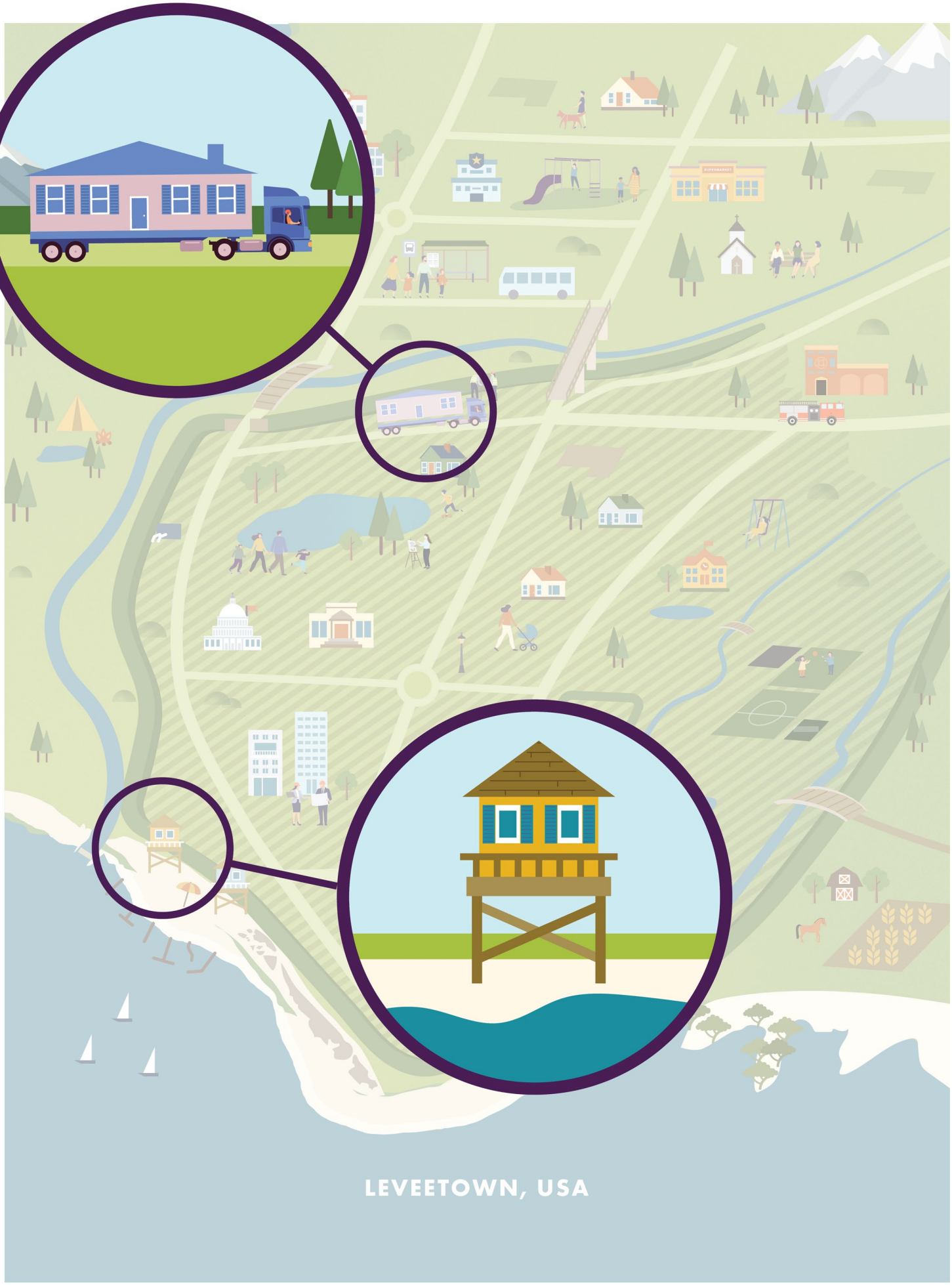
12

Enhancing Community Resilience

Key Messages

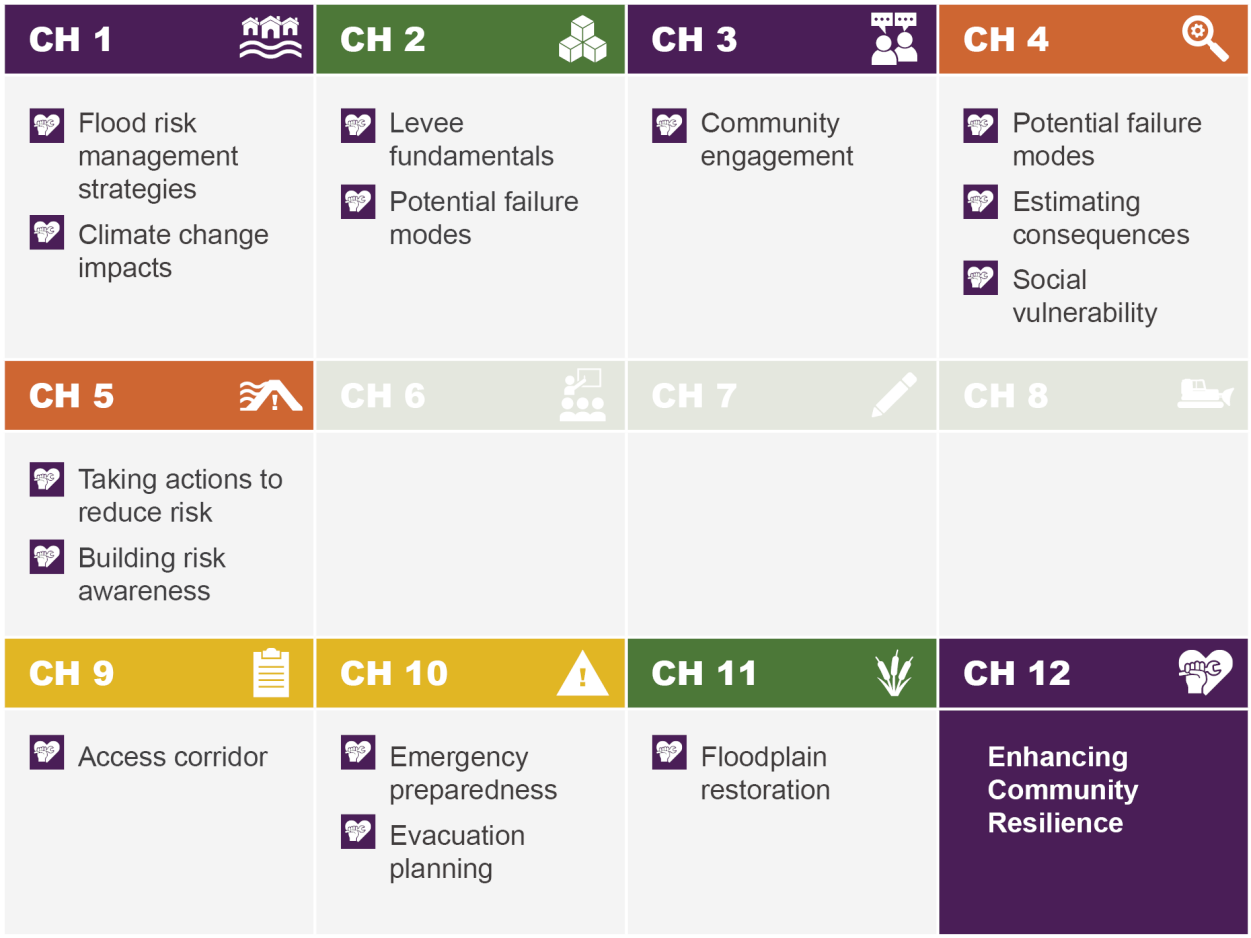
This chapter will enable the reader to:

- **Build resilience.** There are other meaningful flood risk management options that can supplement the role of the levee in building a community's resilience to flooding.
- **Be adaptive.** Communities should evaluate their progress in building resilience and adapt activities to reflect changing needs and conditions.
- **Perform inclusive engagement.** Whole community engagement helps achieve more equitable flood resilience consistent with broader community goals.


LEVEETOWN, USA

Other chapters within the National Levee Safety Guidelines contain more detailed information on certain topics that have an impact on enhancing community resilience, as shown in Figure 12-1. Elements of those chapters were considered and referenced in the development of this chapter and should be referred to for additional content.

Figure 12-1: Related Chapter Content



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1 Introduction

Flooding adversely affects many communities across the nation, resulting in loss of life, destruction of property and infrastructure, environmental harm, and significant recovery costs. In this publication, community flood resilience refers to the ability of a community to persist and recover from the impacts of flooding. Communities which are highly resilient can withstand flooding impacts to a greater degree and more rapidly recover from flooding than those which are less resilient. Flood resilience can be achieved through a combination of structural and nonstructural flood risk management options. As previous chapters have focused on the levee's role as a structural option to build flood resilience, this chapter focuses on nonstructural options that may be implemented to reduce a community's exposure to flooding, minimize losses, and enhance recovery capabilities.

Best practices described within this chapter directly align with the National Levee Safety Program's overarching vision of reducing the impacts of flooding and improving community resilience in areas behind levees. This material is intended to help communities of all sizes and financial capabilities to implement solutions promoting resilience to flooding. Understanding the reality that some level of risk is always present, and flooding may still occur in communities behind levees, the goal is for communities to take tailored actions and consider their unique situations that will result in the best possible outcome for those living and working in the community.

The content outlined within this chapter presents a roadmap to enhance community resilience guided by inclusive and equitable community engagement that involves all those affected by floods and flood risk management decisions in the decision-making process. Once the community sets its vision and establishes overall objectives for flood resilience, an iterative approach to progress towards those objectives may be followed. This approach is guided by continuous engagement of the community and includes the following activities:

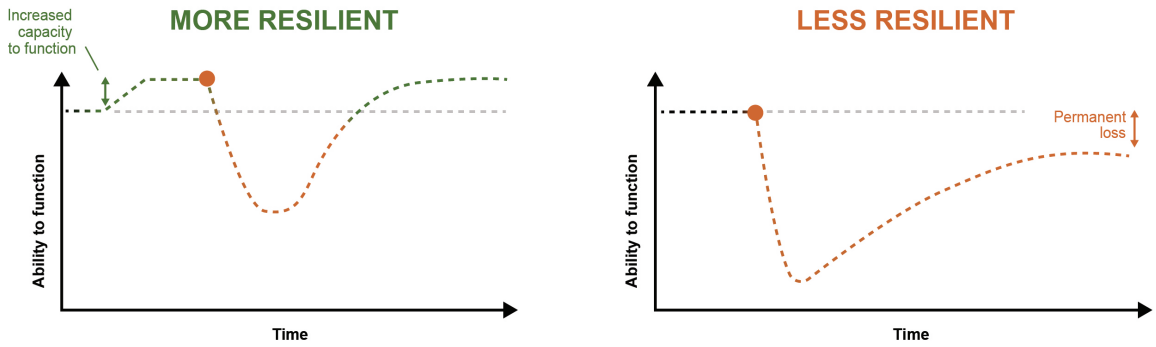
- Understanding the community's flood risk.
- Exploring options to enhance the community's flood resilience.
- Prioritizing and implementing actions to enhance community resilience.
- Evaluating progress and adapting to changing conditions.

2 Building Community Resilience

Each person, business, organization, or government agency can contribute towards building resilience across the entire community, with the intent to improve quality of life and community well-being despite the risks of floods. A community's flood **resilience** is defined by its ability to anticipate, prepare for, respond to, and recover from floods with minimal damage to social well-being, the economy, and the environment.

Figure 12-2 depicts the concept of resilience in terms of a community's ability to function versus the time to recover after a flood, shown as the orange dot (U.S. Department of Commerce and National Institute of Standards and Technology, 2016). In this generalized description, functionality is a measure of how well a community meets its intended services. A resilient community still requires a period of recovery but is able to rebound quicker and to the same level or greater, than its original functionality. In comparison, a less resilient community may not be able to recover to its original level of functionality after a flood. For example, a more resilient community may have a wastewater treatment plant able to quickly return to operation after a flood, minimizing the impact to the quality of life of the people in the community.

Figure 12-2: Resiliency Expressed as Functionality Over Time Following a fFlood



To enhance resilience, communities should understand flood risks and manage those risks with appropriate measures to successfully reduce future impacts of flooding. To do this, community resilience relies on continual improvement through a holistic vision that includes:

- Taking a whole systems approach by considering integrated efforts to improve quality of life, durable systems, economic vitality, and conservation of resources for present and future generations.
- Working together to better understand the community's resilience needs and identify partners who can support them in meeting those needs.
- Embracing community wisdom and respecting and elevating the voice and expertise of those individuals who have been systematically left out of decision making. A more inclusive path to societal security and resilience is built when decisions and solutions are implemented taking the entire community into consideration and reflecting the input of all individuals.
- Strengthening community lifelines. The community lifelines are the most fundamental services in the community that, when stabilized, enable all other aspects of society to function. Lifelines include, but are not limited to, critical infrastructure such as water

PEOPLE: A COMMUNITY RESILIENCE FOUNDATIONAL CONCEPT

The power to define community values and create an inclusive and resilient vision for the future resides with community members. This requires the active engagement of all people, including typically underrepresented groups, in the resilience conversation.

Denham Springs Resilience by LSU Coastal Sustainability Studio (LSU Coastal Sustainability Studio, 2021).

systems for drinking water and wastewater, transportation infrastructure, communications infrastructure, energy grid and fuel, and health and medical facilities. Community members rely on the services that support daily living and serve as the foundation of the community's social and economic fabric such as access to clean drinking water, electricity, health, food, and appropriate elimination of waste.

Approaches used to enhance community resilience should be grounded by the principles of including and listening to the whole community, understanding risk, exploring options to reduce risk, prioritizing and implementing those options based on the unique characteristics and needs of the community, and monitoring and adapting to changing conditions. In short, a best practice is for community decision makers to decide the desired level of resilience. The step-by-step process, depicted in Figure 12-3 and described throughout the remainder of this chapter, begins by establishing the community's vision through engagement of the whole community.

