LESSONS LEARNT FROM ENGINEERING FAILURES

LEARNING FROM THE U.S. EXPERIENCE WITH FLOODS AND FLOOD MITIGATION

Webinar by David Kriebel, PhD, PE

engineering new zealand
te ao rangahau

TABLE OF CONTENTS

INTRODUCTION

This case study summarises the webinar hosted by Engineering New Zealand's Coastal Society and the University of Auckland, featuring Emeritus Professor David Kriebel from the United States Naval Academy. The webinar highlights the urgent need for improved flood risk management in the face of increasing flood losses and the growing influence of climate change on flood hazards. Despite some progress in building codes, standards, and mitigation measures, much work remains to create more flood-resilient communities. Dr Kriebel’s visit to New Zealand was supported by the Fulbright Specialist Program.

Dr Kriebel's experience spans 34 years as a professor at the U.S. Naval Academy, where he taught courses in coastal engineering, ocean waves, ocean structures, foundations, probability and statistics, and coastal design. He has authored over 150 papers and actively consults on coastal engineering projects through his company Coastal Analytics LLC.

Dr Kriebel has played a key role in advancing flood and tsunami load standards through the American Society of Civil Engineers (ASCE). He served on the ASCE 7 Tsunami Loads and Effects Subcommittee that developed new tsunami design provisions. He also contributed to the updated ASCE 7 Flood Loads chapter, which now requires designing for a 500-year average recurrence interval (ARI) flood rather than 100-year. Most recently, he has been part of a team assisting the Government of Canada in developing flood load standards for the National Building Code of Canada.

Through his work with ASCE, and his own research and consulting, Dr Kriebel has gained valuable insights into the evolving understanding of flood risk and the effectiveness of different mitigation strategies. This case study aims to share some of these insights to inform flood risk management practice in New Zealand and beyond.

Figure 1: Annapolis, Maryland -– City Dock, roads, community parking, and local businesses flooded by Winter Storm January 10, 2024 . This was the 3rd highest coastal water level recorded since 1928 and the first that was not hurricane related. Source: Chesapeake Bay Magazine.

NOTABLE FLOOD DISASTERS

The U.S. has experienced many catastrophic floods over the past century, each revealing different vulnerabilities and lessons for flood risk management.

- **1900 Galveston, Texas Hurricane:**
  - Deadliest natural disaster in U.S. history with an estimated 8,000 fatalities
  - Devastated the low-lying barrier island city of Galveston
  - Highlighted the need for hurricane forecasting and warning systems
- **1936 New England Flood:**
  - Caused by a combination of heavy rainfall and hurricane storm surge
  - Resulted in widespread damage across multiple states and over 150 deaths
  - Exposed the vulnerability of aging infrastructure and the need for comprehensive flood control measures
- **1993 Mississippi River Valley Flood:**
  - One of the most costly and devastating floods in U.S. history, impacting nine states
  - Caused by persistent heavy rainfall and multiple levee failures
  - Revealed the limitations of relying solely on levees for flood control
- **2005 Hurricane Katrina in New Orleans:**
  - Catastrophic flooding of up to 80% of the city following levee and floodwall failures
  - Over 1,800 deaths and $125 billion in damages, making it the costliest U.S. natural disaster at the time
  - Exposed deep vulnerabilities in flood protection infrastructure and disproportionate impacts on marginalized communities
- **2012 Hurricane Sandy in New York/New Jersey:**
  - Largest diameter Atlantic hurricane on record, impacting 24 states with particularly severe effects in New York and New Jersey
  - Caused extensive coastal flooding, including in New York City, and damaged over 650,000 homes
  - Highlighted the threat of storm surge in densely populated coastal areas and the need to rethink coastal flood risk management
- **2017 Hurricane Harvey in Houston, Texas:**
  - Unprecedented rainfall of over 60 inches (1,500 mm) in some areas, the highest ever recorded in the U.S. from a tropical cyclone
  - Widespread flash flooding and river flooding inundated hundreds of thousands of homes and businesses
  - Illustrated the growing risk of compound flooding from extreme rainfall, storm surge, and sea level rise in low-lying coastal cities

These events underscore the immense challenges posed by flood hazards in the U.S., which are only expected to worsen with climate change. Earlier disasters were often exacerbated by lack of warning and failure of flood control structures. More recent events have been characterised by extreme conditions exceeding historical records, suggesting the growing influence of climate change.

KEY INSIGHTS

FLOOD FREQUENCY AND IMPACT

Floods are the most common and devastating natural disasters in the United States, with significant economic and human losses, and they keep on increasing in frequency. There is at least one flood event reported in the United States every 8 to 10 days.

- There are more riverine and fluvial flooding events than coastal flooding events
- Non-hurricane flooding is 10 times more likely than flooding in hurricanes

However, hurricanes and coastal flooding are the dominant cause of economic loss

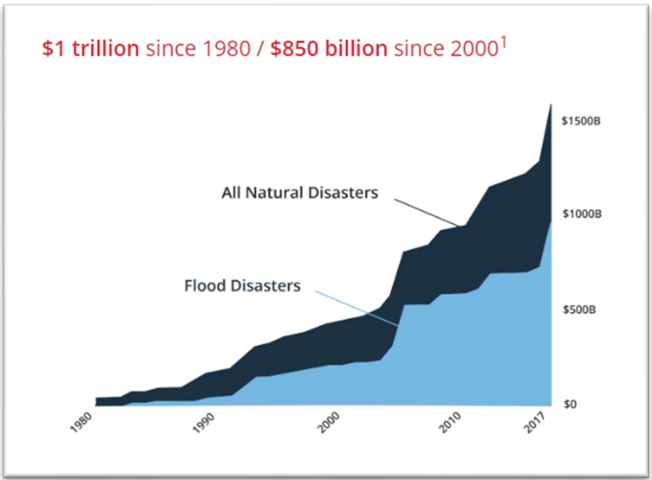

Figure 2: Floods are the dominant disaster type in America. Source https://www.flooddefenders.org/problem

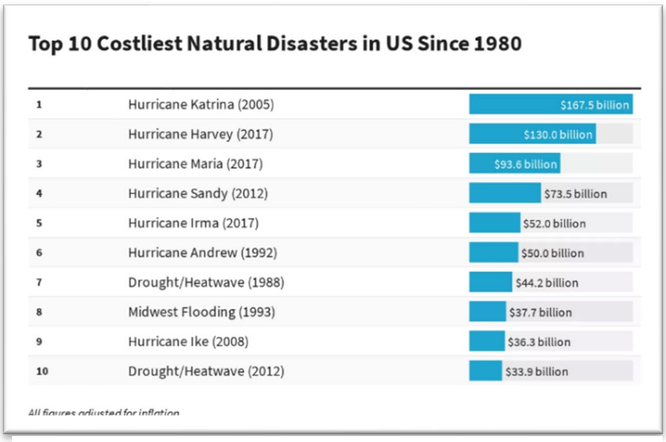

Figure 3: https://www.investopedia.com/hurricane-dorian-4769192

Nationwide impact of flood losses

Flood losses in the US are growing and **most flood victims in the US are not insured**, despite the increasing frequency and severity of flooding.

