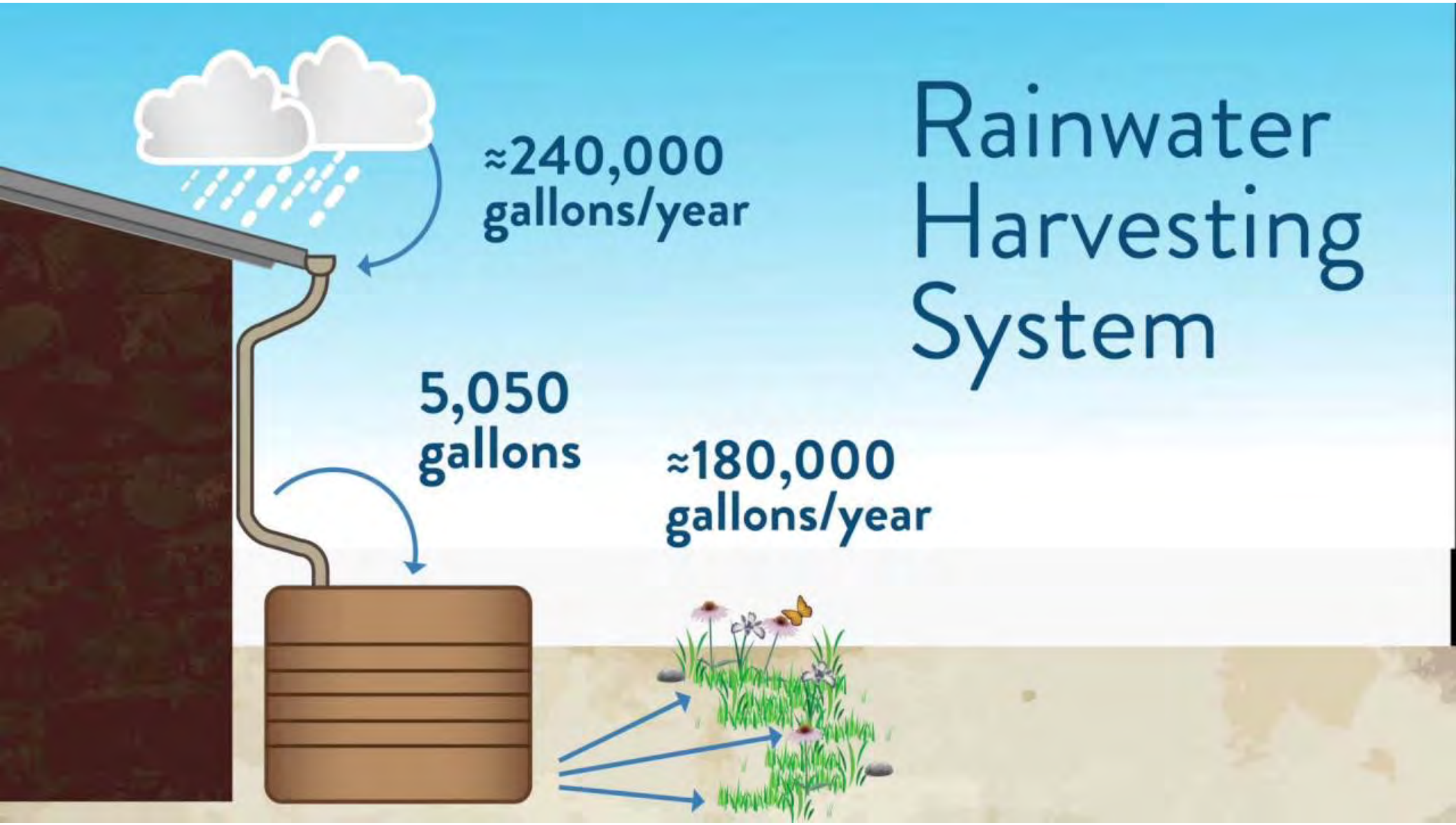
As a design approach , LID manages stormwater by using natural features, by emphasizing conservation, and by using on-site natural resources.