UNITED STATES CLIMATE RESILIENCE TOOLKIT:

This toolkit was created as a problem-solving process communities can implement to prioritize options for reducing risk. The steps to resilience provide a framework for reducing climate-related risks. Communities can use the framework to identify valuable assets, determine which climate-related hazards could harm them, and then identify and take effective actions to reduce risk (NOAA, 2021).

Figure 12-3: Enhancing Community Resilience Approach

Key elements that will improve the outcome of this approach to building resilience are engaging in deliberate planning for resilience, understanding current community capabilities, and seeking opportunities to incorporate environmental justice into resilience planning, as described in section 2.3. These elements will help provide an initial understanding of how resilient a community is to flooding, which then guides the iterative process of enhancing resilience, including which options to explore, select, and prioritize. Developing a reference point of initial community resilience is crucial to all steps of the approach and fundamental to effectively carrying out the fourth step of evaluating effectiveness of activities and making adaptions, as necessary. Principles, strategies, and tools for this evaluation are further detailed in section 6.

2.1 Resilience Planning

Resilience planning sets out a strategic and transparent approach to achieving a community's resilience goals. Plans alone do not increase resilience, but they provide a foundation for implementing actions and should establish a framework with metrics for evaluating their success. The planning process should be used to clearly articulate the values and vision for community resilience that will then guide selection, prioritization, and implementation of resilience building actions.

Some communities develop stand-alone resilience plans or refine existing community planning documents to articulate the overall flood resilience objectives and describe approaches for enhancing flood resilience. At a minimum, it is a best practice for communities to integrate activities that contribute to building resilience into community planning efforts such as:

- Engaging with all members of the community.
- Incorporating the best available flood risk information.
- Identifying and reconciling conflicts with hazard mitigation activities.
- Acknowledging and seeking ways to address impacts of the changing climate.

For example, community-based master plans—sometimes referred to as comprehensive plans—guide the decision-making process for growth and development, economics, housing, and transportation. These efforts present opportunities for communities to address flood hazards, climate change impacts, and inequities in flood risk exposure. Additionally, these plans offer opportunities for communities behind levees to identify gaps in community capabilities and to implement actions to minimize those gaps and make improvements.

PLAN INTEGRATION FOR RESILIENCE SCORECARD™

This tool was created to advance community resilience by helping communities understand and discuss inconsistencies across their networks of plans, the connection between plans and vulnerability to natural hazards, adjustments to current plans, and policy tools to improve integration. One of the innovations is a spatial evaluation of plans, particularly the overlaying of hazard zones with planning districts. This allows communities to understand in a visual way where updates to their land development policies can have the most impact on resilience and where to encourage more resilient development practices. The tool was developed by a team of researchers at Texas A&M University's Institute for Sustainable Communities.

(Malecha, 2019)

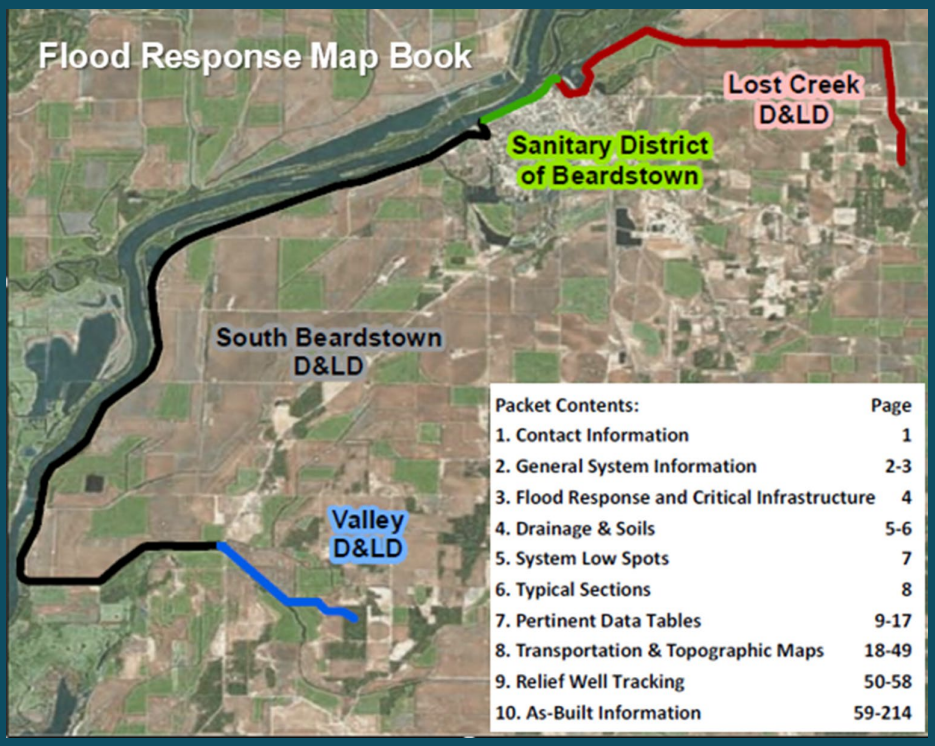
State and federal agencies offer grant programs to assist communities with the cost of preparing plans such as disaster preparedness, hazard mitigation, and emergency action plans—all which can feed into community resilience planning. Local agencies, including emergency management, economic and community development, and environmental protection are good sources of information about funding programs.

CASE STUDY: FLOOD RESPONSE MAP BOOK

The Illinois Flood Risk Management Team brings together federal and state agencies to focus on four themes to reduce flood risk in Illinois: hazard mitigation, emergency response, structural flood reduction measures, and policy evaluation. The team establishes and strengthens intergovernmental partnerships within the state that serve as a catalyst to develop and implement comprehensive and sustainable solutions to flood risk challenges.

For example, the Sid Simpson Levee located along the Illinois River provides flood risk reduction to the city of Beardstown. A levee breach analysis was performed to identify inundation and arrival time for possible breach locations. The intent of this analysis was to inform flood emergency management planning efforts, improve evacuation planning, and reduce future life and safety risks for nearly 6,200 people. Additionally, there is an estimated $1.4 billion of property value within the leveed area.

The team developed an easy-to-use flood response “map book” for the Sid Simpson Levee District. The information and data visualizations collected in the book supports decision making by officials, facilitates communication, and improves interagency coordination for a more efficient flood response. The book includes information such as flood impacts, datum conversion factors, as-built engineering drawings, and river gage information, as well as interior drainage layouts, soil information, and a contact list for local officials. Maps of the entire drainage area show features such as levees, floodwalls, pump stations, and relief wells, as well as aerial photography, evacuation routes, emergency services, and locations of critical infrastructure. This information, when compiled into a single, easily accessible source like the map book, becomes a useful tool for prompt and accurate responses to flooding situations. The map book was most recently used during the near-record Illinois River flood in May 2019.



2.2 Understanding Community Capabilities

Communities have various levels of capabilities to manage flood risk. These capabilities may be influenced by available funding, local technical expertise, or community values and priorities. Understanding what current capabilities exist is key to building an effective flood resilience strategy. The evaluation of capabilities will identify gaps that need to be filled for improved resilience, as well as inform the selection and prioritization of activities based on the resources available for successful implementation. Community capabilities that should be evaluated to assess their current flood resilience—alongside opportunities for strengthening the resilience of a community—include:

- Flood risk management actions:
  - Identify hazards and assess risk.
  - Adopt and enforce land development policies and building codes.
  - Protect natural and cultural resources.
- Public engagement/communication:
  - Conduct equitable public engagement.
  - Test and utilize public information and warning systems.
- Funding and economics:
  - Fund and implement infrastructure projects.
  - Implement economic development programs.
  - Provide affordable housing.
  - Apply for and administer grants to fund projects and programs.
- Community assistance:
  - Provide public health and social service facilities and programs.

CASE STUDY: COLORADO RESILIENCY FRAMEWORK

Following the devastating floods in 2013 and record wildfires in 2010, 2012, and 2013, the state of Colorado developed the 2020 Colorado Resiliency Framework–the first of its kind in the state to serve as a roadmap for helping communities prepare for a more resilient future. It outlines the state's resiliency vision and goals and explores risks across three themes: understanding risks from natural and other hazards, addressing social inequities and unique community needs, and pursuing economic diversity and vibrancy–all within the context of an ever-changing climate. The framework provides 29 strategies across six priority focus areas the state will implement to reduce risk and be adaptive to changing environmental, social, and economic conditions. The six priority focus areas of the framework include community, economic, health and social, housing, infrastructure, and watersheds and natural resources.

Throughout the framework, risks are analyzed, and specific strategies are identified that will strengthen the state's capacity to adapt and support local communities on their path toward resiliency. Two overarching strategies—establishing a statewide resilient and sustainable community/regional program and attracting and leveraging resiliency funding opportunities—are foundational activities that will connect and strengthen all the resiliency priorities.

(Colorado Resiliency Office, 2020)

  - Participate in mutual aid and community assistance charters.
- Emergency preparedness and response:
  - Plan for and conduct emergency preparedness and response activities, including evacuation and sheltering.
  - Invest in hiring and training personnel to support resilience-building strategies.

Federal agencies offer technical assistance to support communities that may not have the resources to begin community resilience planning and engaging the public and stakeholders in exploring and selecting resilience strategies.

2.3 Integrating Environmental Justice

The process of building community resilience should include an evaluation of how equitably the benefits delivered by flood risk management options are distributed throughout a community. Community members most impacted by floods and flood risk management decisions should be meaningfully involved in the decision-making process. Exclusion from this process could cause further harm or put some individuals at greater flood risk than existed before options are implemented.

Environmental justice refers to the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. In many communities, a disproportionate number of underserved populations reside in areas historically prone to flooding due to a combination of housing costs, housing policy, land use policy, residential mortgage lending practices, and insurance practices.

Similarly, vulnerable populations are often left out of community conversations where critical needs and strategies are decided. Both groups can include children, women, pregnant women, elderly, racial or ethnic minorities, underinsured persons, those who are economically disadvantaged, unhoused individuals, persons with medical conditions that predispose them to disparate impacts, and those with limited access to human and social services or infrastructure (e.g., transportation, healthcare, food, potable water).

ENVIRONMENTAL JUSTICE TOOLS:

EJ Screen, EnviroAtlas, and the Climate and Economic Justice Screening Tool are several tools produced by federal agencies that can help communities in areas with historically underserved populations to identify geographic areas of concern using key health, climate, and infrastructure indicators. The data available in these tools are presented spatially and can be overlayed with flood risk data to highlight locations with additional vulnerabilities to flood risk.

Community resilience strategies should recognize the inequalities and inequities which exist and seek to integrate environmental justice into the planning process through exploring flood risk management options that achieve the same degree of risk reduction from flood hazards and equal and equitable access to the decision-making process for all members of the community. Conversely, it is important that all potential negative impacts of options are considered through collaboration with members of the community (**Chapter 3**). Options which can negatively impact the environment, health, or well-being of community members should be avoided.

Table 12-1 provides common flood risk management options and potential environmental justice concerns that could be associated with their implementation. A community should consider

conducting a comprehensive benefit analysis to select the appropriate measure to minimize or avoid these impacts. Engagement with affected populations is essential to identify measures and to monitor needs and preferences of communities.

Table 12-1: Common Flood Risk Management Options with Environmental Justice Concerns

Option	Potential Environmental Justice Concern	Actions to Avoid Concern
Structural measures (dams, levees, channels)	Redirection of floodwaters that disproportionately impact underserved communities who may lack resources to prepare for and/or recover from flood-related damage.	Identify historically underserved communities and vulnerable populations in the study area and include representation of both in planning and decision- making efforts.
Traffic mitigation in flood response and recovery plans	Road closures that divert traffic primarily through underserved community neighborhoods.	Plan for the safest and quickest evacuation routes for all community members. Coordinate with emergency management and health departments to fully understand needs and resources.
Relocation of public facilities (e.g., hospitals, fire stations, parks)	Disproportionate changes in environmental and health impacts from relocated facilities, such as vacant sites or reduced greenspace, or decrease in accessibility of relocated facilities.	Consider dry floodproofing instead of relocating facilities that are important to underserved populations.
Residential buyouts of flood prone properties	Lack of affordable housing to relocate; stress of relocation; broken community social ties; destruction or degradation of property with cultural significance; creation of vacant lots.	Provide affordable housing with access to public transportation, parks, and social services.
Temporary housing strategies in flood recovery plans for displaced residents	Placing housing in an area with existing environmental health hazards or limited access to employment opportunities, public schools, or community lifeline services.	Provide temporary housing in areas where wrap-around services exist (i.e., medical/ dental clinics, behavioral health, employment services).

3 Understand Risk

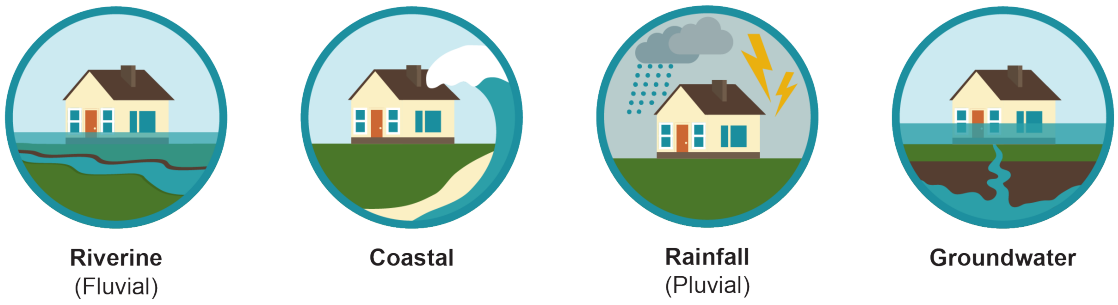
A comprehensive understanding of how flood hazards, expected levee performance, and potential consequences contribute to risk in the leveed area is vital. This understanding helps to inform the selection and prioritization of viable flood risk management options to build or enhance a community's resilience. **Chapter 1** describes the sources of flood risk and options to manage that risk, highlighting the levee as one option that may be implemented. Subsequent chapters—2 through 11—provide best practices related to a levee as the flood risk reduction option.