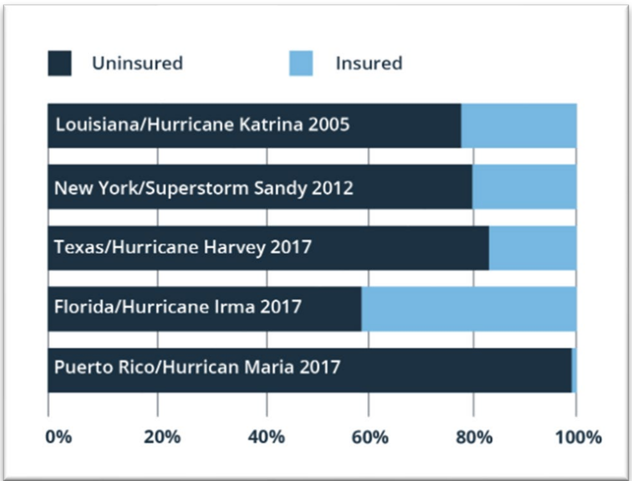

Figure 4:: https://www.flooddefenders.org/problem

Figure 5: https://www.govexec.com/federal-news/2023/06/femas-buyout-program-reduces-flood-risk-does-it-deepen-degregation/387631/

Approximately 5% of US population lives within a floodplain with an average recurrence interval of 100 years

Approximately 10% of the population lives within a floodplain with an average recurrence interval of 500-years

Riverine Flood Risk

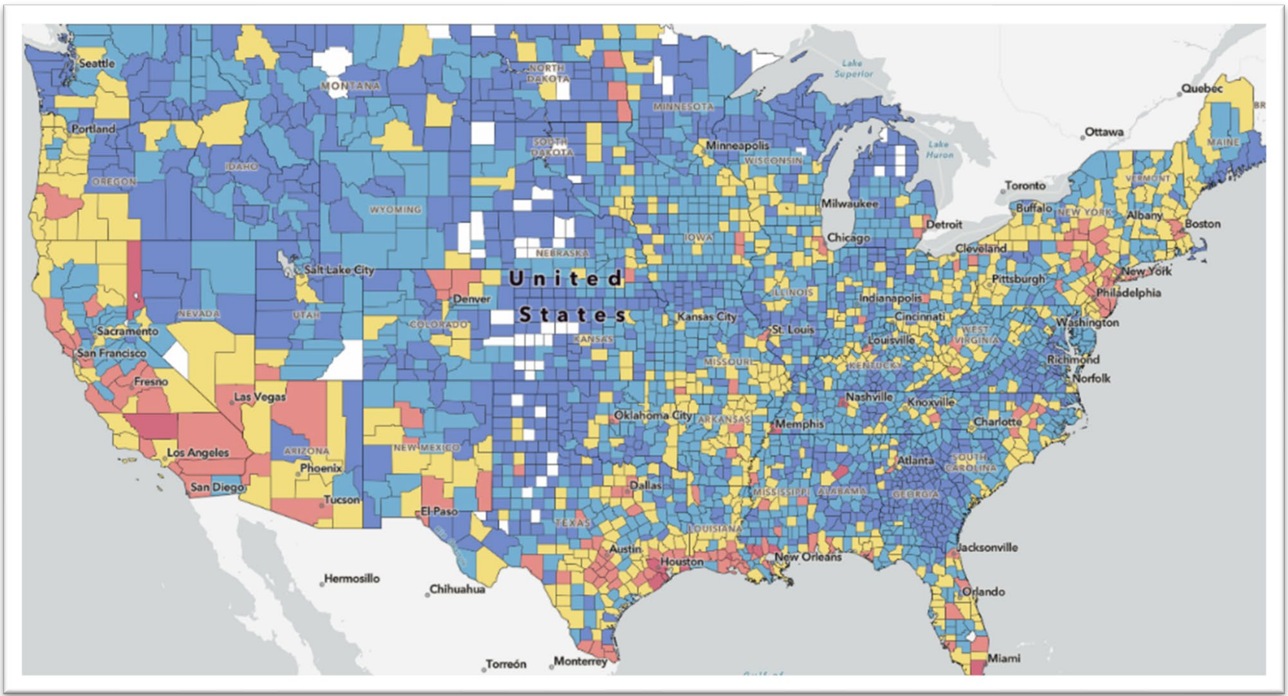

Figure 6: Source ***https://www.fema.gov/***

Hurricane Flood Risk

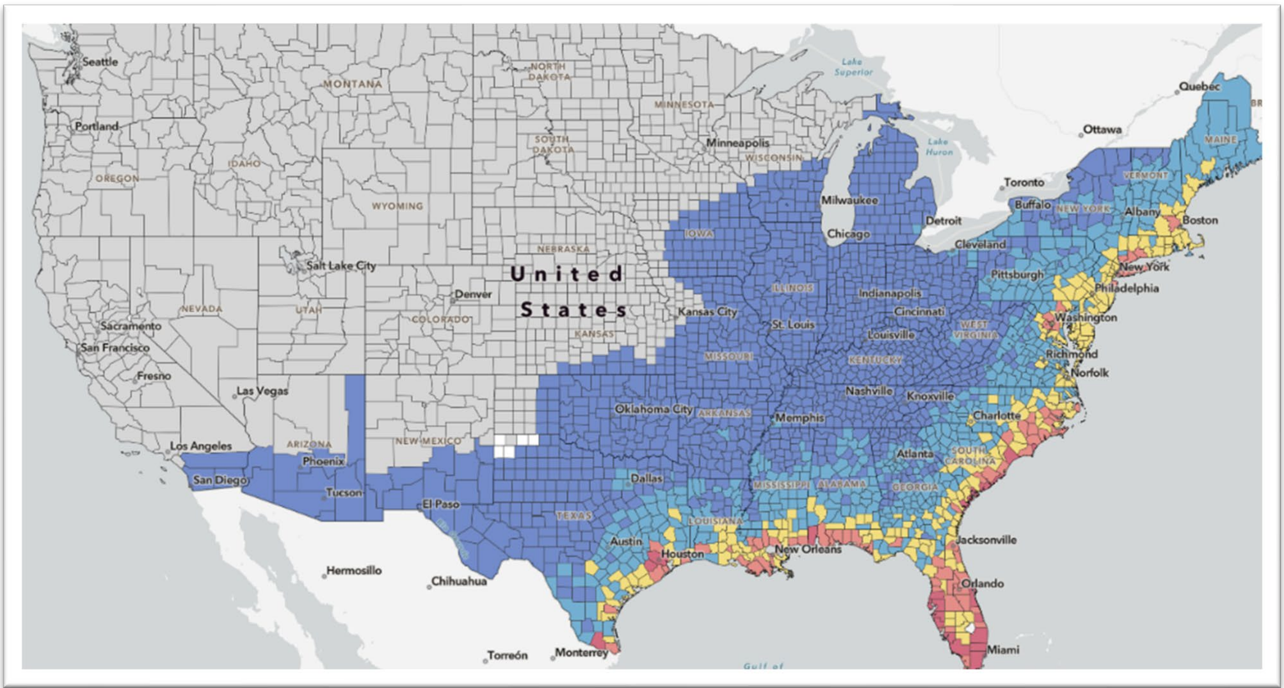

Figure 7: Source https://www.fema.gov/

Unique aspects of flood impacts

What makes flood loads unique compared to other natural hazards, such as wind or earthquake hazards, is that the flood risk depends on location relative to the flood zone, and the effects of flooding depend on flood elevation relative to the ground.