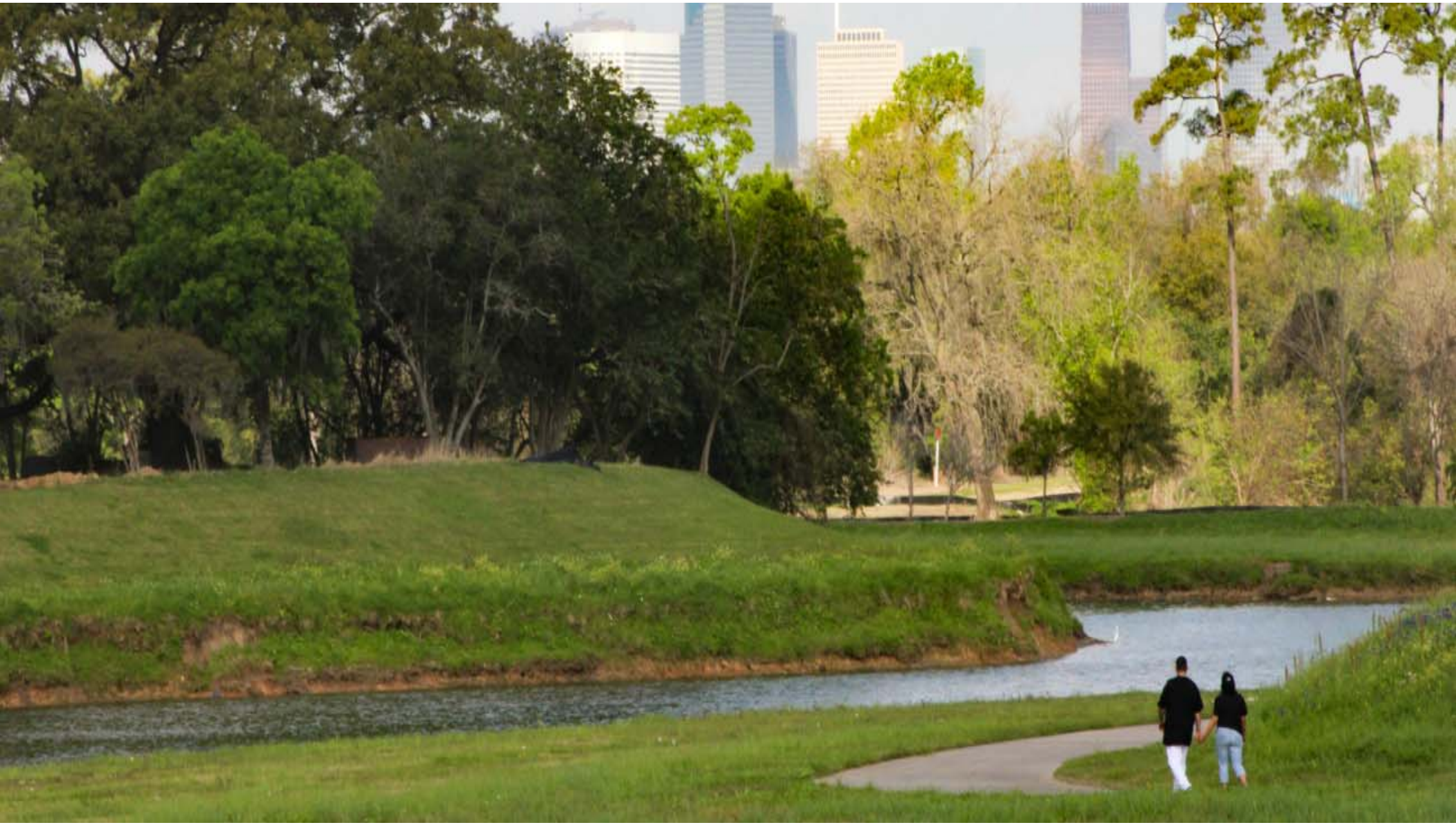
Stormwater is viewed as a resource, not a waste product.

Green Infrastructure	Low Impact Development
Neighborhood/Regional Scale	Site/Block Scale
Constructed Wetlands	Bioswales/Vegetated Swales
Green Streets	Bioretention Ponds
Open Space/Land Conservation	Rainwater Harvesting
Retention/Detention Basins	Green Roofs and Walls
Urban Forests and Parks	Rain Barrels
Greenways	Permeable Pavement
River Corridors	

Urban green infrastructure




Rainwater Harvesting System
≈240,000 gallons/year
5,050 gallons
≈180,000 gallons/year



Green/Gray Infra. Best Practices

Green infrastructure has multiple benefits and for this reason it is often integrated with hazard mitigation planning, resilience planning, climate adaptation planning, regional park planning, and comprehensive planning.