3.1 Flood Hazards within the Leveed Area

Common sources of flood hazards (Figure 12-4) are described in **Chapter 1** including:

- Riverine (fluvial)
- Coastal
- Rainfall (pluvial)
- Groundwater

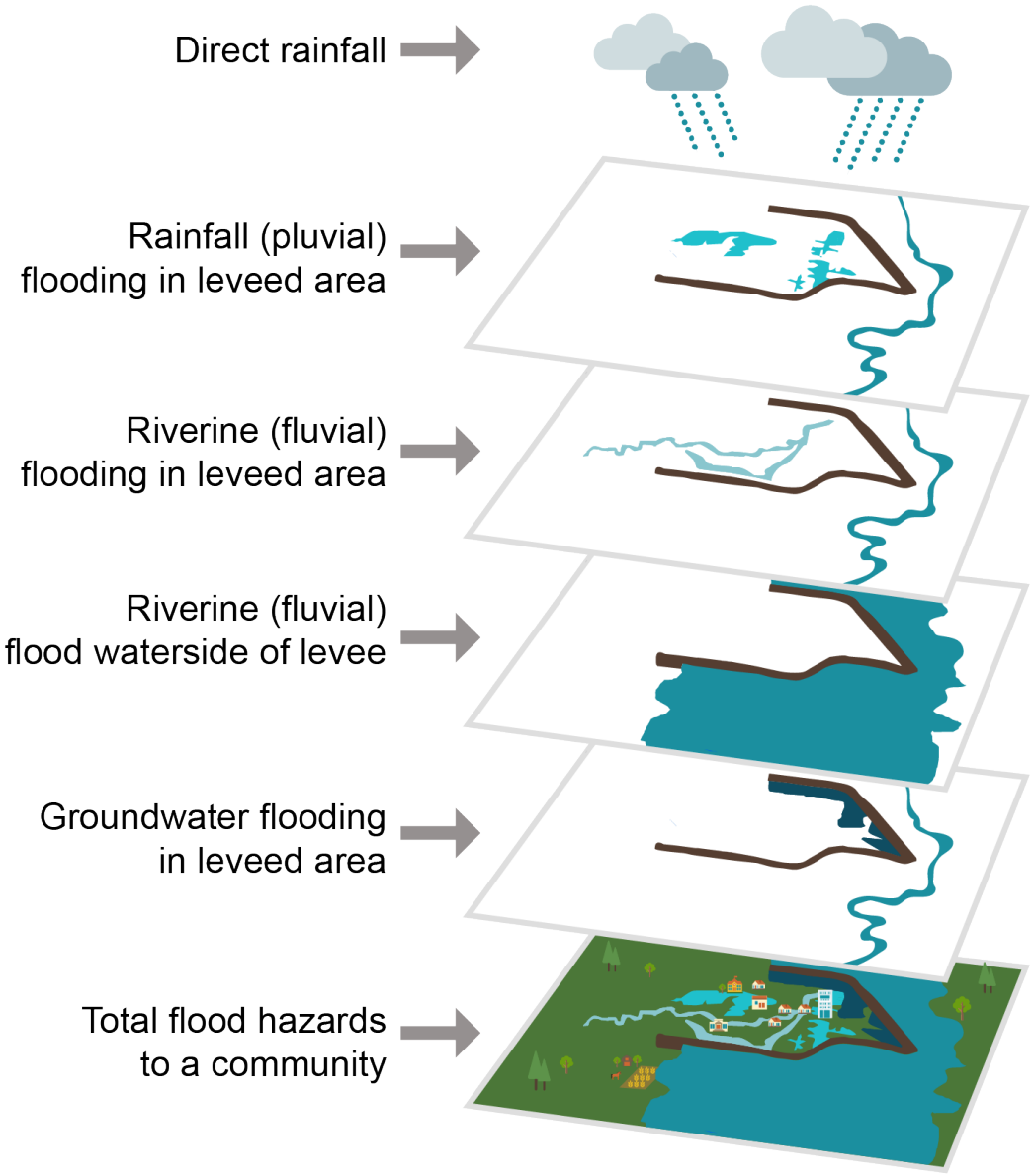
Figure 12-4: Sources of Flooding



Floods may occur from a singular source or multiple sources in combination with one another, as shown in Figure 12-5. Flood hazards will change over time, requiring regular monitoring of conditions to understand if and how risks have changed, and as community resilience needs evolve. As discussed in **Chapter 1**, changes to weather patterns and other natural processes from a warming climate and human activity will impact hazards and how they influence a community's flood risk.

It is important to understand the various sources of hazards and ensure current flood risk management measures are in place to address the hazards, as well as understand their limitations, when exploring additional community resilience building options.

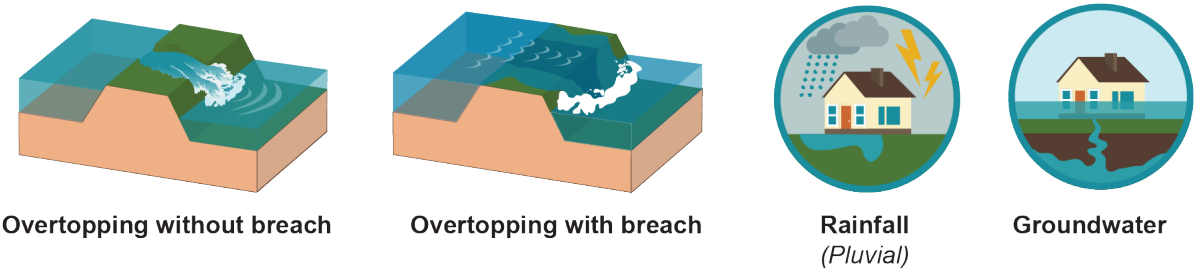
Figure 12-5: Flooding Sources to Leveed Area



3.2 Remaining Flood Risk within the Leveed Area

Levees reduce flood risks to communities but do not address all flood hazards, nor do they eliminate all flood risks. The flood risks that remain in a community with a levee in place are the overtopping (with or without breach), rainfall, and groundwater (Figure 12-6). **Chapters 4 and 5** discuss the evaluation and management of flood risk associated with levees and how the overtopping (with or without breach) contributes to flood risk. The following focuses on remaining flood risk within the leveed area.

Figure 12-6: Remaining Flood Risk Contributors



Overtopping without breach | Overtopping with breach | Rainfall *(Pluvial)* | Groundwater

3.2.1 Overtopping

Levees are designed to reduce flood risks associated with a limited range of certain riverine or coastal hazards. Levees may be overwhelmed by these flood hazards with water flowing over the top of the levee (overtop) leading to flooding of the leveed area.

3.2.2 Rainfall and Groundwater

A levee's primary function does not address the risks associated with rainfall and groundwater hazards, though levee features may be designed to provide some limited capacity to evacuate their associated flood waters through or over the levee. Therefore, even with a levee in place, flood risk in the leveed area from rainfall and groundwater must be accounted for.

3.3 Levee Performance

Risk assessments identify how the levee performance contributes to the flood risk of a community. Understanding **potential failure modes**—mechanisms that, once initiated, could progress to the breach of a levee or inundation of the leveed area and their likelihood of occurrence—will assist in identifying effective resilience building options. The five most common potential failure modes for a levee are introduced in **Chapter 2** and are discussed in more detail in **Chapter 4**.

In some situations, levees may be very vulnerable to certain potential failure modes during a flood, but permanent repairs are not financially or physically viable. In this case, community-based flood risk management options—such as developing and practicing sophisticated plans for emergency response and evacuation should the issue lead to levee breach—are the best ways to manage the associated risks and build resilience to potential flooding in the community. Best practices for emergency response planning are discussed in **Chapter 10**.

3.4 Consequences

Flood consequences broadly refer to short- and long-term impacts attributable to flooding. Consequences of flooding can include immediate or long-term life safety and health impacts, monetary and economic impacts, environmental impacts, and social and cultural impacts. Consequences of levee breach or overtopping are evaluated in levee risk assessments, detailed in **Chapter 4**. These consequence assessments typically focus on the exposure and vulnerability of people and infrastructure in the leveed area, with life safety considered

paramount. Understanding the ways communities may be impacted by potential flooding is critical to developing effective resilience strategies.

Keeping life safety paramount, the ability of those living and working within the leveed area to prepare for and respond to floods should guide communities in their exploration and selection of options that successfully and equitably reduce flood risk. A number of factors, including wealth, access to transportation, and affordable housing, may either strengthen or weaken a community's ability to prevent human suffering and financial loss in a disaster.

SOCIAL VULNERABILITY INDEX:

The Social Vulnerability Index published by the Centers for Disease Control utilizes 15 variables from the U.S. Census to identify populations that may need additional support before, during, and after disasters (CDC, 2022).

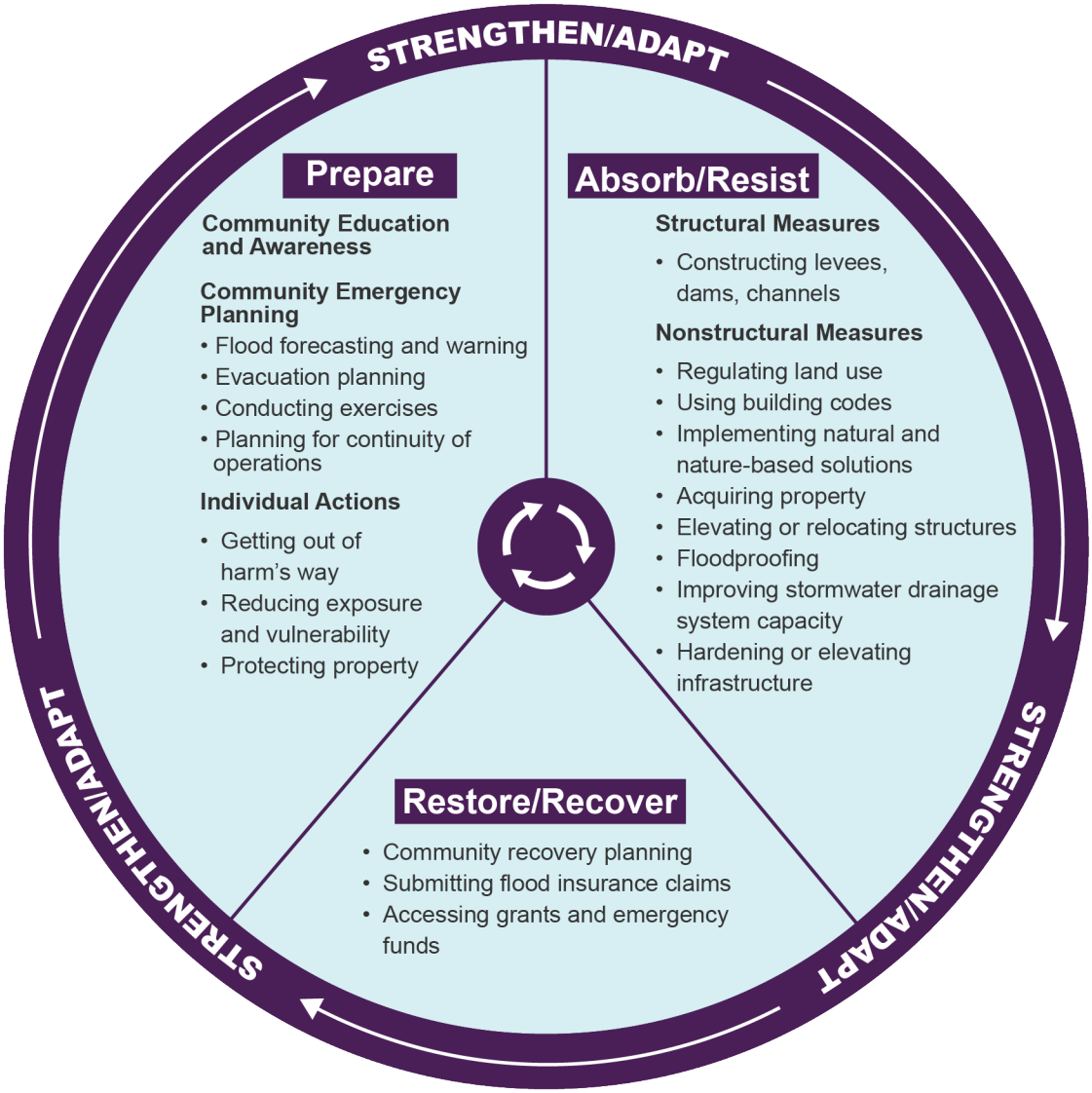
Social vulnerability refers to the susceptibility of social groups to adverse impacts from a variety of hazards, including flooding. Understanding and giving intentional consideration to social vulnerability and how it may amplify consequences during flooding can lead to solutions that build resilience of the whole community. For example, a community that contains a senior living facility in an area susceptible to flooding should focus on how to successfully protect the individuals living in the facility during a flood. This may result in a focused effort on evacuation or shelter-in place planning for individuals with varying medical access and functional needs, and a more deliberate consideration of vulnerabilities community-wide. Additionally, it may result in the development of more effective means of evacuation from which the whole community may benefit, thereby improving evacuation effectiveness for all community members. Additional considerations and best practices for evacuation planning are discussed in section 4.1.3.2.

4 Explore Options

Understanding a community's exposure to flood risk, its greatest vulnerabilities, and its vision for community resilience should guide the exploration of options to most effectively sustain or increase a community's flood resilience. A variety of options exist that can support a community's goal.