For Wind:

- All buildings within a city face similar wind hazard
- Wind loads impact all buildings to some extent

But For Flood:

- Buildings are mapped as either "in" or "out" of flood zone
- Flood loads are computed on buildings "in" zone
- No flood loads are computed on buildings "out" of flood zone
- Flood impacts increase with scour or erosion during the event and the associated undermining of structures
- Loading conditions depend on structural members that get wet, which are typically the foundation and lower parts of the structure
- The most severe and rare floods often impact buildings outside of mapped flood zones impacting buildings that were unprepared and uninsured.

UNITED STATES APPROACHES TO FLOOD RESILIENCY

The U.S. has experienced a shift from an historical emphasis on flood prevention and relief to a focus on building resilience - preparing for, living with, responding to, and recovering from floods to minimize impacts. Current approaches involve a combination of flood insurance, codes and standards, and mitigation measures.

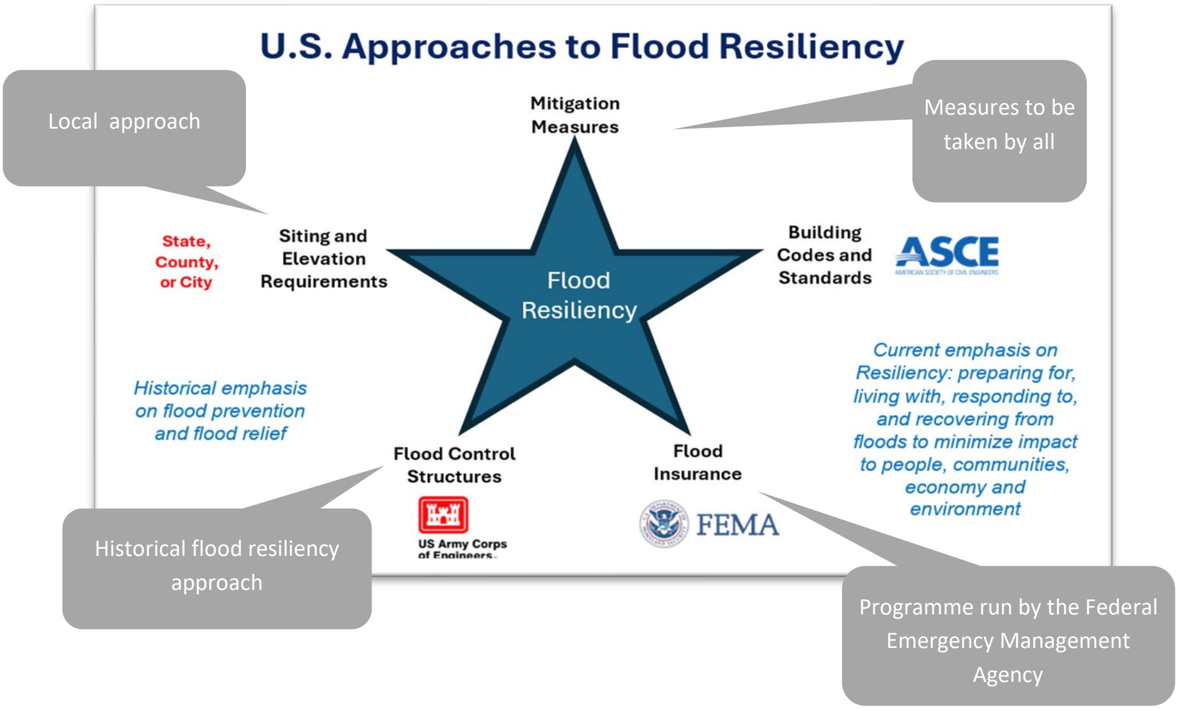

Figure 8: Source David Kriebel

FEMA Flood Insurance Program

The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP), which was established in 1968 to provide subsidized flood insurance to communities that adopt minimum floodplain management regulations.

Key aspects of the program include:

- Flood hazard mapping: FEMA develops Flood Insurance Rate Maps (FIRMs) that delineate Special Flood Hazard Areas (SFHAs) based on the 1% annual exceedance probability (AEP), or approximately 100-year average recurrence interval (ARI) flood.
- Separate mapping procedures are used for riverine and coastal flood hazards.
- Buildings within the SFHA are subject to floodplain management regulations which are usually adopted by local authorities in planning and zoning
- Construction standards: The NFIP establishes minimum design and construction standards for new and substantially improved buildings in flood hazard areas. These include requirements for elevating or floodproofing structures to or above the Base Flood Elevation (BFE).
- Flood insurance: Flood insurance is required for buildings in the SFHA with federally-backed mortgages but optional for buildings that do not have federally-backed mortgages.
- Coverage is limited, and available up to $250,000 for residential buildings and $500,000 for non-residential buildings.

However, the NFIP faces significant challenges. Many at-risk properties remain uninsured, either because insurance is not mandatory or because premiums are unaffordable. The program has also been criticized for outdated flood maps, subsidized rates that do not reflect true risk, and a lack of incentives for risk reduction. Reforms have been proposed to improve the program's solvency and effectiveness.

FEMA Flood hazard mapping – Riverine

- FEMA uses contractors to map flood hazard zones based on historical rainfall-runoff and HEC-RAS modelling
- 100-year event is regulatory flood plain while 500-year flood plain is advisory
- Mapping is based on historical data and does not include any component for changes in rainfall intensity related to climate change

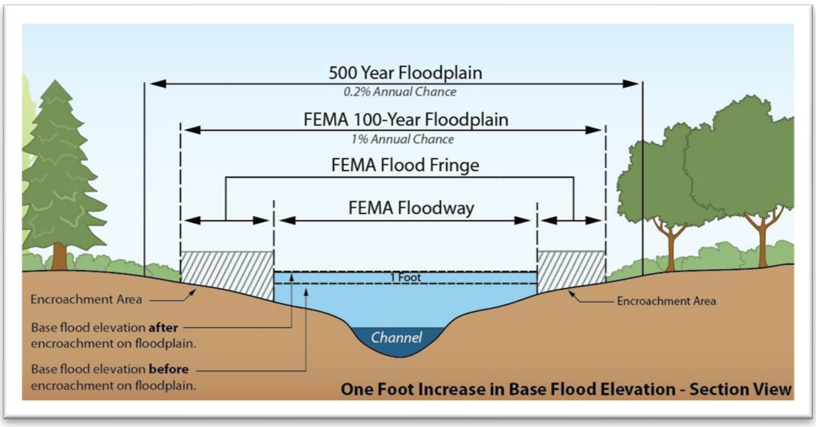

Figure 9: Source https://www.fema.gov/

FEMA Flood hazard - Coastal

Figure 10: Source https://www.fema.gov/

FEMA Mapping – Coastal

FEMA maps in coastal areas show the upper limit of wave crests as the waves break and dissipate energy, which is used to determine the catastrophic failure of coastal structures. In areas where there are steeper slopes, then mapping is continued to the run-up limit. The inland extent of the run-up limit is then mapped and defined as a minimum elevation across the profile.