Green/Gray Infra. Best Practices

Use regulation and incentives to pursue the improved green-gray infrastructure approach.

Account for projects at many scales, from single lots to regional infrastructure systems.

Green/Gray Infra. Best Practices

Ensure that existing gray infrastructure is in good working order.

Use adequate design risk levels to account for changing storms.

Gray infrastructure must be large enough to handle major events.

Model Cities for Integration of Green/Gray Infrastructure

- Rotterdam
- Amsterdam

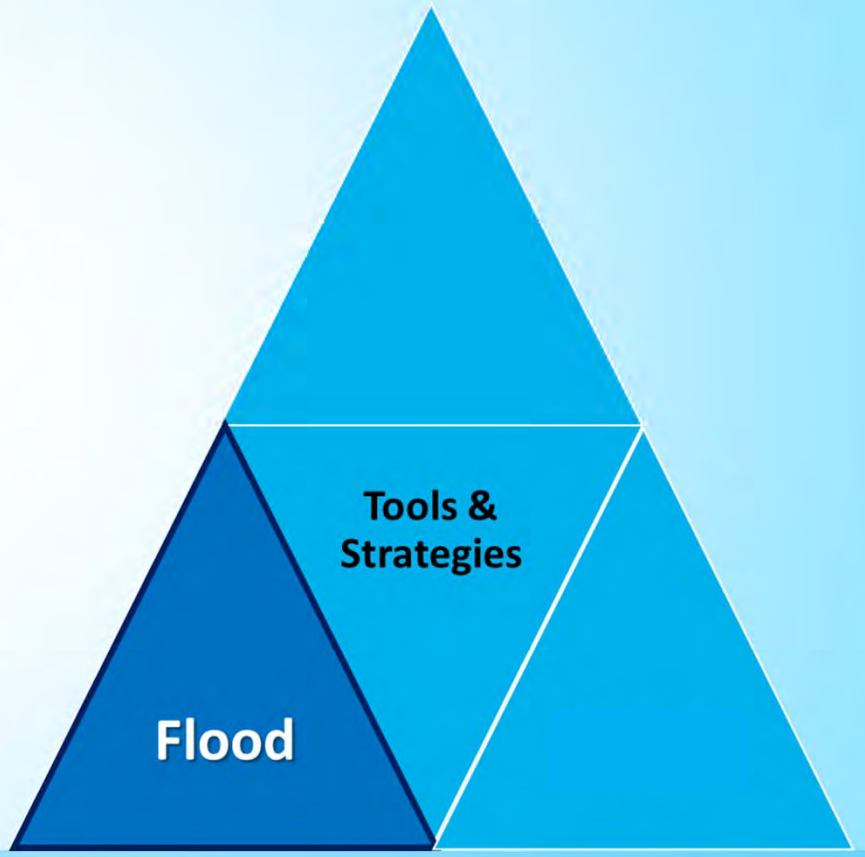
Model Cities for LID

- Philadelphia
- Dallas
- San Antonio
- Chicago
- Los Angeles
- Flagstaff

Model Cities for Green Infrastructure

- Seattle
- Portland
- Montgomery County, MD

Combining gray and green infrastructure allows cities to modify the floods they experience.