These guidelines consider those options through commonly understood principles of community resilience—prepare, absorb and resist, restore and recover, and strengthen and adapt. The latter principle, strengthen and adapt, refers to the continual assessment of resilience and identification of new or improved ways to achieve resilience goals. Therefore, the following options are categorized into the three principles of prepare, absorb and resist, and restore and recover, as shown in Figure 12-7.

Figure 12-7: Flood Risk Management Options



4.1 Prepare

Proper planning for and education about flood risks prior to a flood can build and sustain the capabilities needed to prevent or manage the effects of flooding. This principle includes all elements needed to be ready before, during, and immediately after a disruption or changing condition. Preparedness includes activities such as understanding risks, developing emergency plans, and training based on those plans. The principle of 'prepare' considers all other principles—what is needed to absorb and resist and to restore and recover from flooding.

4.1.1 Community Education and Awareness

Important characteristics of resilient communities are that residents are knowledgeable about their risk of flooding and are aware of actions that may be taken to reduce flood risk. As described in **Chapter 3**, knowledge about general flood risk and levee fundamentals is an

essential first step. If other dams or levees exist within the watershed, it is important for communities to understand the risk and benefits of other infrastructure and how they may work together to manage flood risks. For instance, upstream dams can regulate flow in the watershed, decreasing the probability of flooding. However, large releases can cause rapid increase in river levels downstream.

A greater understanding of flood risk, combined with increased awareness of how hazards can change over time and the consequences in the leveed area, can motivate leaders and residents to take action to reduce their risk. Communities who understand their flood risks may also feel more comfortable participating in the engagement process for building community resilience and take action on a personal level to reduce their individual flood risk.

4.1.2 Individual Actions

Once individuals have an understanding of flood risks, they can choose to implement actions to protect their property and/or reduce exposure and vulnerability of property to flood risks, such as:

- Purchasing flood insurance.
- Elevating their homes or other structures.
- Flood proofing their homes, businesses, or other structures.
- Accessing grant programs or loans for rebuilding or relocation.
- Participating in a community's strategy for acquiring flood prone property or relocating flood prone structures.

Individuals can also take actions that improve their ability to safely get out of harm's way when flooding does occur, such as:

- Assembling emergency supply kits, also known as 'go-bags,' which contain essential items in the event community members are displaced from their homes. Kits include items specific to individual needs, such as medication, batteries, food, water, lightweight clothes, and items for young children and pets.
- Developing and practicing family communication plans that include strategies for how to communicate before, during, and after a disaster.
- Signing up for emergency notifications through local jurisdictions or office of emergency management.
- Assembling and protecting personal documents such as birth certificates, passports, medical records, property deeds, and insurance papers. Documents can be stored in a waterproof safe, as digital copies in the cloud, or multiple copies in separate locations such as a safe deposit box.
- Identifying and practicing evacuation routes. Practicing is essential to understanding the safety and practicality of plans, in particular for those in elevated or flood proofed structures.

- Learning the locations of local shelters and aid distribution centers, as well as those in neighboring jurisdictions.

4.1.3 Community Emergency Planning

To effectively enhance resilience, every community should have an emergency response plan specific to flooding. **Chapter 10** details best practices for emergency preparedness, management, and response activities specific to levees. Community-based emergency planning should be done collaboratively and in a manner that is complementary to the levee-specific efforts. Planning should include response activities for when the scope of the incident expands beyond the levee itself and has the potential to impact the surrounding community. These efforts should also acknowledge that flooding can also occur from rainfall or other flood sources not related to the levee, which in some cases pose a greater risk to the community. The community emergency preparedness efforts should include evacuation planning, training and exercises of emergency response plans, and a continuity of operations plan.

4.1.3.1 Flood Forecasting and Warning

Flood forecasting is a process of estimating and predicting the magnitude, timing, and duration of flooding based on known characteristics of a watershed. Flood forecasting can provide communities with the time and information necessary to prepare for potential flooding impacts and take necessary flood risk management measures—such as closing recreational areas, initiating evacuations, and relocating property. A flood warning should be disseminated through an emergency management system or the National Weather Service to the community when the threat of flooding is imminent or already happening based upon flood forecasting.

An effective flood forecasting and warning system requires attention to three basic factors:

- Collect data via the flood forecasting sensing equipment such as rainfall and stream gaging through automated systems, as well as manual observations of field conditions.
- Process data using hardware, software, and manual observations to produce flood hazard information.
- Disseminate the flood hazard information, such as an automated alert, when the processed data indicates a threshold is reached. This flood warning dissemination system should reach communities quickly through sirens, phone calls, and text messages.

To be effective, flood warnings must be understood and received by community members. If actions are required by individuals to receive the warnings, such as registering their mobile phone number, campaigns informing and encouraging community members to take the necessary steps should be carried out.

CASE STUDY: HARRIS COUNTY FLOOD CONTROL DISTRICT'S FLOOD WARNING SYSTEM

The Harris County Flood Control District's flood warning system measures rainfall amounts and monitors water levels in surrounding bayous and creeks on a real-time basis to inform officials and the public of dangerous conditions. The system relies on 188 gage stations strategically placed throughout Harris County bayous and their tributaries. The stations contain sensors that transmit valuable data during times of heavy rainfall and during tropical storms and hurricanes.

When rain begins, data-collecting sensors transmit rainfall amounts and bayou and stream levels to repeaters, which then relay the data to primary and back-up base stations. Harris County Flood Control District staff monitors the data daily to ensure the gages are properly functioning and transmitting accurate data.

This information is used by the Flood Control District and by Harris County's Office of Homeland Security and Emergency Management to inform the public of imminent and current flooding conditions along bayous. It also is used by the National Weather Service to assist in the issuing of flood watches and warnings. The information is provided on a website with an interactive map that can be accessed by community members. The Harris County flood warning system also includes text, email, and social media (Twitter, Facebook, Google) notifications that anyone can register to receive.

Accurate rainfall and bayou/stream level data helps the public and emergency management officials make critical decisions that can ultimately reduce the risk of property damage, injuries, and loss of life. The Flood Control District urges the public to use this information and take the appropriate precautions during times of heavy rain and flooding (Harris County Flood Control District, 2023).

4.1.3.2 Evacuation Planning

Evacuation plans provide strategies to relocate individuals out of harm's way safely and effectively during a hazardous flood. Flood-related evacuation planning must consider a community's unique flood risk and response capabilities, and the potential impacts to a community from a levee breach or overtopping.

Past natural disasters have been widely studied, critiqued, and used as an opportunity to identify lessons learned and subsequent development of evacuation best practices. Many after-action review sessions looked throughout the pipeline of federal agencies to local jurisdictions, including a review of emergency services response efforts such as search and rescue, health and medical services, and key partners throughout emergency evacuation activities.

The reviews highlighted the integrated nature of impacts from flooding. For example, physical damage to infrastructure and the built environment can have immediate and long-term impacts to evacuation, displacement, safety measures, and loss of life. Key understandings from the reviews include the importance of:

- Preparedness by government and other response agencies.
- Effective communication prior to a storm or flood and throughout all activities, both within and across response agencies, hospitals, and other local organizations.
- Coordinated efforts across all entities.
- Tailoring response actions to the unique circumstances of an impacted community, including an understanding of residents' needs, matching efforts to attend to their needs, and protecting residents' life and safety.

Table 12-2 provides a list of lessons learned and associated best practices documented in these reviews. Refer to **Chapter 10** for additional information related to communication before, during, and after a flood.

Table 12-2: Emergency Evacuation Lessons Learned and Informed Best Practices

Lesson Learned	Best Practice
Effective, efficient communications are essential to successful and equitable evacuation.	• Utilize alerts and early warning systems. • Asses needs, develop messages, identify key partners, and select tactics for message delivery as early as possible, and continue throughout response and recovery activities. • Ensure communication content is clear, concise, and timely. • Incorporate redundant platforms. • Ensure content is accessible (e.g., produce in multiple languages for those who are non-English speaking, ensure Americans with Disability Act compliance for those with visual disabilities). • Include all key partners in communications, including hospitals/healthcare facilities, essential services, and community organizations.
Interagency coordination facilitates successful evacuation by improving timely actions, compliance, communications, and resourcing.	• Coordinate activities across sectors that support and enhance evacuation activities. • Include local organizations to improve reach and knowledge of impacted areas. • Integrate platforms within and across agencies for seamless sharing of information and coordinating efforts.
Evacuation plans and plan management can improve successful actions throughout an incident and is key to safety and life-protecting measures.	• Prior to a flood, develop comprehensive, realistic, usable evacuation plans. • Update plans annually, at a minimum. • Provide annual trainings and exercises for response personnel, key partners, and stakeholders. • Provide ongoing educational opportunities for residents to increase awareness of risks, up-to-date evacuation routes, and available resources and services. Updated information should be communicated during a flood if/as resources or available services change. • Prior to a flood, encourage critical facilities to have their own evacuation plans for seamless integration into broader response activities. • Ensure evacuation plans include resource lists with emergency equipment, personnel contact information, evacuation routes and facilities, sheltering needs, and personnel. • Focus on leveed communities, immediate surrounding areas, and neighboring jurisdictions. • Include unique needs and characteristics of vulnerable populations and underserved communities in all evacuation plans.

Lesson Learned	Best Practice
Resourcing across response activities is essential and can be a distinguishing factor between life and death. This is inclusive of material goods, human resources, or financing.	• Ensure resources are sufficient, stockpiled, and funded prior to a flood. • Assess equipment for operability and accessibility prior to a flood; include fuel availability and coordinate with fuel management plans. • Train and staff human resources, including redundant sources of staff such as volunteers. • Coordinate with volunteer agencies and include them in planning activities. • Coordinate with donations management for critical goods, including medical supplies, equipment, and financial assistance. • Review Mutual Aid Agreements/Memorandums of Understanding on an annual basis to ensure agreements are active and up to date.
Timely actions are critical to ensure safety and life protection measures.	• Monitor and assess the situation throughout response activities during a flood and into recovery as necessary. • Activate flood warning systems to the public as early as possible. • Activate interagency coordination protocols prior to an incident as able, or as soon as possible in a no-notice flood. • Ensure resources are available. • Review and secure agency capabilities. • Activate evacuation procedures and orders as early as possible, even prior to an incident, as necessary. • Follow above best practices, as soon as an incident occurs and throughout the incident.
Evacuation routes/improved transportation is a key item for evacuating a community impacted by floods, as the mass disruptions to public transportation mechanisms, road closures, and the inequitable distribution of access to transportation restricts ability for residents to leave.	• Ensure accessible transportation is provided to individuals with access and functional needs. • Build awareness of evacuation routes for at-risk communities through public engagement and educational opportunities prior to a flood. • Communicate updates for evacuation orders to impacted communities throughout a flood. • Monitor functionality of public transportation services and evacuation routes for access throughout response and recovery activities.
Vulnerable populations and underserved communities need to be considered and included throughout the planning process and associated response activities.	• Include the unique resourcing needs and/or specialized assistance for vulnerable populations and underserved communities into all evacuation planning and response activities. • Integrate training and exercise activities to strengthen capabilities and build awareness. • Coordinate government agencies with community organizations and other trusted messengers specializing in accessibility needs, community leaders who have knowledge of and access to immigrant communities, and those populations with differing needs.

Evacuation plans should consider the range of exposure for all members of the community and tailor actions based on the potential flood depths throughout the leveed area, accessibility of transportation systems, and the unique vulnerabilities of community members. Further, impacts of floods to transportation systems should be considered when identifying evacuation routes. The time required for those within the leveed area to evacuate should be considered when establishing flood warning systems so that people can evacuate before roads become impassable and buildings get inundated.

CASE STUDY: NEW ORLEANS CITY-ASSISTED EVACUATION

The city of New Orleans developed the City Assisted Evacuation to help New Orleans' residents and visitors who wish to evacuate during an emergency but lack the capability to self-evacuate. It is meant to be an evacuation method of last resort, and only for those who have no other means or have physical limitations that prohibit self-evacuation.

The City Assisted Evacuation utilizes city facilities, personnel, and other resources to provide the service. The service allows individuals to bring one carry-on sized bag with supplies (not including medical devices, diaper bags, and other necessary personal items). It also provides accommodation for pets to be taken to an animal shelter near where the person is sheltered.

A dedicated center is established as the hub for evacuation for those who can't leave on their own, where individuals are registered for evacuation. From there, evacuees would board a bus, train, or airplane to a state or federal shelter. Multiple options are provided to transport individuals to the dedicated location, including:

- **Evacuspots**: There are 17 pickup locations across the city, called evacuspots, where dedicated shuttle buses will be bringing evacuees to the center. Five evacuspots are specifically for seniors. An example of an evacuspot is shown here at Mary Queen of Vietnam.

- **Bus routes**: Buses run on a Saturday schedule and all bus routes ending at Duncan Plaza will make a final stop at the center.
- **Drop-offs and walk ups**: Evacuees can be dropped off or walk to the center.
- **Rideshare**: Instructions are provided for drop-off locations if evacuees are using a rideshare to get to the center.

If individuals are unable to evacuate on their own because of medical needs, instructions are provided to apply to be picked up from your home. Eligibility requirements apply (City of New Orleans Office of Homeland Security and Emergency Preparedness , 2023).

Evacuation planning efforts should also identify and consider the needs of those who would experience challenges to evacuating, such as those without personal transportation, residents of nursing homes, hospitals and day cares, persons with access and functional needs, those experiencing extreme poverty, and those with pets. Accommodations should be in place to help support evacuation—such as providing transportation suitable to safely accommodate physically disabled persons during evacuation and designating elevated structures to shelter in place.

4.1.3.3 Exercises

Local emergency management agencies typically conduct table-top, functional, and full-scale drills and exercises of their emergency action plans on a regular basis. These exercises mimic real emergency events and are a best practice for training and preparing to activate an emergency plan. Drills and exercises also provide an opportunity for participants to build relationships with partner agencies and identify opportunities to improve emergency capabilities.