> Mapped elevations include storm surge flood elevation plus wave crests or wave runup
>
> VE-Zones = wave heights > 3 feet
>
> AE-Zones = wave heights < 3 feet

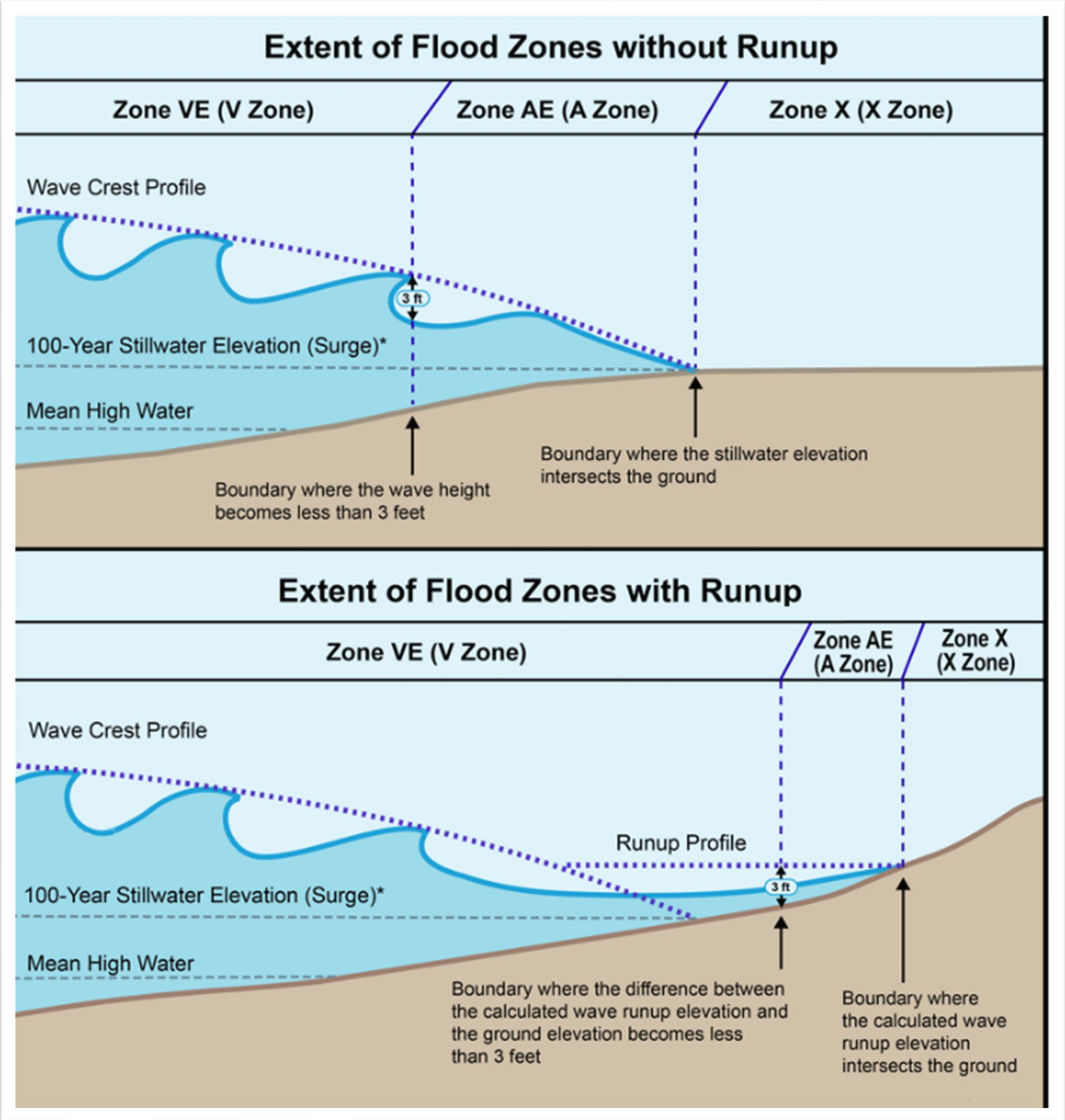

Figure 11: Source https://www.fema.gov/

FEMA Emphasis on Elevation and Freeboard

- A key component of reducing flood losses is the adoption of freeboard for new building construction.
- Freeboard is often used as a catch-all for both uncertainties in predicting the historical base flood elevation and for uncertainties due to climate change.