part 3. Land Use Planning

Miami Beach 1926

Wendler Collection

Miami Beach 2006

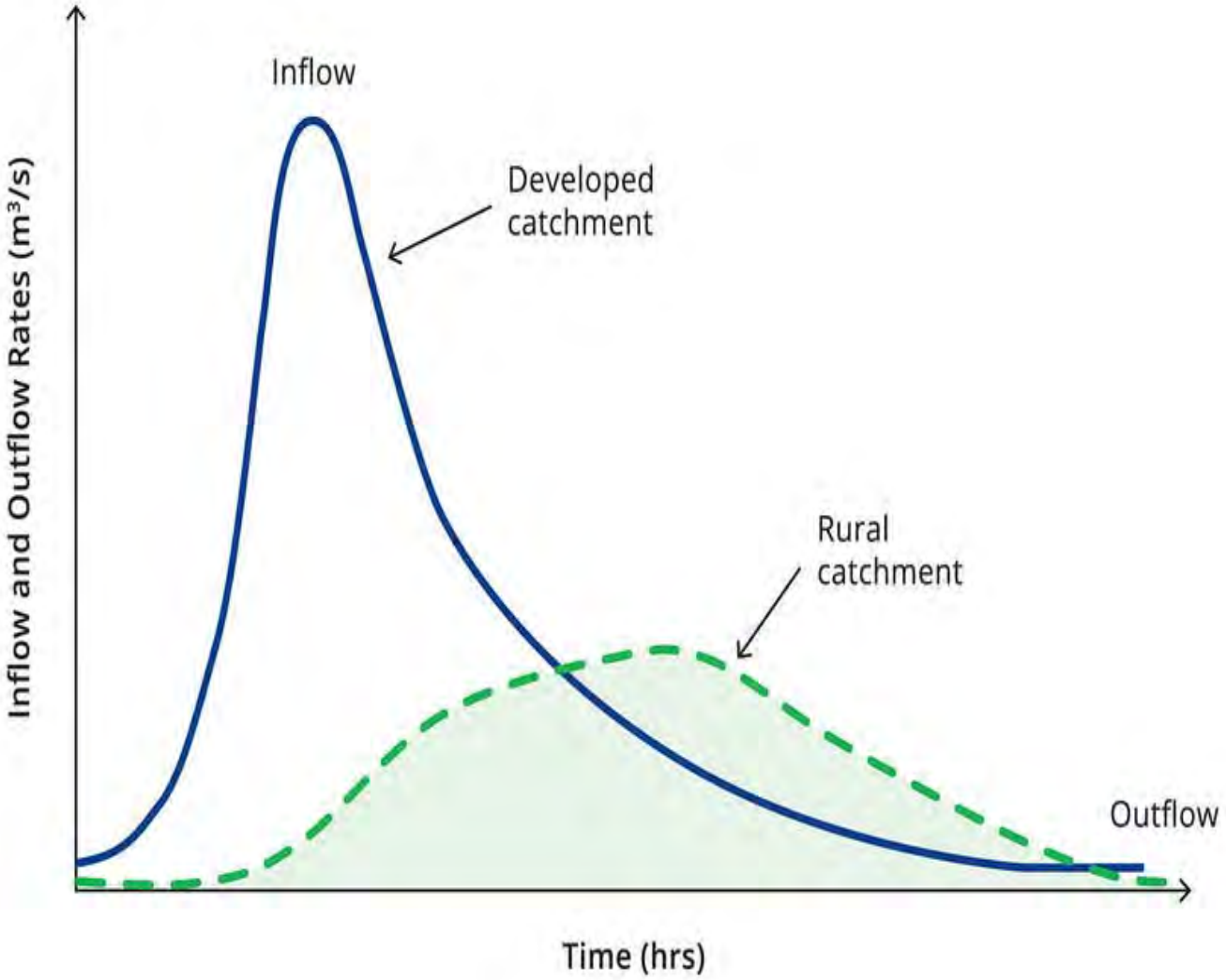
Joel Gratz, 2006

Miami Beach 2016

Chris Condon/PGA TOUR/MetLife Blimp.

Sacramento, CA

US Army Corps



Urban Development Increases Flooding

Coombes and Roso, 2018

Land Use Tools for Cities

- Ordinances
- Building codes
- Zoning
- Incentives (grants, fee reductions, credits, bonuses, rebates, etc.)
- Design risk level
- Easements

Land Use Tools for Cities, cont.

- Transfer of development rights
- Land conservation/open space
- Developer agreements
- Urban growth boundary

Land Use Tools for Counties

- Floodplain permits
- Incentives (grants, fee reductions, credits, bonuses, rebates, etc.)
- Design risk level
- Easements
- Land conservation/open space
- Urban growth boundary

Land Use Best Practices

Consider options for limiting development in areas identified as risk-prone. This could take the form of:

1) prohibition on development in specific areas;
2) the use of easements or the transfer of development rights to keep vulnerable areas undeveloped; or
3) encourage the purchase of land by public or private entities with the intent to conserve and preserve greenspace.

Land Use Best Practices

- Create programs that address grandfathered buildings in floodplains and areas outside of floodplains.
- Ensure that residents in areas with these homes have access to a wide array of solutions, including financial resources.

Land Use Best Practices

- Implement programs and collaborative partnerships that can simplify the mix of jurisdictions responsible for permitting and oversight of development within the region.