While not all exercises will involve flooding, flood-related exercises should consider a community's specific flood risks and incorporate levee and flood emergencies into their exercises to mimic the activation of the levee emergency action plan and the community's evacuation plan.

Drills and exercises present an opportunity for emergency management or other partner agencies to familiarize themselves with the strategies and practice suggested actions, to ensure that access and functional needs are integrated, and the whole community is appropriately included.

CASE STUDY: CITY OF SACRAMENTO, CALIFORNIA FLOOD DEPTH AND EVACUATION MAPS

The city of Sacramento has prepared detailed maps showing hypothetical levee breaches for a 200-year flood. These maps estimate the inundation levels and the time it would take for waters to rise in affected neighborhoods and rescue and evacuation zones after seven days without mitigation. These maps, along with evacuation instructions, are provided to community members. Community members are encouraged to learn possible evacuation routes and heed instructions issued by emergency management personnel during a flood (City of Sacramento Department of Utilities, 2022).

4.1.3.4 Planning for Continuity of Operations

A continuity of operations plan details how an organization will remain operational and perform essential functions following any flood that makes it unsafe or impossible for employees to work under normal conditions or in the normal location. Continuity of operations plans go beyond activities detailed in an emergency action plan including:

- Delegation or transfer of authority.
- Identification of essential functions (information technology, payroll, communications).
- Alternate facilities for performing work.
- Alternate transportation and remote work capabilities.

- Access to and safeguarding of information (physical, local server, cloud).
- Return to normal operations.

The development and execution of these plans for all community lifelines—which are the most fundamental services in the community that, when stabilized, enable all other aspects of society to function—is critical to a community's ability to absorb and recover from flooding impacts.

4.2 Absorb and Resist

To absorb means to receive a stress or endure change with minimal damage and without loss of normal functionality. To resist means to withstand the force or effect of flooding. A range of options can be considered to improve a community's ability to absorb or resist flooding from a full range of hazards, including those not associated with the levee.

Options can vary from small-scale projects on individual properties to large-scale projects on a community level. Small-scale projects on individual properties can typically be taken on at the owner's discretion. While benefits to the property can be significant, they are typically concentrated to a localized area. Large-scale community-level projects require more extensive resources and engagement but can have significant impacts on the community's flood resilience. Because large-scale projects can have such far reaching impacts, community engagement is essential to fully understand potential adverse impacts, select the most meaningful options, and offer community members a voice in the decision-making process. The following sections present options to absorb and resist flooding that can be applied on a community level, as well as by individual property owners.

4.2.1 Land Use Planning

Adopting land development policies or zoning codes which reduce, restrict, or establish standards for development in flood prone areas can effectively enhance a community's ability to absorb and resist impacts of flooding. Communities should consider the likelihood of flooding from all sources and potential consequences in order to adopt policies or codes that are commensurate with their values and tolerability to flood risk.

Many communities adopt a flood damage prevention ordinance which establishes a minimum first floor elevation for houses and buildings to reduce a building's exposure to floods and the subsequent damages if flooding occurs. This designated

CASE STUDY: STATE OF NEW JERSEY MODEL FLOOD DAMAGE PREVENTION ORDINANCES

The state of New Jersey model flood damage prevention ordinance provides a higher standard for development than that which is required for participation in FEMA's National Flood Insurance Program. New Jersey regulates flood hazard areas that are in watersheds measuring 50 acres or greater in size and most riparian zones in the state. The model ordinance requires a comparison of the state-identified floodplains with the FEMA effective flood insurance rate map and FEMA preliminary flood hazard data. The most restrictive of these datasets establishes the flood elevation by which development is regulated.

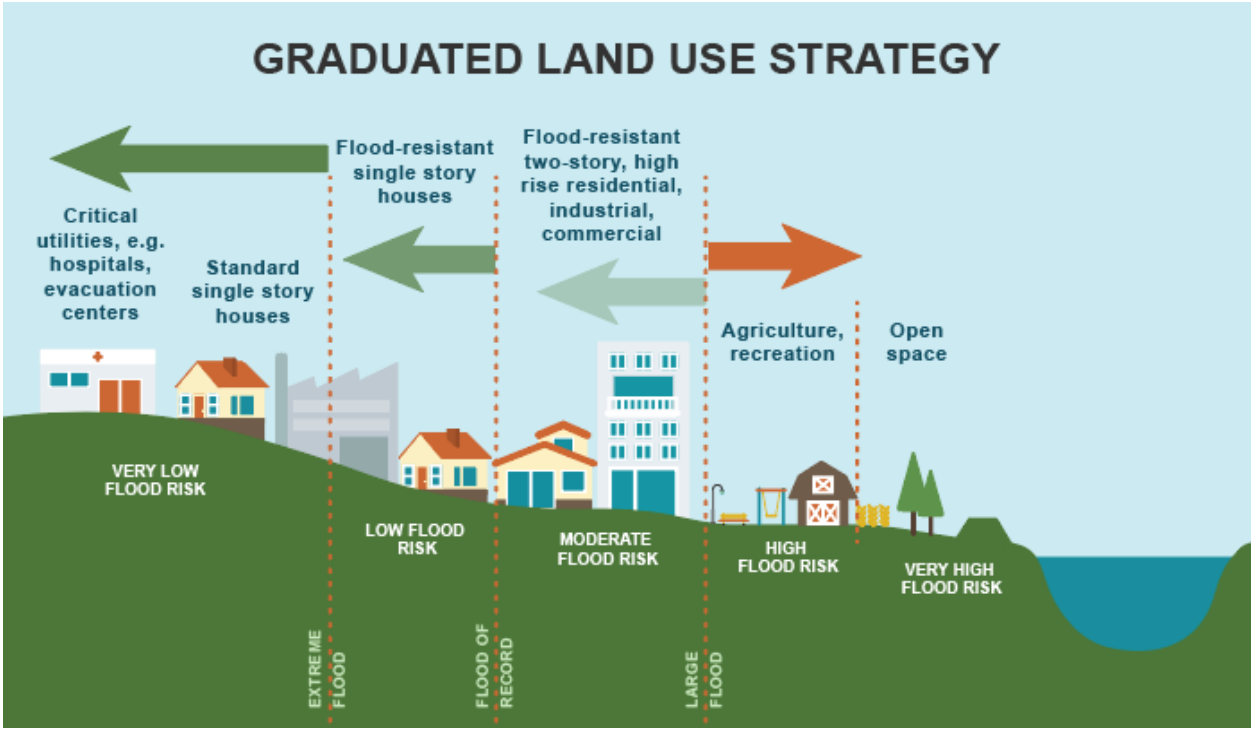
Within the regulated flood hazard area, the model ordinance includes a standard for communities to build the first floor of a building to at least 1 foot higher than this established flood elevation. The first floor of critical facilities must be built to either 2 feet above the flood elevation or the 0.2% annual exceedance probability flood elevation. Because of these higher standards, the regulated flood hazard area in New Jersey is more expansive and more restrictive than FEMA (State of New Jersey Department of Environmental Protection, 2023).

elevation typically correlates to a probability of flooding and is at least 1 foot higher than the 1% annual exceedance flood in most communities. Most states offer a model ordinance to help communities adopt a legally defensible ordinance.

If a levee overtops or breaches, areas immediately adjacent to levees are most susceptible to flood damages due to the velocity and quantity of flow moving through or over the levee. In addition to the access corridor discussed in **Chapter 9**, communities may acquire additional right of way or adopt an ordinance restricting development in areas adjacent to the levee.

Policies may also establish zones based on flood risk that have graduated restrictions on development based on the expected flooding levels and frequency for an area. For example, areas closest to the levee with very high flood risk might only allow recreational or agricultural uses, while areas further from the levee with very low flood risk might allow commercial and industrial uses. In between zones may allow residential and commercial development but require minimum first floor elevations. Figure 12-8 demonstrates the concept of a graduated land use planning policy behind a levee. Not only does this approach reduce consequences of flooding, but can also decrease severity of floods by decreasing runoff and obstructions to flow of floodwaters and increasing the ability of the environment to absorb water.

Figure 12-8: Graduated Land Use Strategy



Stormwater ordinances can also reduce flood risk. Best practices in stormwater ordinances on new construction include requiring ‘zero run-off,’ on-site detention, permeable pavement, vegetative buffers, and erosion and sedimentation control. Similar ordinances can apply to agricultural activity. These practices can improve the environment’s ability to naturally absorb water from rainfall or convey rainfall into drainage systems.

4.2.2 Building Codes

Building codes are laws that set minimum requirements for how structural systems, plumbing, heating, ventilation and air conditioning, natural gas systems, and other aspects of residential and commercial buildings should be designed and constructed. These laws are enforced at a state or local government agency. An example of a flood resistant building code is the requirement for steel exposed to salt water, salt spray, or other corrosive agents to be hot-dipped galvanized after fabrication.

The international codes—developed by the international code council—are a family of 15 coordinated, modern building safety codes that help ensure the engineering of safe, sustainable, affordable, and resilient structures. These consensus-based building codes incorporate the latest technical standards and best practices as published by many different industry groups and stakeholders, such as the American Society of Civil Engineers and the Federal Emergency Management Agency (FEMA). The international codes are updated approximately every three years incorporating the latest technical standards and best practices as published by many different industry groups and stakeholders. Therefore, adopting building codes based on the latest editions of the international codes is one of the best tools communities can use to enhance their resilience to floods in their jurisdictions, particularly for new construction.

Flood resilience provisions in buildings codes require design and construction to be resistant to floods. Two specific examples of flood resilience provisions include:

- Requiring the lowest floors to be elevated 1 foot above the 1% annual chance exceedance probability flood elevation.
- Requiring electrical, mechanical, and plumbing systems and components—if they are located below the pertinent flood elevation—to be designed and installed to prevent water infiltration and resist forces exerted by water depths and flows.

As described in the previous section, communities are encouraged to adopt a flood damage prevention ordinance. These ordinances complement the building codes by including standards for flood resistant design and construction of buildings and structures. In addition to making buildings more resilient, strong building code enforcement can improve competitiveness for resilience grants that are available from state and federal agencies.

4.2.3 Natural and Nature-Based Solutions

Natural and nature-based solutions focus on conserving, restoring, and engineering natural systems for the benefit of people and ecosystems. Natural features (those produced purely by natural processes) and nature-based features (those produced by a combination of natural processes and human engineering) can provide flood risk management benefits along with other economic, environmental, and social benefits. In response to changing natural hazards and to proactively address climate-related risks, many communities are looking for ways to build resilience that yield the most benefit for the least cost. Thoughtfully planned nature-based solutions can contribute to a community's resilience. The International Guidelines on Natural and Nature-Based Features for Flood Risk Management offer a comprehensive guide to identifying, planning, and implementing natural and nature-based features (Bridges *et al.*, 2021).

Natural and nature-based solutions that increase flood resilience for communities with levees can vary widely in size and location. Larger sized solutions on a watershed scale involve interconnected systems of features such as natural areas and open space. These solutions reduce flood risk by keeping flood prone areas clear of development and provide flood storage to lower water surface elevation and velocity which lowers risk to levees and communities. A good source for more information is The Building Community Resilience with Nature-Based Solutions, A Guide for Local Communities (FEMA, 2021). Common solutions include:

- **Land conservation:** Land conservation involves preserving open space through acquisitions and easements to reduce the potential for development. It is most effective on a large scale with a system of interconnecting open space. This enhances community resilience by leaving land undeveloped to store and infiltrate rainwater, slow stormwater runoff, and preserve floodplains from development. These benefits reduce a community's flood risk and conserve habitat for native species.
- **Greenway protection:** Greenways are corridors of protected open space managed for both conservation and recreation. Greenway protection prevents development within corridors along rivers and streams and creates recreational opportunities and improved quality of life by providing access to the water and trail systems. Greenways often follow rivers or other natural features linking habitats. Communities benefit with improved social ties by the presence of nearby natural areas open for recreational public use where individuals are more likely to work together to achieve common goals, exchange information, and maintain informal social controls, which improves community resilience.
- **Wetland restoration:** Reestablishing wetlands will absorb, filter, and store excess water and provide important wildlife habitat. Levee removal is a common method for reconnecting a floodplain to the stream or coastal waters, thereby creating wetland areas. Community resilience is enhanced by having healthier environments with wildlife habitat and recreational opportunities, improved water quality, and open spaces that draw people together.
- **Floodplain restoration:** Reconnecting floodplains to rivers allows their natural functions to return, including storing floodwater and providing wildlife habitat. Community resilience to flood risk is enhanced by lower water surface elevations and slower movement of water. Floodplain restoration also sustains riparian buffers, improves water quality, and supports wildlife habitat diversity. Setback levees are a common example of a way to achieve floodplain restoration. Refer to **Chapter 11** for more information.

CASE STUDY: NAPA COUNTY, CALIFORNIA

In February of 1986, a flash flood took three lives, damaged 245 homes and 120 businesses, caused the evacuation of roughly 7,000 people, and left 25,000 people without power for several days. In total, Napa County suffered an estimated $100 million in property damages. While Napa County has long been plagued by significant floods, the 1986 disaster solidified the importance of enacting a flood risk management strategy.

In 1998, the community opted to pursue a floodplain restoration approach, with a focus on addressing the many environmental issues (water quality, waste disposal, habitat destruction, etc.) throughout the region. The local governments of Napa and surrounding counties backed the initiative to create a more cohesive approach that used many different features and techniques to provide flood risk reduction. The design aimed to create a 'living river' returning the river to its natural state and using the river's natural features to reduce the likelihood of flooding.

The Napa River project was completed in 2015 and used more environmentally friendly techniques that have added benefits. One key aspect of the plan removed bridges that blocked the river's natural water flows. Designers wanted to ensure that the river was reconnected to its historic floodplain, thereby naturally attenuating flood flows, improving instream habitat for native fish, and helping to reduce excess sedimentation and improve water quality. Riverbank terracing allowed the water to spread horizontally into defined areas. Downstream, historic tidal wetlands that had been converted to pastureland were purchased as part of the project and restored back to a wetland habitat capable of holding water. When floodwaters rise to 'flood stage,' the water is diverted via a bypass channel that sends fast-flowing water around the sharp turns of the river's natural banks. Since this bypass can only be utilized once waters reach a certain level, the oxbow of the main river remains connected to the main channel, preserving the existing habitat. Finally, low floodwalls and tiered levees were also constructed to further enhance flood risk reduction.