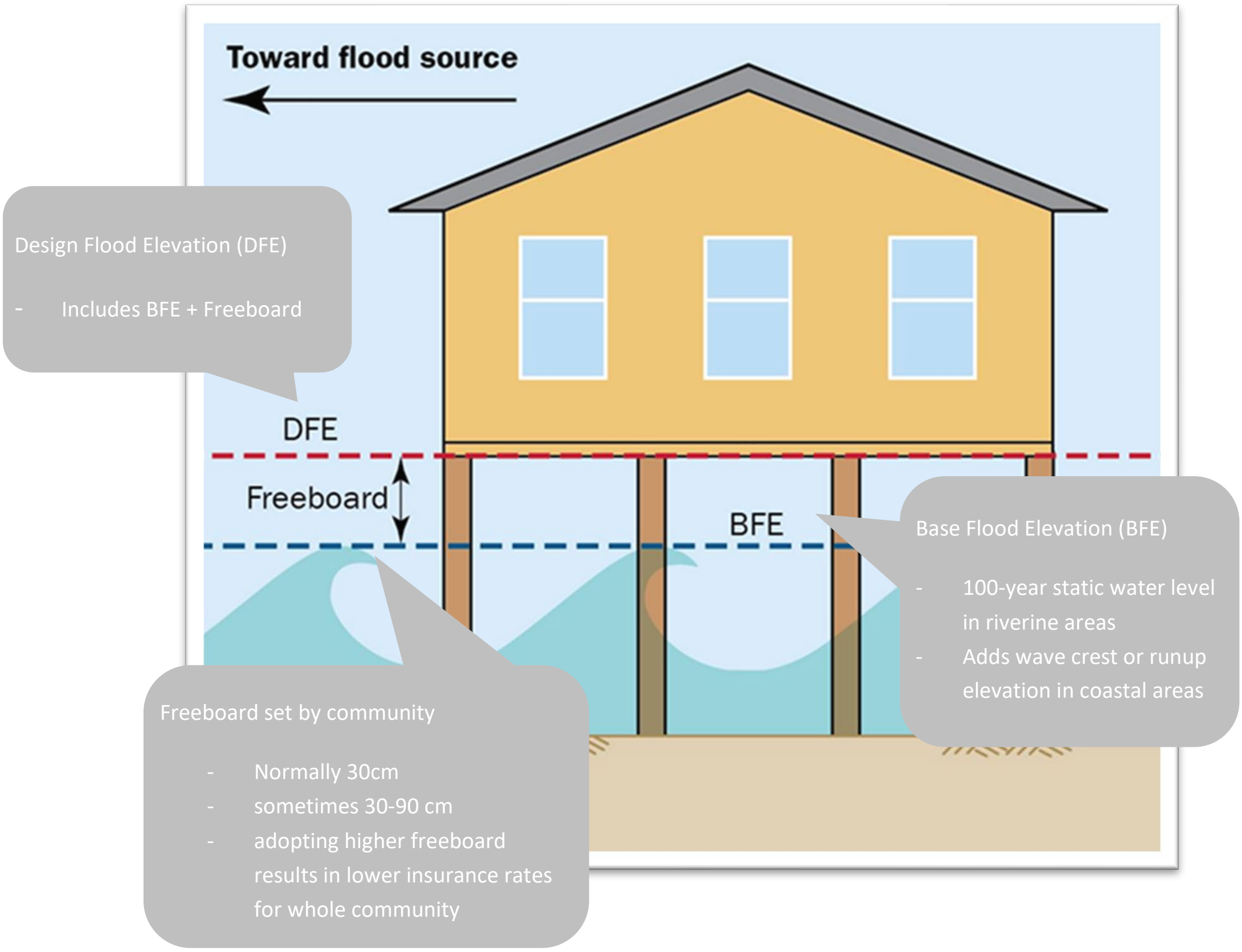

Figure 12: Source https://www.fema.gov/

BUILDING CODES AND STANDARDS

The American Society of Civil Engineers (ASCE) publishes consensus standards on flood-resistant design and flood loads, which form the basis for flood provisions in the International Building Code (IBC) and International Residential Code (IRC).

- ASCE 24: Flood Resistant Design and Construction provides minimum requirements for flood-resistant design and construction of structures located in flood hazard areas. It includes detailed provisions for elevation, foundation design, use of fill, and floodproofing.
- ASCE 7: Minimum Design Loads and Associated Criteria for Buildings and Other Structures includes chapters on flood loads (Chapter 5) and tsunami loads and effects (Chapter 6). These chapters provide guidance on determining design flood elevations, flood forces on structures, and load combinations that include flood effects.

Recent updates to the ASCE standards have made significant changes to align with the latest understanding of flood risk:

- The design flood elevation for most buildings has been increased from the 100-year average recurrence interval (ARI) flood (1% AEP) to the 500-year average recurrence interval (ARI) flood (0.2%annual chance), except for critical facilities like hospitals which are designed for the 1,000-year average recurrence interval (ARI) flood (0.1% annual chance). This change was motivated by the recognition that a 100-year average recurrence interval (ARI) flood level of protection is inadequate given the relatively high probability of occurring during the structural life is a building and the potential consequences of flooding.

- The flood load provisions now require consideration of future conditions, including the effects of sea level rise, to ensure that buildings are designed for the flood hazards they will likely face over their lifetimes. However, specific guidance on how to incorporate sea level rise is still limited. Future conditions could include changes in flood frequency or severity due to climate change.

Despite these advances, there are still gaps in the flood provisions. Continued research and collaboration between engineers, scientists, and policymakers is needed to further improve the standards.

Supplement 2 for Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-22) | Standards | Vol ASCE/SEI 7-22, No (ascelibrary.org).

FLOOD MITIGATION MEASURES

A variety of structural and non-structural measures are used to mitigate flood risk and improve resilience:

Retreat or Abandon

- Buy outs – removal from floodplain
- Relocation – move outside of floodplain
- Elevation – raise above flood elevation

Armour or Defend

- Floodwalls/Levees – protect from flood waters
- Raise Bulkheads – keep coastal flood waters out
- Pump systems – remove flood waters

Adapt

- Enhanced building codes – better resist flood
- Dry Floodproofing – keep flood out of building
- Wet Floodproofing – allow flood in, floodproof interior
- Utility Protection – raise or re-route utilities
- Nature-Based Approaches – improve water management, reduce wave effects

MITIGATION CONSIDERATIONS

Elevation

Raising structures above the design flood elevation is one of the most effective ways to reduce flood damage.

- FEMA and ASCE 24 require new and substantially improved buildings in flood hazard areas to be elevated above the regulatory flood level

- Fill can be used in riverine areas but not in coastal V-zones
- Coastal V-zones have wave heights greater than 3 feet (0.9m) and are thus assumed to have large scour potential requiring pile foundations.
- Elevation is often a more feasible alternative to relocation, which can be costly and disruptive to communities.

After Hurricane Sandy in New Jersey, about 7,000 homes were raised (compared to 800 buy outs)

Figure 13: Source https://floodlist.com/protection/elevation-buildings-flood-prone-locations

Floodproofing

- Dry floodproofing involves sealing buildings to prevent water from entering. Dry floodproofing to keep water out of buildings is being more widely implemented. Features of dry floodproofing systems from FEMA or ASCE24:
    - Sealants or membranes to reduce seepage through walls
    - Reinforcement of walls and doors to withstand floodwater and debris
    - Anchoring of the building to resist flotation, collapse, and lateral movement
    - Pumps to control interior water levels due to seepage
    - Check valves to prevent the entrance of floodwater or sewage flows through utilities
    - Elevate electrical, mechanical, and other valuable damageable equipment
- Wet floodproofing allows water to enter a building but minimizes damage through the use of flood damage-resistant materials, protection of utilities and mechanical equipment, and openings to equalize hydrostatic pressure. It is recommended for enclosures below elevated buildings.
    - Anchor structure to foundation to prevent movement
    - Assume free flooding or encourage the use of openings
    - Flood resistant materials below and immediately above BFE
    - Elevate utilities and equipment
    - Drop electrical from floor above