Land Use Best Practices

- Create interconnected development regulations to build for resilience, not just to prevent flooding.
- Authorize counties to enforce regulations using ordinances, which would expand the strategies available for limiting land use in high hazard areas.

Land Use Best Practices

- Keep future development out of known hazard areas.
- Guide new public and private investment away from hazardous locations using zoning, subdivision regulations, and capital improvement plans.

Land Use Best Practices

- Keep hazards from affecting existing developed areas.
- Use structural mitigation and environmental management to modify the hazard and protect existing areas that are not protected by new rules and maps.

Land Use Best Practices

- Strengthen existing development to resist hazards.
- Enhance and enforce construction requirements, design standards, and building codes to resist hazards.

Land Use Best Practices

- **Use regulations** – for example, only open space land use in floodplains
- **Set backs** – to minimize flood exposure of buildings, provide waterfront buffers, maintain natural vegetation, and limit runoff
- **Non-conforming use regulations** – standards for allowable reconstruction of flood-damaged structures
- **Special-use permits** – requires new development to meet established criteria to minimize future flooding
- **Overlay districts** – adds a separate layer of regulation for sensitive hazard areas

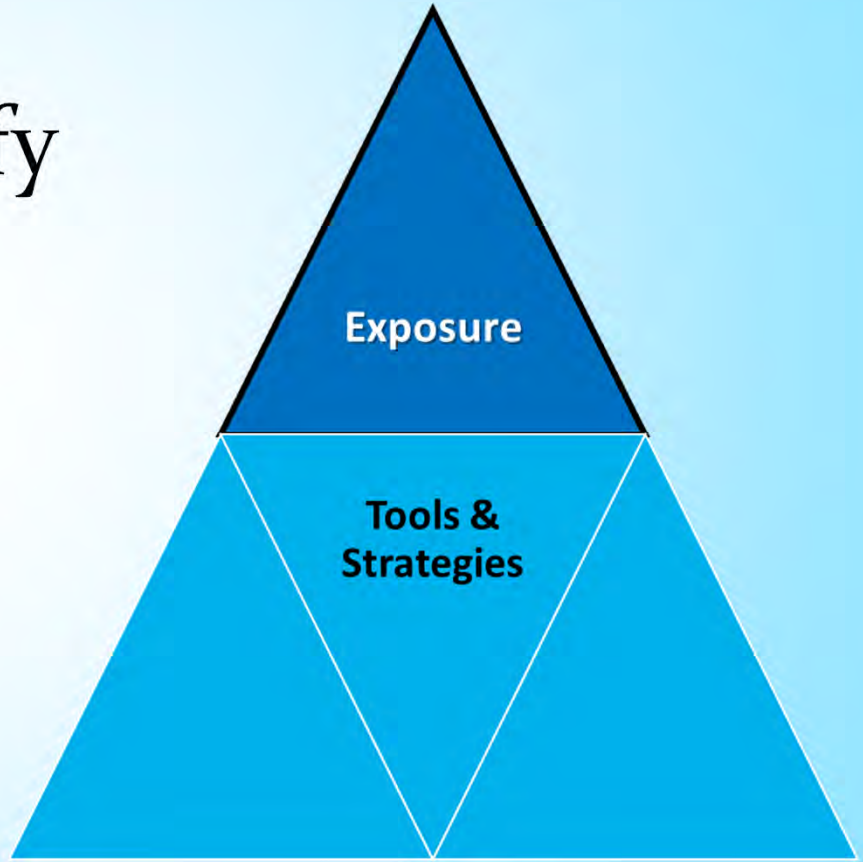
Land Use Best Practices

- Create a vision of how the city can grow safely.
- Guide growth away from high-risk locations.
- Locate critical facilities away from high-risk zones.
- Preserve protective features of the natural environment.
- Retrofit buildings and facilities at risk in redeveloping areas.
- Develop knowledgeable community leaders and networks.
- Monitor and update programs and plans.