Although flood risk management is the main goal, the design of this project considered other possible benefits including recreation, access, and environmental restoration. The expanded and restored wetlands provide critical habitat for threatened native birds and other wildlife, social and recreational benefits have been realized through the creation of additional open space areas such as parks, and over six miles of trails have been created–enhancing the river's aesthetic appeal and increasing riverfront access. Other benefits include potential economic investment as a result of restoring the river and minimizing once flood-prone areas thereby attracting increased and new business development in downtown Napa.

The photo displays the elevated railroad and roadway bridges over the new bypass channel. The bypass channel converges with the more natural river downstream (Napa County Flood Control & Water Conservaton District, 2023).

Smaller sized natural and nature-based solutions can be implemented in localized areas within a neighborhood or individual property. These solutions, often referred to as 'green infrastructure,' typically involve distributed stormwater management practices that manage rainwater where it falls, slowing stormwater runoff. These practices can be built into a site's structure, corridor, or neighborhood without requiring additional space.

These smaller-sized solutions are highly effective for leveed areas in managing flood risk from stormwater and may include:

- **Stormwater parks, rain gardens, and bioretention systems**: A variety of types and scales of vegetated, low areas exist which can effectively collect and absorb stormwater runoff. These elements include attractive landscape features, habitat, and safe environments for walking and biking in urban settings. Stormwater parks are recreational spaces that are specifically designed to withstand flood impacts, store stormwater, promote groundwater recharge, and protect adjacent areas from flooding. Stormwater parks can be a single playground and ball field or a large urban area park with multiple features. Rain gardens and bioretention systems work in the same way, but on a smaller scale. By storing and treating stormwater, these projects can reduce flooding elsewhere and improve water quality.
- **Green roofs**: Green roofs involve planted mediums and vegetation on the top of structures like buildings to absorb rainwater and reduce runoff.
- **Rainwater harvesting**: Rainwater harvesting is the collection and storage of rainfall in man-made or natural basins to reduce runoff. Harvesting can be achieved with projects as large as a retention pond or as small as a household rain barrel.
- **Permeable pavement**: Constructing roadways or walkways with permeable pavement allows rainwater to soak through the top layer into the ground, reducing runoff.
- **Trees**: Natural vegetation reduces runoff by catching rainfall on leaves and branches, which have co-benefits of capturing carbon and reducing urban heat island effect.
- **Green streets**: Green streets integrate multiple green infrastructure features into the design of a street or alleyway to store and filter stormwater. Permeable pavement, bioswales (i.e., long, vegetated trenches), planter boxes, and trees are among the common features that can be woven into street or alley design, while also providing a safer environment for biking and walking.

CASE STUDY: SMART SEWER PROGRAM FOR KANSAS CITY WATER

Kansas City leaders have added nature-based solution elements to traditional infrastructure to reduce stormwater flooding. They have partnered with the Environmental Protection Agency to address its sewer and stormwater overflows during rain events by combining nature-based solutions and traditional infrastructure. When planning these projects, Kansas City Water engages the public at community meetings. By learning about neighborhood needs, project leaders can prioritize different types of nature-based solutions.

The Smart Sewer program is using small-scale solutions like rain gardens, green roofs, and pervious pavers to go with larger projects, which include bioswales, permeable pavement, infiltration trenches, prairies, and detention wetlands. Nature-based solutions help the city meet its stormwater flooding and overflow goals, as well as its goal to have net zero emissions by 2040 (FEMA, 2023).

Green infrastructure at Liberty Courtyard in Kansas City, Missouri.

CASE STUDY: CITY PARK, NEW ORLEANS, LOUISIANA

City Park is a 1,300-acre urban park located in the northern section of New Orleans. Founded in 1854, the park has provided recreational opportunities to the citizens of New Orleans for nearly two centuries. Today the park features athletic fields, two 18-hole golf courses, museums, and restaurants.

A defining feature of the park is the 137 acres of lakes and lagoons that serve as drainage features, while also providing recreation opportunities including boating and fishing. The lagoon system connects to the city of New Orleans drainage system including Bayou St. John and the Orleans Canal. An operable weir allows the city to lower water levels in the lagoons in advance of a rain event. New Orleans relies substantially on pump stations connected to its canal system to drain the city during rain. The rainwater storage provided by City Park allows the city's drainage pump system to catch up before stormwater is released to the system.

Pictured is a graphic of the conceived lagoon cycle on the left and an aerial photo of the lagoon after construction on the right (City Park Conservancy, 2023).

4.2.4 Property Acquisitions

Property acquisitions (or buyouts) can have both immediate and long-term benefits. Through acquisition and demolition of existing flood-prone properties, communities effectively eliminate flood risk for a particular residence, business, or infrastructure. In some cases, property acquisition may create the opportunity to convert high-risk developed areas to open space and natural areas, thereby increasing the ability to absorb flood impacts.

Property acquisition must be done with careful and extensive community engagement, particularly if the property impacted is comprised of residences or has cultural importance to the community. Availability of affordable housing is an important consideration if property that is targeted for buyout includes residences that are rented or owned by individuals experiencing poverty. Pursuing property acquisition without gaining community consensus on the option can have negative impacts on the community's identity and social cohesion and can exacerbate social inequities.

4.2.5 Structure Elevations

Where property acquisition is not a viable option, elevating structures can achieve a similar level of risk avoidance. Elevating structures so that the first floor is lifted above a determined flood elevation will provide individuals with the opportunity to shelter in place during floods to a certain level but may also create a false sense of security that the structures are always safe in all situations. In determining if structure elevation is an appropriate option, communities must evaluate multiple factors including accessibility during a flood, depth of flooding, velocity of flood flows, safety of first responders, and evacuation routes for each structure. Local ordinances and/or building codes which set standards for first floor elevations on new construction should also be considered.

A GUIDE TO BUYOUTS

University of North Carolina's 'Floodplain Buyouts: An Action Guide for Local Governments on How to Maximize Community Benefits, Habitat Connectivity, and Resilience' provides a comprehensive overview of property acquisition for flood-prone structures including potential funding sources and considerations for long-term management (Environmental Law Institute, University of North Carolina Institute for the Environment, 2017).

4.2.6 Floodproofing

Floodproofing involves modifications to structures or equipment to reduce damage caused by inundation and shorten the recovery period after a flood. Flood proofing critical facilities is especially important for reducing the impact and disruption to a community from flooding. These measures can be employed as retrofits to existing structures or designed into new construction. Like structure elevations, accessibility and evacuation capabilities are important factors when considering investments in flood proofing. Floodproofing is not recommended for areas subject to flood depths greater than 3 feet or high velocity flows because pressures exerted by greater depths and velocities can cause walls to buckle or collapse. Two types of floodproofing exist—dry and wet.

Dry floodproofing involves waterproofing exterior walls and closing off penetrations and entry points to prevent flood waters from entering the building. This can be done to residential homes as well as commercial and industrial structures. For buildings with basements and/or crawlspaces prone to flooding, dry floodproofing could be considered to protect upper levels by creating a barrier which makes the first floor impermeable to the passage of floodwater from below. Dry floodproofing is used to enhance the resilience of a building by keeping water out of the building so the building can continue operation. Dry floodproofing is a common strategy for critical facilities such as hospitals. Figure 12-9 shows an example of dry floodproofing of impermeable wall surface and a temporary closure at building entry point (FEMA, 2013).

Figure 12-9: Dry Floodproofed Building with Aluminum Shield Temporary Closure

Wet floodproofing involves a combination of strategies that reduce damage to structures and belongings, while allowing flood waters to enter an uninhabited portion of a building. This is done through relocating or elevating equipment, appliances, or utilities to a higher level, installing flood-resistant materials, such as concrete floors, and providing flood vents, or permanent openings, that allow water to enter the structure, thereby reducing pressure differential between exterior and interior and reducing the likelihood of structural damage or collapse. Structures which are likely to experience flooding, such as riverfront businesses, can more quickly rebound and be functional following a flood if floodproofed. Figure 12-10 shows an example of flood openings that allow water to enter and exit the lower level of the building (FEMA, 2013).

Figure 12-10: Wet Floodproofed Building with Flood Openings

4.2.7 Improve Stormwater Drainage System Capacity

While levees can reduce flood risk from major flooding sources, those same levees can also prevent stormwater from draining out of the leveed area. Stormwater collecting in the leveed area creates flood risk to people and property if it is not managed. In some levees, pumps evacuate water from the leveed area. In extreme floods, pumping systems may struggle to keep up with rainfall. Alternatives to pumping include creating storage and conveyance features that allow stormwater to safely collect during a storm and be drained or pumped out following the storm. This can be accomplished with some of the nature-based solutions discussed earlier or with larger infrastructure projects such as underground storage facilities.

4.2.8 Harden or Elevate Infrastructure

Infrastructure such as roads, bridges, water, and wastewater treatment plants are commonly located in flood-prone areas. Elevating roads and bridges above flood elevation can improve access for first responders and lengthen evacuation windows during floods. Additional hardening measures such as armoring shoulders, embankments, and bridge components (e.g., abutments, piers, approaches) can decrease their risk to flood damage. Flood risks can be reduced for water and wastewater treatment plants and other critical facilities that cannot easily be relocated by elevating important systems critical to the facilities' operation such as control equipment, pumps, and power supplies. Even if the facility gets shut down during a flood, critical equipment that is elevated above flood levels will likely remain unaffected, allowing the plant to come back online sooner, with fewer flood damage-related repairs and costs.

4.3 Restore and Recover

To restore and recover is to return to the previous or improved state of functionality following a disruption or when conditions have changed. This includes re-openings of critical facilities, such as schools or community centers, and building back in a way that allows for less damage or disruption from similar future events.

Small, rural, and low-income communities, as well as others who have been historically marginalized, may need additional support in recovery. Accessing federal assistance programs which can support individuals in their recovery is complex. People from underserved populations have historically received less federal recovery assistance than wealthier and more-resourced communities. Therefore, it is important to identify ways to make the process and distribution of resources more equitable and inclusive.

The following options can build community resilience by focusing on opportunities during the recovery phase.

4.3.1 Recovery Planning

Preparing to recover from flooding can be as impactful on a community's resilience as preparing for the flood itself. Recovery efforts aimed at restoring, redeveloping, and revitalizing the health, social, economic, natural, and environmental fabric of the community often begin while response is still occurring. While a recovery plan should be based on the specific conditions at the time, advanced planning and training can set those immediate recovery efforts up for success, making it more seamless and efficient. This advanced, or pre-flood, planning should include strategies to engage the whole community and to ensure current conditions are well understood to then base recovery actions upon. Recovery planning should also include engagement with partners at the federal, state, tribal, and local levels to establish an understanding of each of their roles and responsibilities.

Seven important elements of recovery planning include:

- **Identify a planning team** pre-flood to oversee the recovery planning process and activities. This should be an inclusive team who can represent or understand the diverse needs of the community.
- **Complete an initial recovery plan** that provides an overall strategy and timeline and integrates socioeconomic, demographic, accessibility, technology, and flood risk considerations.
- **Establish a leadership team** to lead, coordinate, and drive the recovery process.
- **Manage community expectations** through clarity, accuracy, and transparency in recovery plans and actions.
- **Focus on restoring and sustaining essential services** to maintain community functionality.
- **Assess economic issues** and identify potential inhibitors to fostering stabilization of the affected communities.

- **Identify affected populations**, groups, and key partners in recovery. Effective planning can lead to opportunities to advance equity by prioritizing the needs, services, assets, housing, and jobs for people from vulnerable populations and underserved communities.

4.3.2 Flood Insurance

Flood damage is not typically covered under standard homeowners' and renters' insurance policies; a separate flood insurance policy is usually needed. Flood insurance is available for residential and commercial properties and can pay for the costs of repairing damage or rebuilding structures, up to the policy limit. Flood insurance works like other insurance products—the property owner pays an annual premium based on the property's flood risk and the deductible chosen. If the property or its contents are damaged or destroyed by flooding, the policy owner will be paid for the amount required to repair the damage or rebuild the structure up to the policy limit.

Anyone can purchase flood insurance regardless of whether or not the property is situated in a floodplain, since property and structures may be at risk of flooding even if they are not located in a floodplain. Flood insurance can help make the recovery process quicker, easier, and less costly for property owners.

NATIONAL FLOOD INSURANCE PROGRAM

FEMA administers the National Flood Insurance Program. This program offers flood insurance to property owners, renters, and businesses in participating communities through private insurance companies. Participation in the National Flood Insurance Program is voluntary. Communities that join agree to adopt minimum floodplain management regulations that contribute to reduced flood risk for the community.

4.3.3 Grants and Emergency Funding

In the event of a flood, disaster assistance may be limited or unavailable. A variety of local, state, and federal financial assistance may be available, depending upon circumstances of the flooding, as well as the county and state in which a community resides. States typically have a Disaster Emergency Fund to help finance recovery efforts, and some states and counties have additional resources that may be available. Federal disaster assistance may also be available if a disaster declaration is made by the president. It is important communities understand the resources available to them and the process for accessing the funds before a flood occurs. Accessing these resources can present opportunities for communities to implement the various options discussed in this chapter to make communities more resilient.

The American Planning Association has created a list of resources among federal agencies and some national nonprofits which can assist with the recovery process.[1]

[1] The list of resources from the American Planning Association can be accessed at: https://www.planning.org/research/postdisaster/programs.htm.