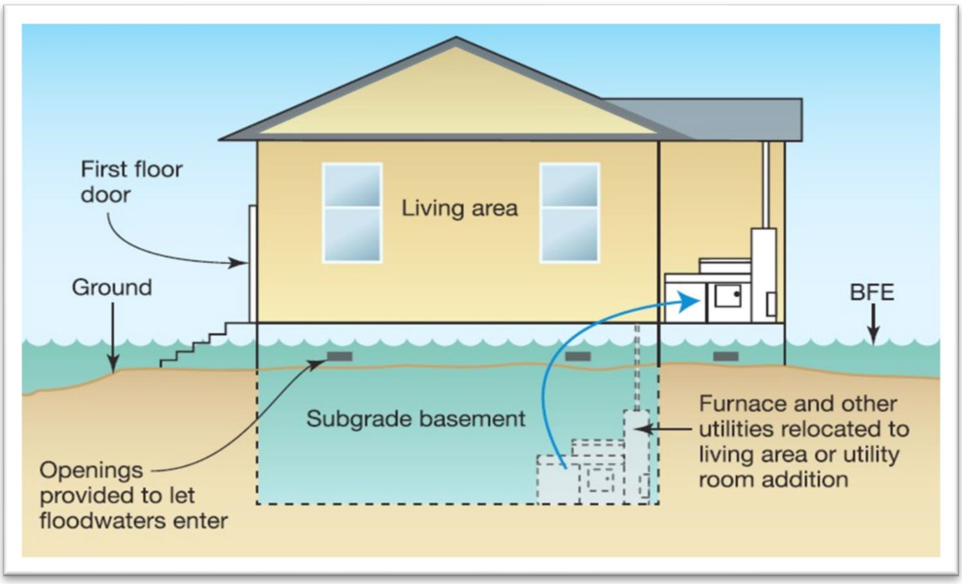

Figure 14 : https://fema.gov/

Flood barriers

Permanent or deployable flood barriers can protect individual buildings or larger areas from flooding.

Temporary Barriers

- Must be deployed each time there is a threat of flooding
- Take time and may be labour intensive to deploy
- May be costly as often need to deploy for an anticipated event that never materializes
- Are only as good as the weakest link

Figure 15: Source photo taken by David Kriebel

Permanent Barriers

- Affixed to the build
- Fixed or self deploying
- Passive devices to reduce or eliminate human interaction in the implementation process
- Levees and floodwalls are used to protect communities from river and coastal flooding, but can be overtopped or fail during extreme events
- Seawalls, bulkheads, and revetments are used to protect coastal properties from erosion and wave action but can have negative environmental impacts
- Required to be certified by American National Standards Institute ANSI 2510 for Flood Abatement
  - Collaborative testing and certification program
  - Program website: https://nationalfloodbarrier.org/

Nature-based solutions

- Natural features like wetlands, dunes, and mangroves can reduce flood impacts by storing water, dissipating wave energy, and stabilizing shorelines.

- Nature-based solutions are increasingly being integrated into flood risk management plans to provide co-benefits like habitat restoration and recreational opportunities.
- However, their effectiveness in mitigating extreme events is still being studied and they should be combined with other measures as part of a multi-layered approach.
- A key concern is that a porous nature-based approach won't be effective against high static water levels during coastal flooding.

FEMA Examples of Nature-Based Solutions

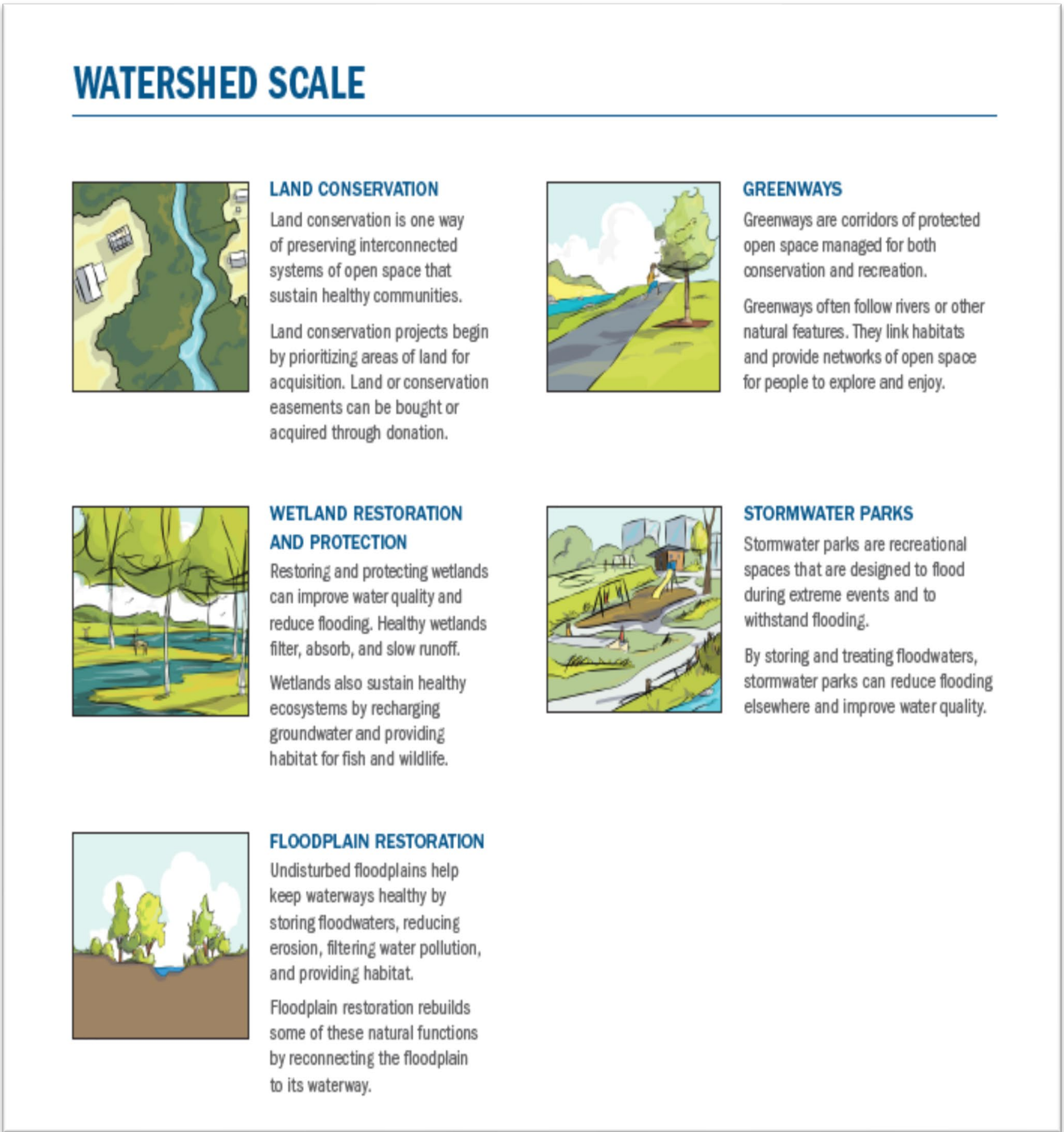

Figure 16: Source https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide_2021.pdf