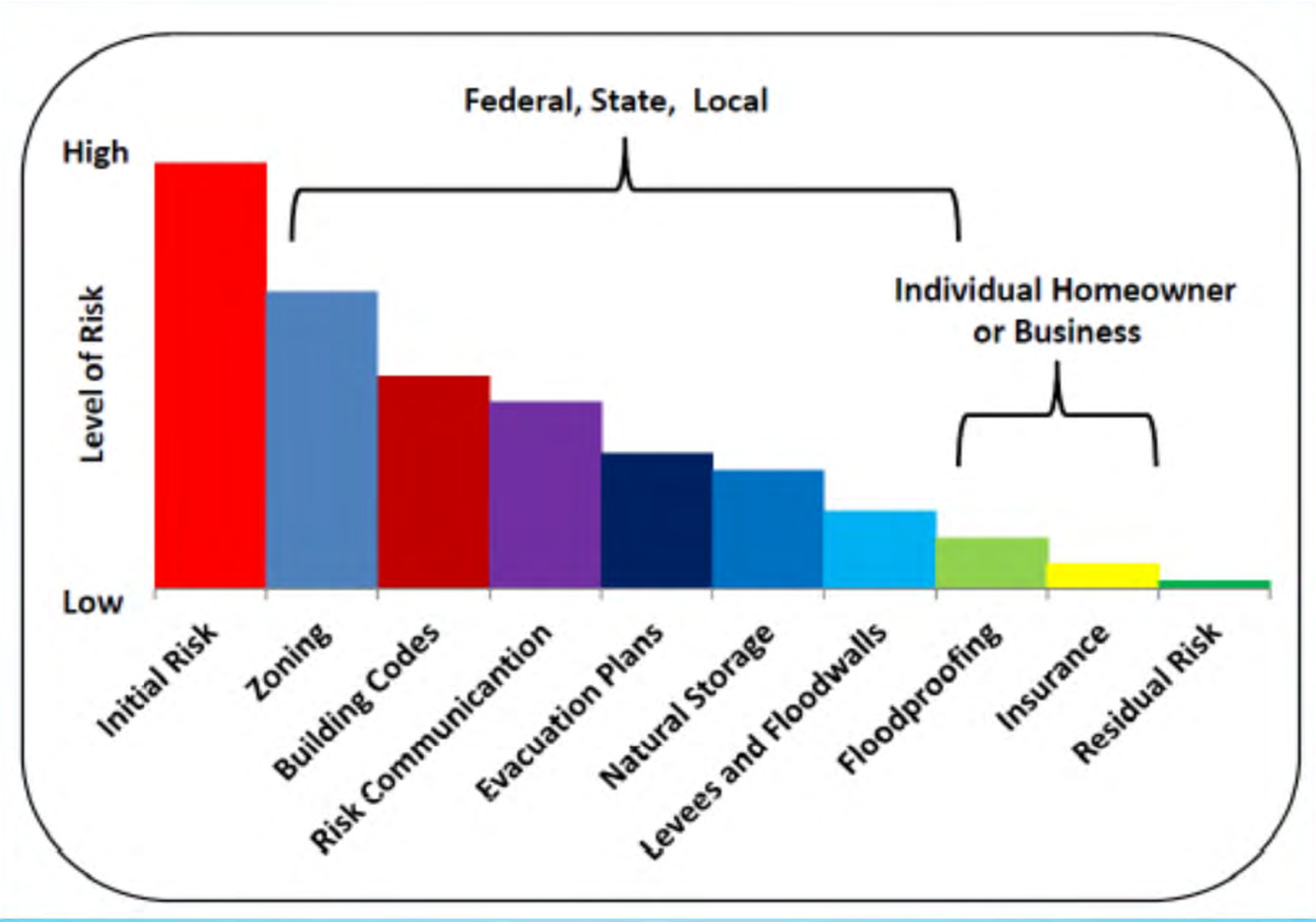
Model Cities for Land Use

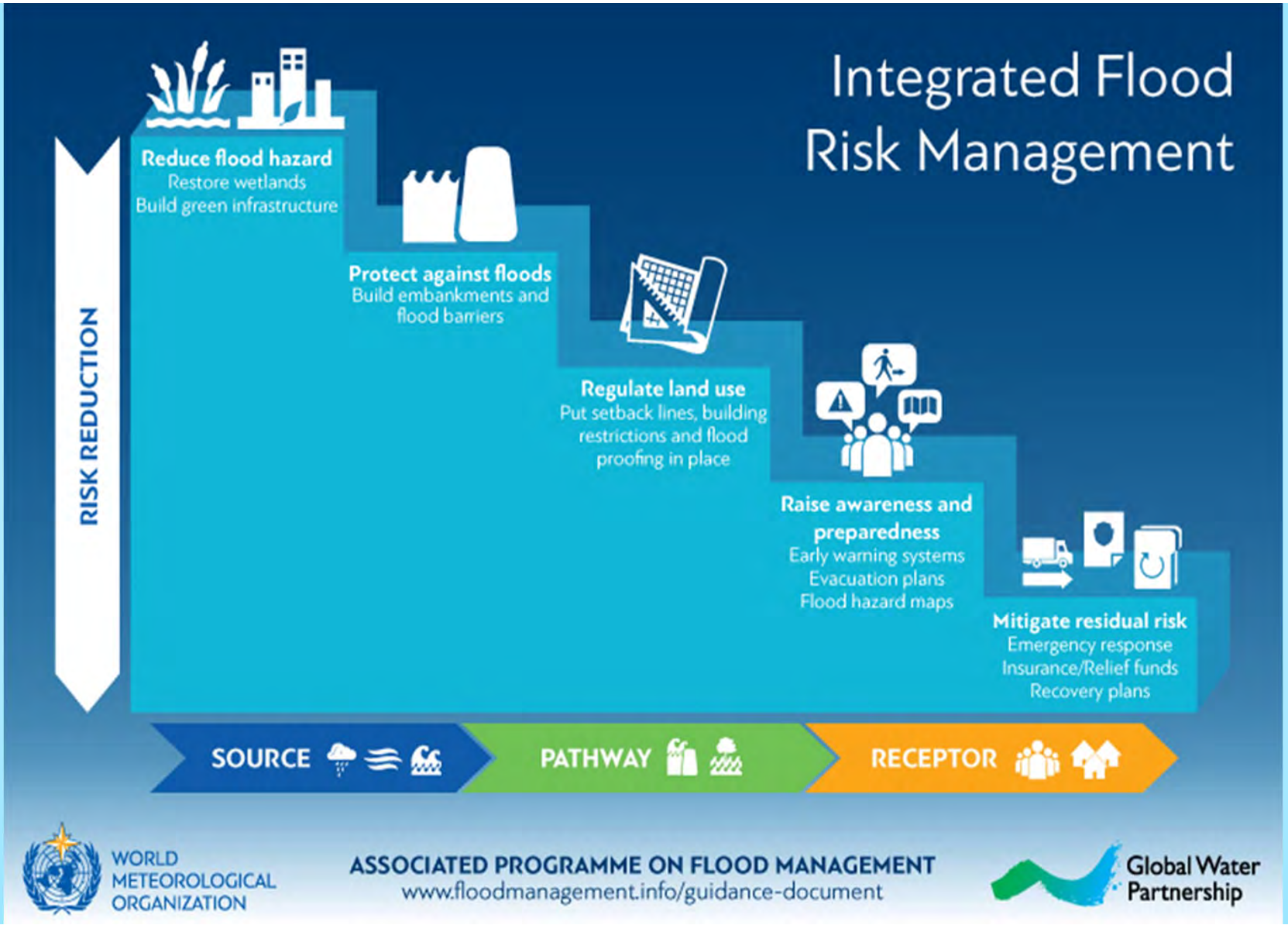
- Norfolk, VA
- Tulsa, OK
- Charlotte and Mecklenburg, NC
- Cedar Falls, IA
- Pierce County, WA
- Rotterdam, The Netherlands

Cities use land use planning tools to modify exposure to flood damage.



Conclusions and Take-Home Points


Federal, State, Local
High
Level of Risk
Low
Individual Homeowner or Business
Initial Risk
Zoning
Building Codes
Risk Communicantion
Evacuation Plans
Natural Storage
Levees and Floodwalls
Floodproofing
Insurance
Residual Risk


Integrated Flood Risk Management
RISK REDUCTION
Reduce flood hazard
Restore wetlands
Build green infrastructure
Protect against floods
Build embankments and flood barriers
Regulate land use
Put setback lines, building restrictions and flood proofing in place
Raise awareness and preparedness
Early warning systems
Evacuation plans
Flood hazard maps
Mitigate residual risk
Emergency response
Insurance/Relief funds
Recovery plans
SOURCE
PATHWAY
RECEPTOR
WORLD METEOROLOGICAL ORGANIZATION
ASSOCIATED PROGRAMME ON FLOOD MANAGEMENT
www.floodmanagement.info/guidance-document
Global Water Partnership

Actionable Take-Home Point

Today's technology supports modern flood risk analysis.