CASE STUDY: JASPER COUNTY, TEXAS USE OF NATURAL RESOURCES CONSERVATION SERVICE EMERGENCY WATERSHED PROTECTION PROGRAM

Rural areas like Jasper County, Texas, lack the resources for large-scale construction projects when storms like Hurricane Laura cause damage to critical infrastructure within the watershed. The Natural Resources Conservation Service's Emergency Watershed Protection program provides a lifeline for these local communities to recover. The Natural Resources Conservation Service has been doing business with Jasper County for decades supporting the county throughout many storms, including Hurricanes Harvey and Laura. It also includes support for flooding from rainstorms that don't get names. This has been a huge help for Jasper County since the county has limited staff.

The photo shows a segment of the 33-foot by 8-foot sand-cement bag headwall that stabilizes the downstream slope of the road down to the creek channel.

Photo by Adele Swearingen, Natural Resources Conservation Service Public Affairs Specialist, Bryan, Texas (Adele Swearingen, 2023).

5 Prioritize and Implement

Once a broad range of options are considered, community engagement should guide the next steps of determining which options are the most appropriate for the community—in terms of their effectiveness (impact on community flood risks), efficacy (considering community resources and capabilities), and support of community values and vision for flood resilience. Developing a transparent process for prioritizing and implementing the options will increase the likelihood of successful completion. This section introduces common factors communities use in prioritizing options and a set of standard elements found in implementation planning.

5.1 Prioritization

Community engagement plays a key role in the prioritization and eventual selection of flood resilience options that are most appropriate for the community. It is essential that all community members are given equitable opportunity to participate in the process. Examples could include holding community meetings in locations convenient for those who lack access to transportation, enlisting the help of trusted messengers in culturally diverse neighborhoods, and

ensuring information is available in different formats and languages. **Chapter 3** describes additional considerations for ensuring equitable engagement.

The common factors communities may use to prioritize flood risk management options include:

- **Feasibility.** This is determined by the community's ability to implement the option and whether or not they have identified and/or secured sufficient funding. Further consideration may be given to the ease or complexity of the proposed option implementation.
- **Equity. This** is determined by the option's ability to advance the community's equity goals and if it directly benefits vulnerable populations and underserved communities.
- **Climate resilience. This** is determined through the option's ability to improve the community's ability to prepare for and adapt to changing climate conditions and withstand and recover rapidly from disruptions.
- **Community values**. These are reflected in prioritization by how well the option aligns with input and ideas received through engagement activities designed to identify community preferences for different types of projects and the issues that concern them the most.
- **Risk reduction**. This includes the economic, social, and environmental losses avoided or benefits gained through the option.
- **Costs**. These are considered in prioritization and include staff time, design, construction, and lifecycle operation and maintenance (O&M) costs. Full benefit-cost analyses are not typically feasible at this point in the planning process, however, may be required when applying for grant funding.

Additional prioritization factors specific to a community may be identified during engagement.

CASE STUDY: ANN ARBOR MITIGATION ACTION PRIORITIZATION

The city of Ann Arbor, Michigan, and its residents place a high value on equity, inclusive engagement, and addressing climate change. When the city updated its hazard mitigation plan in 2022, it wanted to make sure equity and community priorities were addressed in the mitigation actions and in how those actions were prioritized. The prioritization process included five prioritization metrics, weighting factors, and scoring criteria described in Table 12-3. Beyond the typical prioritization metrics of feasibility, risk reduction, and cost, Ann Arbor elected to include equity, community values, and climate resilience (Stantec, 2022).

For equity, the city chose to incorporate an Opportunity Index, which identifies neighborhoods with low access to opportunity. The index measures access to opportunity by combining 16 indicators into five categories: health, job access, economic well-being, education and training, and community engagement and stability. Mitigation actions benefiting areas identified as having 'very low access to opportunity' received maximum points for equity. For climate resilience, the criteria and points were based on how well the action helped the city mitigate and adapt to climate change. Finally, for community values, criteria and points reflected the results of the project's public survey.

The weighting factors chosen for the three metrics also reflect the city's commitment to equity, inclusive engagement, and addressing climate change. The equity and climate resilience metrics received the same weighting factor as feasibility (20%), while the community values metrics each received weighting factors of 10%, equal to risk reduction/benefits and cost. These weighting factors send a strong message about the city's priorities. The emphasis on equity allowed the following mitigation action to score highest among the actions included in the hazard mitigation plan:

- Utilize neighborhood asset mapping to improve community mutual aid by identifying residents' resources, skills, and needs.
- Develop a community resilience public engagement strategy that focuses on building partnerships and creating space for vulnerable populations to share their lived experiences and use this information to help shape the city's approach to emergency planning and mitigation.
- Include the Housing Commission and low-income and senior housing entities in emergency action plan updates.

Table 12-3: Example Resilience Project/Program Prioritization

	Prioritization Metric	Weighting Factor	Scoring Criteria	Possible Points
1	Feasibility	20%	5 – Funding identified, easily implemented within five years. 3 – Funding identified, implemented with only moderate complexity or delays. 1 – Funding identified, implementation is complex and faces certain delays for implementation. 0 – Not feasible, no funding identified and/or not able to be implemented.	100
2	Equity (as tied to a city's opportunity index)	20%	5 – Very low access to opportunity. 3 – Low access to opportunity. 1 – High access to opportunity. 0 – Very high access to opportunity.	100

	Prioritization Metric	Weighting Factor	Scoring Criteria	Possible Points
3	Climate resilience	20%	5 – Very high (Action provides multiple benefits for climate resilience, including greenhouse gas or adaptive measures). 3 – High (Action provides at least one benefit for climate resilience). 1 – Moderate (Action provides limited benefits for climate resilience). 0 – Low (Action does not provide benefits for climate resilience).	100
4	Community values (project type)	10%	5 – Prevention. 5 – Emergency services. 3 – Natural resources protection. 3 – Public education and awareness. 3 – Structural projects. 1 – Property protection. 1 – Social cohesion projects.	50
5	Community values (hazard of greatest concern)	10%	5 – Action addresses one or more hazards identified for the public as of greatest concern (More extreme rain/flood, heat, thunderstorm, tornado, winter weather). 3 – Action addresses one or more hazards identified for the public as of lesser concern (Loss and change of vegetation (including trees), reduced air quality, habitat disruption). 1 – Action addresses one or more hazards identified for the public as of least concern (In-migration of people to the area from areas more severely impacted by climate change).	50
6	Risk reduction/ benefits	10%	5 – Very high (Significant losses avoided and/or significant benefits with consideration to economic, social, and environmental factors). 3 – High (Numerous losses avoided and/or numerous benefits with consideration to economic, social, and environmental factors). 1 – Moderate (Some losses avoided, some benefits with consideration to economic, social, and environmental factors). 0 – Low (No losses avoided, no public benefits with consideration to economic, social, and environmental factors).	50
7	Costs	10%	5 – Project costs are predominantly staff time. 3 – Project costs are estimated between $0-$100,000. 1 – Project costs are estimated between $100,001-$500,000. 0 – Project costs are estimated above $500,000.	50
TOTAL		100%	Sum of parameter scores (max = 500)	

5.2 Implementation

Implementing flood risk management options to reduce flood risk and enhance community resilience involves time, engaged people, and financial resources. Successful completion of actions relies upon deliberate planning for implementation, which includes the following key elements.

- **Champion/responsible entity**: Projects do not implement themselves. Every project or program needs an individual and a department or agency to take ownership, secure funding, and see it through to completion. Project champions find and coordinate partners who will share responsibility for implementation and potentially for funding.
- **Partners**: In addition to the responsible entity, one or more partners may contribute staff time, technical expertise, and funding. Partners may also influence policy decisions or changes necessary for implementation and provide additional leverage needed to get a project funded.
- **Timeline**: The start to a project's timeline can depend on when funding is available and when personnel can support implementation. Sequencing projects based on funding and personnel availability can increase their likelihood for success. Project champions set the timeline based on when funding can/will be available and when the project must be complete.
- **Next steps and milestones**: Successful implementation relies on following a sequential set of actions and milestones. The implementation plan outlines the actions that must be completed by the project champion and partners in the appropriate order to accomplish the project. The project champion assigns completion of these steps to specific individuals along with key milestone dates that follow the project timeline. The steps and timeline require flexibility to adjust to changing conditions while keeping the project moving.
- **Capability needs**: Beyond funding, communities may need additional support and capabilities to implement a project or program. Capability needs may include technical expertise, staff availability, equipment, and supplies. Project champions and partners take responsibility for addressing capability needs and building them into the project timeline.
- **Cost estimates and funding**: Communities must know the cost of their projects and programs and where they will secure the funding. High-cost projects may require significant time to secure necessary funding, which project champions will build into the project timeline. Project champions may also work with partners to combine multiple funding sources. Partners often bring knowledge and expertise in a variety of funding sources and play a pivotal role in securing funds for the project.

CASE STUDY: FUNDING THE FARGO-MOORHEAD METROPOLITAN AREA FLOOD RISK MANAGEMENT PROJECT

The Fargo-Moorhead diversion project will cost roughly $3 billion to provide flood risk management for nearly 260,000 people and 70 square miles of infrastructure in the communities of Fargo, Moorhead, West Fargo, Horace, and Harwood and is being implemented by the U.S. Army Corps of Engineers (USACE), the cities of Fargo and Moorhead, and the Metro Flood Diversion Authority. It includes building a 30-mile diversion channel in North Dakota to include several highway and railroad bridges, as well as two aqueduct structures, and a 22-mile dam embankment with three gated control structures. The total cost of the project is being covered by the federal government, state governments of North Dakota and Minnesota, and local funding through sales taxes.

The Metro Flood Diversion Authority developed a multi-faceted plan to finance their share, utilizing a public-private partnership model that includes a mix of state grants from North Dakota and Minnesota, low-interest loans such as the Environmental Protection Agency Water Infrastructure Finance and Innovation Act loan, the North Dakota Clean Water State Revolving Fund loan, and sales tax revenues. The Metro Flood Diversion Authority also established an ongoing O&M program that will be funded by excess sales and tax revenues, an annual maintenance district levy, and stormwater maintenance fees from Minnesota member entities. The program will also fund any unforeseen mitigation needs that may arise during operation.

The Wild Rice River structure being built as part of the Fargo-Moorhead Metropolitan Area Flood Risk Management project, designed and constructed by USACE (Metro Flood Diversion Authority, 2023).

CASE STUDY: VIRGINIA COMMUNITY FLOOD PREPAREDNESS FUND

In 2020, the Commonwealth of Virginia General Assembly created the Community Flood Preparedness Fund. The fund provides support for regions and localities across Virginia to reduce the impacts of flooding, including flooding driven by climate change. The fund prioritizes projects that are in concert with local, state, and federal floodplain management standards, local resilience plans, and the Virginia Coastal Resilience Master Plan. The fund empowers communities to complete vulnerability assessments and develop and implement action-oriented approaches to bolster flood preparedness and resilience. Eligible activities include flood prevention and protection projects and studies, capacity building, and planning. The following five core principles, known as the Commonwealth Resilience Planning Principles, guide the fund (Virginia Department of Conservation and Recreation, 2023).

- Acknowledge climate change and its consequences, and base decision making on the best available science.
- Identify and address socioeconomic inequities and work to enhance equity through adaptation and protection efforts.
- Utilize community and regional scale planning to the maximum extent possible, seeking region-specific approaches tailored to the needs of individual communities.
- Understand fiscal realities and focus on the most cost-effective solutions for the protection and adaptation of communities, businesses, and critical infrastructure. The solutions will, to the extent possible, prioritize effective natural solutions.
- Recognize the importance of protecting and enhancing green infrastructure in all regions and in the coastal region, natural coastal barriers, and fish and wildlife habitat by prioritizing nature-based solutions.

6 Evaluate and Adapt

As communities implement flood risk management options, climate conditions will change, new information will become available, and community values will evolve. These factors will require communities to adapt to their new reality by understanding any changes to the community's flood risk, understanding how well current flood risk management strategies are meeting their objectives, affirming or adjusting community vision for flood resiliency, and, if necessary, identifying and prioritizing a new set of resilience building actions. Engagement of the whole community is essential to ensure all experiences and perspectives of the community are considered during this process. An important first step is to monitor and evaluate progress in building resilience.

6.1 Evaluate Using Indicators

A community's resilience to flooding can be measured by assessing the impacts of floods. Identifying what indicators to measure, and how to track and evaluate those indicators over time is central to quantifying results. Good measurement indicators provide:

- A baseline that indicates the starting point.
- A target for where the community is going.
- An indication if there is something wrong.

- Highlights when the community achieves its goal.

Further, well designed measurement indicators can help tell a story for why resilience building is necessary, attract political support and funding, and focus efforts while providing a feedback mechanism about whether decisions, investments, and actions to improve resilience are making a difference and can help guide future decisions. Good indicators should be designed to do the following:

- Connect to goals, community values, and desired outcomes.
- Track information required to measure the indicator. Note: When setting an indicator, it is important to keep in mind the ease and cost of obtaining the data required to measure the indicator.
- Provide meaning rather than a count. For example, an indicator that counts the number of people who received training does not necessarily correlate to knowledge gained.
- Provide data for accountability, guiding action, telling a story, and measuring success.
- Be adaptable and scalable with the effort.

6.1.1 Capitals to Measure a Community Flood Resilience

Capitals are assets that add to the long-term resilience of a community. Capitals include various elements, resources, and relationships within a community and their contribution to the overall functioning of the community. Measuring the capitals involves using indicators that are scored on a scale of poor (low) to best practice (high) level of maturity. The maturity matrix should be unique to each community and tailored to align with a community's values and vision for resilience.

The following six capitals[2] are a good way to measure and report on a community's flood resilience:

- Natural
- Built
- Financial
- Health and human
- Social and cultural
- Institutional and governance

MATURITY MATRIX

Adapted from the National Academy of Sciences, Dam and Levee Safety and Community Resilience: A Vision for Future Practice, a maturity matrix is a tool to help gauge the level of resilience practice with respect to an indicator being measured (National Research Council, 2012). The matrix can allow communities to communicate operations in place, identify areas in need of enhancements, and identify the means of meeting goals.