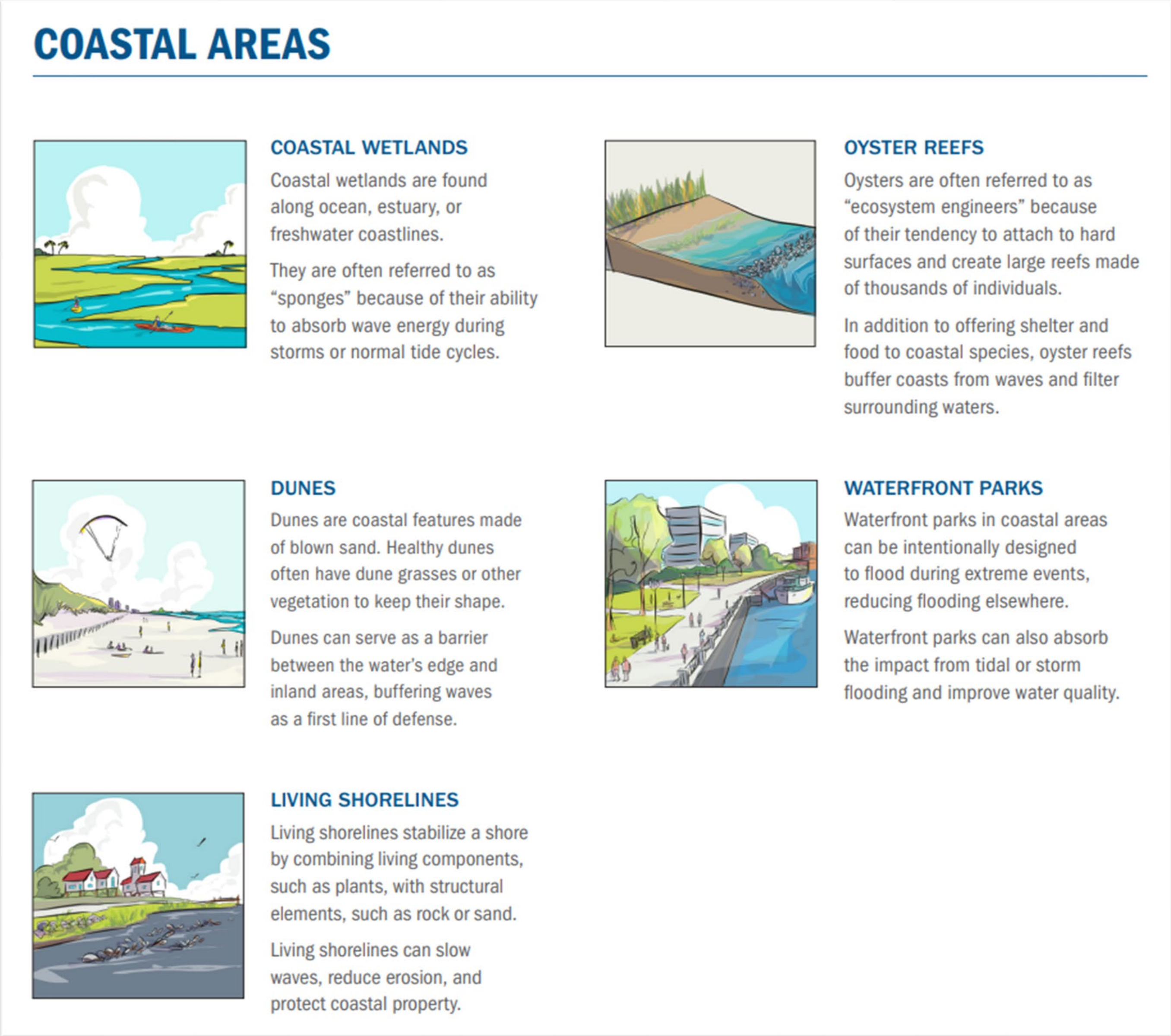

Figure 17: Source https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide_2021.pdf

Retreat

- In some cases, the most effective way to reduce flood risk is to remove development from high-risk areas through buyouts, relocation, or restrictions on rebuilding after disasters.
- Managed retreat can be a controversial and costly option but may become necessary in the face of rising sea levels and more intense storms.
- Proactive planning and community engagement are essential for successful implementation of retreat strategies.

Effective flood mitigation often requires a combination of measures tailored to the specific needs and characteristics of a community. Structural measures like elevation and floodproofing can reduce damages to individual buildings, while non-structural measures like zoning, building codes, and insurance can help manage risk at a broader scale. Nature-based solutions and retreat may become increasingly important as the impacts of climate change worsen.

LESSONS LEARNT

The U.S. experience with floods offers valuable lessons for improving flood risk management:

1. Flooding is a complex, multi-faceted problem that requires a comprehensive approach. No single solution, whether it be structural measures, insurance, or regulations, is sufficient on its own. Effective flood risk management demands a combination of strategies that are tailored to the unique needs and characteristics of each community.
2. Flood risks are not static and are increasingly being influenced by climate change. Historical flood records are no longer a reliable indicator of future risk. Have a strategy in place regarding how (and how often) flood hazard maps, design standards, and mitigation measures are updated to account for changing conditions, including sea level rise, more intense storms, and expanding floodplains. There is a need to consider compound flood risks.
3. Many existing flood-prone buildings were constructed before modern building codes and standards were in place. These older structures are particularly vulnerable to damage and are often uninsured. Retrofitting, moving or replacing these buildings should be a priority for reducing overall flood risk. While these actions may be a priority, they may not be simple to execute.
4. Flood insurance plays a critical role in managing flood risk by providing financial protection to property owners and incentivizing risk reduction through premiums that reflect actual risk. However, maintaining the affordability and accessibility of flood insurance while ensuring the solvency of insurance programs is an ongoing challenge.
5. Building codes and standards are essential tools for ensuring that new constructions and substantial improvements are designed to withstand future flood hazards. However, the process of updating codes and standards can be slow and contentious. Continued research, education, and collaboration among engineers, policymakers, and stakeholders are needed to support the adoption of more resilient standards.
6. Flood mitigation projects, whether structural or nature-based, can have unintended consequences and limitations. Careful planning, design, and monitoring are necessary to ensure that mitigation measures are effective, sustainable, and equitable. Balancing the benefits and costs of different mitigation options is an important consideration.
7. Effective flood risk communication and community engagement are critical for building support for mitigation measures and promoting individual and collective action. Property owners, businesses, and local governments must understand their flood risk and the options available for reducing it. Outreach and education efforts should be tailored to the needs and concerns of different audiences.
8. Flood risk management is a shared responsibility that requires coordination and collaboration among all levels of government, the private sector, and civil society. No single entity has the resources or authority to address flood risks alone. Partnerships and networks that leverage the strengths and expertise of different stakeholders are essential for developing and implementing effective solutions.

Integrating these lessons into flood risk management practice requires a sustained commitment to learning, innovation, and adaptation. By sharing knowledge and experiences across disciplines and jurisdictions, communities can become more resilient to the growing threat of flooding in a changing climate.