See modern flood risk mapping in action at https://fris.nc.gov/fris/?ST=NC and https://flood.nc.gov/ncflood/

Actionable Take-Home Point

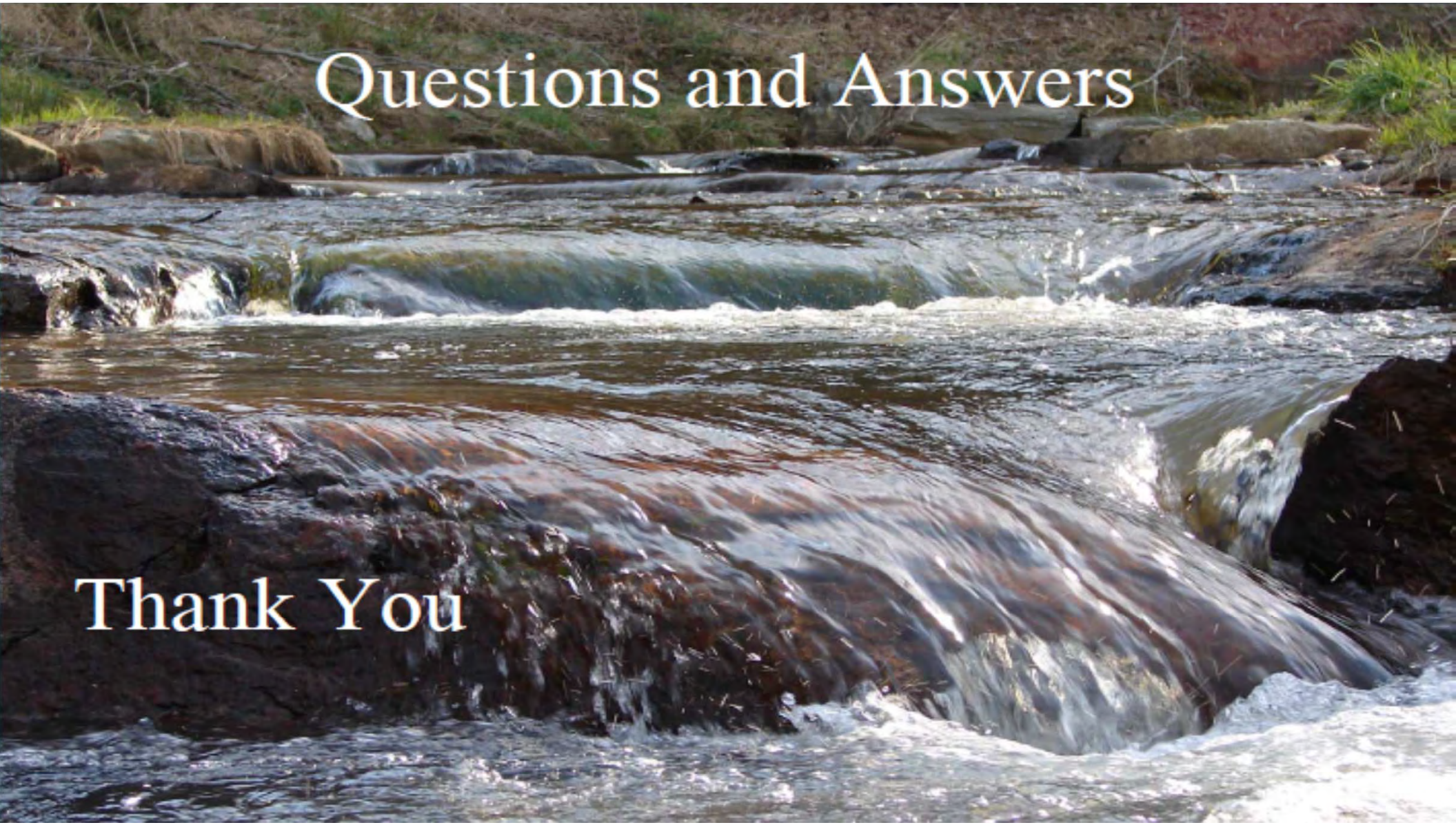
Today's most flood resilient cities are integrating gray & green infrastructure.

Think of creative ways for your city to promote green infrastructure.

Actionable Take-Home Point

Land use regulation is one of the most important tools available to cities for mitigating flood hazards.

Initiate an audit of your city's land use ordinances to reduce flood exposure.


Questions and Answers
Thank You