IMPLICATIONS FOR PRACTICE

The lessons from the U.S. experience with floods suggest several implications for flood risk management practice:

1. Adopt a risk-based approach to flood management that considers the likelihood and consequences of flooding over the lifetime of buildings and infrastructure. Structures with high importance to life-safety (hospitals, evacuation centres, police/fire, hazardous industrial facilities, etc.) should be designed for much larger events with average recurrence intervals of 1000-years or more.
2. This may require designing for larger, less frequent events (e.g. average recurrence interval of 500 years versus 100 years) and account for increasing risks due to climate change.
3. Have a strategy in place to for the update of flood hazard maps and design standards to incorporate the best available science on changing flood risks, including the effects of sea level rise, more intense storms, and urbanization. Engage stakeholders in the process to build understanding and support for the changes.
4. Prioritize the mitigation of high-risk buildings and infrastructure through a combination of structural and non-structural measures, such as elevation, floodproofing, and relocation. Target resources to the most vulnerable communities and critical facilities.
5. Reform flood insurance programs to better reflect actual risk, incentivize risk reduction, and ensure affordability and accessibility. Explore public-private partnerships and other innovative financing mechanisms to support the uptake of flood insurance.
6. Strengthen building codes and standards to promote flood-resistant design and construction practices. Provide training and resources to help design professionals, builders, and local officials understand and implement the requirements.
7. Encourage the appropriate use of nature-based solutions, such as wetland restoration, green infrastructure, and natural shoreline protection, as part of a multi-layered approach to flood risk management. Quantify and communicate the multiple benefits of these solutions to build support for their implementation.
8. Invest in effective risk communication and outreach programs to help individuals, businesses, and communities understand their flood risk and the actions they can take to reduce it. Use a variety of channels and formats to reach diverse audiences and tailor messages to their needs and concerns.
9. Foster collaboration and partnerships among government agencies, academic institutions, professional organizations, and community groups to share data, tools, and best practices for flood risk management. Establish networks and forums to facilitate ongoing learning and innovation.
10. Incorporate equity and social justice considerations into all aspects of flood risk management, from planning and decision-making to implementation and evaluation. Engage diverse stakeholders, particularly those from historically marginalized communities, in the process and prioritize actions that benefit the most vulnerable populations.
11. Develop and implement comprehensive flood risk management plans that integrate structural and non-structural measures, nature-based solutions, and risk communication and outreach. Regularly update and adapt the plans based on new information, changing conditions, and feedback from stakeholders.

Implementing these practices will require significant investments in research, capacity building, and infrastructure. However, the costs of inaction are likely to be much greater as the impacts of flooding continue to worsen. By learning from past experiences and embracing a proactive, multi-faceted approach to flood risk management, we can build more resilient communities that are better prepared to withstand the growing challenges of flooding in a changing climate.

WEBINAR QUESTIONS AND ANSWERS

Q: How does FEMA currently handle climate change effects in their flood mapping and design flood elevations? Where do you see this going in the future?

A: Right now, FEMA does not include any climate change effects in their flood mapping. Even today, if a contractor started a flood study, there would not be any climate change considerations included. However, FEMA recognizes the need to move in that direction, and the US national government is supportive of that. Communities, states, and professional societies also understand the necessity. There will likely be a movement in that direction, but it hasn't happened yet. Other groups, like the Federal Highway Administration and the American Association of State Highway Transportation Officials (AASHTO), are also wrestling with how to include climate effects in their guidance for roads and bridges. But as of now, no one has fully incorporated climate effects.

Q: Beyond just considering building elevations, what considerations are put into things like access to services, wastewater, power, and hospital/medical access during floods? How can we address flooded driveways and roads to ensure pedestrian and vehicular access?

A: While homes are being raised in many places, roads, parking areas, and sidewalks are generally not being elevated, except for a couple of places in the US. The emphasis so far has been on the residential unit itself. Highway drainage and culvert systems are addressed in parallel documents by the transportation sector. However, local stormwater effects don't fall under the guidance levels discussed here and are typically handled at the local level. Many places are updating their stormwater management practices to account for climate change effects.

Q: What is the balance of interaction between private insurance and the National Flood Insurance Program (NFIP)?

A: Private homeowners' insurance typically covers fire, wind, electrical damage, and so forth, but not flooding. The federal government runs the NFIP, which covers floods. Homeowners need to get separate policies for homeowners' insurance and flood insurance. Recently, a system has been introduced where local insurance agents who sell homeowners policies can also sell government flood policies, but they remain separate policies.

Q: Why is the use of fill not allowed in coastal zones?

A: Fill is not allowed in coastal zones where there are wave effects that could cause scour. The consensus within FEMA and the professional society is that, for the survival of the house, foundation piles are the best approach. Using fill was likely the cheapest way to elevate a house, but it is not as effective as piles in zones with wave effects.

Q: How are uncertainties in flood estimates, such as the 100-year or 500-year flood, acknowledged in prescriptive codes?

A: Prescriptive codes typically do not account for uncertainties in flood estimates. The idea is to come up with the median estimate or the 500-year value, and even the 1000-year level for higher-risk category structures. Prescriptive codes allow the use of flood maps and various corrections. For major structures like hospitals, a site-specific analysis would be conducted, including uncertainty estimates. However, at the fundamental level, prescriptive codes do not have provisions for incorporating uncertainties. Freeboard is often used as a simple way to account for some uncertainties.

Q: As more recent extreme events are incorporated, how are flood event definitions (e.g., 100-year flood) updated? Is there a provision for updating, or does the published definition get baked in over time?

A: For flood insurance purposes, the definition gets baked in at the time the flood maps are generated. In the 1980s, a 100-year level was established in the first round of flood studies, and values have been updated in most areas in subsequent studies. In some cases, the revised 100-year level is higher than the previous, but in several studies it has been lowered, presumably due to more and better data, and better modelling. But this is contentious. In one study in Annapolis Maryland, a revised 2016 study resulted in a 100-year level about 1.5 feet lower than previous studies, even though the new lower level had already been exceeded twice in the past 80 years. This illustrates the problem of outdated flood level definitions and lack of uncertainties in the regulatory flood level. While communities might find it appealing when flood elevations are lowered, professionals find it dangerous, as it can lead to a false sense of security and decreased flood insurance uptake.

Q: How are breakaway walls designed to prevent them from becoming debris once they break?

A: Breakaway walls, which could be made of masonry or wood frame, are designed to minimize the debris they generate when they fail. For masonry walls, they would typically fall over and stay in place on the ground. Wood frame walls are designed to be very light, with connection details that allow the wall to break apart quickly. The dimensions of the wall panels are chosen such that, based on debris load knowledge, they won't impart a huge load or cause damage to the structure. The main goal is to prevent the entire building or large sections of it from failing.

Q: Are local water, wastewater, and stormwater agencies insured for flood damage to their networks?

A: I don't know exactly how insurance works for local water, wastewater, and stormwater agencies. Most of these are community-based and community-funded, so I don't think there's a particular insurance network involved, but I could be wrong.

Q. Are local agencies pushing for coastal retreat?

Regarding coastal retreat, not many local agencies are pushing for it, as it's not popular with homeowners and difficult to implement. Private property rights are highly valued in the States, and there's often no place to relocate people. Buyouts can be complicated, especially for multi-owner properties like condominiums. While agencies would like to promote coastal retreat, it has proven too difficult to implement on a large scale so far. Relocations have been more successful on public property, such as lighthouses and national park buildings, but it has not worked well in urban environments with thousands of individual owners.