The **natural capital** is described as the natural resources base or environmental conditions within communities. This includes air, land, water, mineral resources, stability and health of ecosystems, natural land cover, and/or indicators of environmental quality. Natural resources, as well as the water and biological resources, combined with the human actions to sustain productivity from these resources enhance resilience to floods.

[2] Adapted from the National Academy of Sciences Building and Measuring Community Resilience: Actions for Communities and the Gulf Research Program.

An example indicator to evaluate the natural capital is the condition of the watershed basin that influences the intensity of the flood hazard in the leveed area. The example maturity matrix for this indicator is show in Table 12-4.

Table 12-4: Example Indicator in the Natural Capital Maturity Matrix

Indicator	Scale	Description
Watershed basin condition that influences the intensity of flood hazard.	Level 1 (Less resilience)	Fully developed watershed with little amount of natural landscape. High amounts of impervious surfaces.
	Level 2	Developed with significantly altered conditions with no purpose of flood resilience.
	Level 3	Partially developed conditions altered to different uses.
	Level 4	Mostly undeveloped with altered conditions maintain flood resilience services.
	Level 5 (More resilience)	Undeveloped watershed or restored natural conditions near perfect as could be expected.

The **built capital** are things produced by economic activity such as buildings and infrastructure systems within communities. This includes critical response support facilities, residential housing, schools, commercial and industrial buildings, and supporting infrastructure such as power, transportation, bridges, roads, communication, water, and wastewater.

An example indicator to evaluate the built capital is the continued functionality of healthcare facilities during and after floods. The measurement should account for the location of the building, the way the buildings are constructed, and how flood risk is managed. There should also be strategies in place to guarantee healthcare service provision to people during and after floods, as well as access to medical supplies. The example maturity matrix for this indicator is show in Table 12-5.

Table 12-5: Example Indicator in the Built Capital Maturity Matrix

Indicator	Scale	Description
Healthcare facilities ability to function during and after floods.	Level 1 (Less resilience)	Facilities are in flood-prone areas with loss of function and no access during floods.
	Level 2	Facilities are impacted by flooding and can provide essential services only. Access is severely limited.
	Level 3	Facilities are located within flood-prone area and are impacted by flooding but can continue to provide essential health services. Facilities remain accessible to the community.

Indicator	Scale	Description
	Level 4	Facilities are located within flood-prone area but managed in such a way that there is no negative impact on healthcare services. The facilities are fully accessible during floods for all relevant vulnerable populations.
	Level 5 (More resilience)	Facilities are located away from flood-prone areas and are not affected in the event of major flooding.

The **financial capital** is the totality of economic assets and livelihoods in a community, including income levels, personal wealth, income equality, overall employment rates, sector-specific employment, and business size and diversity.

An example indicator to evaluate the financial capital is the capability of community members to recover their assets should a flood occur without having to resort to negative coping strategies, such as selling off assets. This could be in the form of accessible savings for emergencies, available credit lines (loans), or having an insurance policy in place. The example maturity matrix for this indicator is shown in Table 12-6.

Table 12-6: Example Indicator in the Financial Capital Maturity Matrix

Indicator	Scale	Description
Household asset recovery capability.	Level 1 (Less resilience)	No households have insurance or savings while located in flood-prone areas.
	Level 2	Less than 20% of households have insurance or there is limited opportunity for households to save.
	Level 3	20% to 50% of households have insurance or have savings to recover their assets.
	Level 4	50% to 80% of households have insurance or have savings to recover their assets.
	Level 5 (More resilience)	More than 80% of households have flood insurance or a way to recover their assets through savings (i.e., an emergency fund).

The **health and human capital** is the knowledge, skills, health, and physical abilities of community members. It includes language competencies, cultural symbols, and belief systems. Some specific examples are educational levels, age distributions, health insurance, access to medical and mental health services, food security, special needs populations, and access to transportation and communication services.

An example indicator to evaluate the health and human capital is the community's awareness of flood risk, specifically where in the community it is likely to be flooded. If people in the

community do not know which areas of the community are likely to flood, then their lives and assets may be at risk. The example maturity matrix for this indicator is shown in Table 12-7.

Table 12-7: Example Indicator in the Health and Human Capital Maturity Matrix

Indicator	Scale	Description
Flood risk awareness.	Level 1 (Less resilience)	Community's flood hazards are not identified.
	Level 2	Less than 20% of the population know which areas in the community are likely to flood.
	Level 3	20% to 50% of the population know which areas in the community are likely to flood.
	Level 4	50% to 80% of the population know which areas in the community are likely to flood.
	Level 5 (More resilience)	More than 80% of the population know which areas in the community are likely to flood.

The **social and cultural capital** is the social networks and connectivity among groups and individuals within a community. This includes levels of trust and reciprocity, political engagement, length of residency, volunteerism, religious affiliation, and community organizations and services. Also included is the feeling of belonging to and a sense of place about the community.

An example indicator to evaluate the social and cultural capital is the incorporation of a collaborative stakeholder engagement process into the community flood risk management planning process in order to develop a shared vision about future development in the community and strategies to reduce the risk of floods. The example maturity matrix for this indicator is shown in Table 12-8.

Table 12-8: Example Indicator in the Social and Cultural Capital Maturity Matrix

Indicator	Scale	Description
Incorporation of stakeholder engagement in community flood risk management planning.	Level 1 (Less resilience)	No community emergency response plan in place.
	Level 2	A community flood risk management plan is in place and was developed with little or no local participation or inclusion. There is little or no acceptance of it within the community.
	Level 3	A community flood risk management plan is in place and was developed with a moderate degree of local participation and inclusion. It is fairly well accepted within the community.

Indicator	Scale	Description
	Level 4	A community flood risk management plan is in place and was developed with a high degree of local participation and inclusion. It is widely accepted within the community.
	Level 5 (More resilience)	A community flood risk management plan is integrated into the whole community's comprehensive resilience plan. It was developed with a high degree of local participation and inclusion and is widely accepted within the community.

The **institutional and governance capital** is the community's access to public resources and the ability/power to influence the distribution of the resources, as well as the ability to engage entities external to the community in order to achieve community goals. This includes access to disaster insurance coverage (e.g., flood, crop), the degree to which relevant jurisdictions are coordinated or fragmented, experience in flood response and recovery, effectiveness of mitigation spending, and emergency management capacities.

An example indicator to evaluate the institutional and governance capital is the presence of a community disaster fund, which is a budget for members in the community to get emergency funding for response and recovery if their income is disrupted, especially for those that are unable to afford insurance or have no emergency fund savings account. The example maturity matrix for this indicator is shown in Table 12-9.

Table 12-9: Example Indicator in the Institutional and Governance Capital Maturity Matrix

Indicator	Scale	Description
Availability of community disaster fund for response and recovery.	Level 1 (Less resilience)	No fund established.
	Level 2	There is a fund, but it does not always function reliably either due to a lack of funding or a complicated bureaucracy. Community members are unaware of the program.
	Level 3	There is a fund but does not always function reliably either due to a lack of funding or a complicated bureaucracy. Community members are aware of the program but do not understand how to access the funds.
	Level 4	There is a functioning fund. Community members are aware of the program but have difficulty accessing the funds in the event of a flood or receiving disbursement.
	Level 5 (More resilience)	There is a functioning fund. Community members are aware of the program and how to access the funds in the event of a flood. Disbursement of the funds is quick and adequate for recovery.

CASE STUDY: ZURICH FLOOD RESILIENCE ALLIANCE FLOOD RESILIENCE MEASUREMENT FOR COMMUNITIES

The Zurich Flood Resilience Measurement for Communities was created by the Zurich Flood Resilience Alliance in 2013 and is an innovation in community flood resilience theory and practice (Zurich Flood Resilience Alliance, 2023). It allows users to generate evidence about the ways in which a given area or community is already resilient to floods, as well as providing a guide to further develop this resilience region.

The Flood Resilience Measurement for Communities framework is also called the 5C-4R framework. It combines a series of indicator, or 'sources of resilience,' on five complementary 'capitals' (5C), as well as four properties derived from resilient system-thinking (4R), that can help communities on their development path and provide capacity to withstand and respond to shocks. The 5Cs comprise human, social, physical, financial, and natural capital. The 5Cs provide greater richness of data about a community's sources of resilience than any single metric.

Each capital group contains a set of generic and discrete sources of resilience. Across the 5Cs there are 44 sources of resilience, each specifically defined. Sources of resilience are grouped under the four headings (4R) of robustness (ability to withstand a shock), redundancy (functional diversity), resourcefulness (ability to mobilize when threatened), and rapidity (ability to contain losses and recover in a timely manner).

This systems-thinking approach considers the assets, interactions, and interconnections at community level, and provides consistency when it comes to identifying and testing sources of resilience. To measure each source of resilience in a given community, data can be collected in four different ways (i.e., household surveys, key informant interviews, focus group discussions, and through the use of secondary sources) according to context and need. After data is collected, a trained assessor grades each of the sources of resilience on a scale from A to D (where A is best practice and D is poor). The grades between A and D awarded to each community are then aggregated in different ways for analysis. Aggregations, or 'lenses' by which resilience can be viewed, include the 5Cs and the 4Rs. Further lenses are the seven themes by which questions are sequenced thematically (such as healthcare, education, livelihoods, etc.), the five steps of the disaster risk management cycle (preparedness, response, recovery, prospective risk reduction, and corrective risk reduction), and many more.

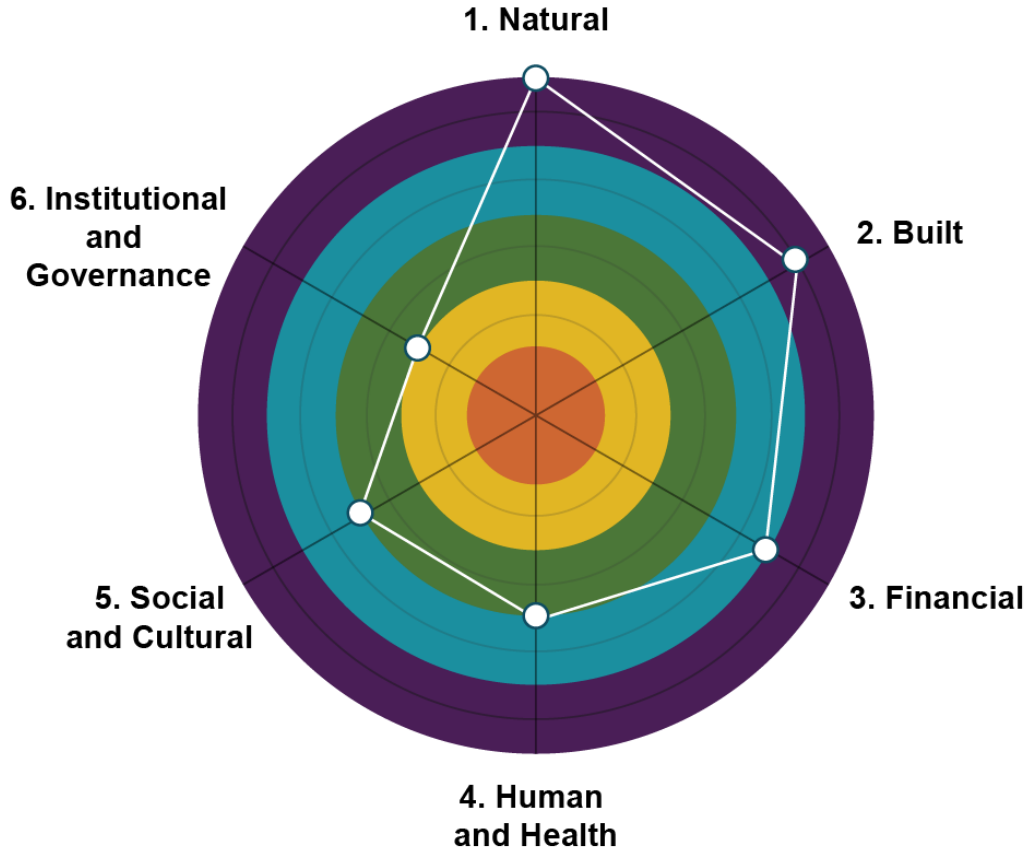
As of year 2022, the Zurich Flood Resilience Alliance has successfully been developing and implementing the Flood Resilience Measurement for Communities process in over 400 communities globally.

6.1.2 Evaluate Results

Evaluating a community's progress in building flood resilience should be an annual activity. This repetition allows communities to demonstrate improvement, identify newly found gaps, and identify the need for new, more effective strategies. Evaluation results should be shared with the community to raise awareness and support for resilience activities and justify continued investment.

The results of the evaluation of indicators using the maturity matrices can be summarized into a total score for each capital. One effective way to present results is with a spider chart, as seen in Figure 12-11. As communities get closer to achieving the maturity for their resilience indicators in each capital, the points on the chart move outward. A more resilient community will have most of its points near the outer edge of the circle and the connecting lines will create a more circular shape. The chart should be compared to prior year's results. When results do not show progress, communities can clearly see where they need to adapt their resilience building activities.

Figure 12-11: Example Spider Chart Showing Measurement Per Capital



6.2 Adapt to Change

The changing environment increases uncertainty in predicting the effectiveness of flood risk management strategies. Adapting to this changing environment requires an iterative process of evaluations to reduce uncertainty about flood risk and improves the potential for achieving desired results from flood risk management options.

Adopting an adaptive management approach to community flood resilience is an effective way to manage the impacts of change. Adaptive management is a multi-step, iterative process for adjusting management measures to changing circumstances or new information about the effectiveness of flood risk management options for the system being managed. Adaptive management reduces uncertainties regarding performance of flood risk management options by developing and using new information and evaluating key uncertainties. Each iteration facilitates the ability for future adjustments or enhancements to existing flood risk management options as necessary to meet or improve expected outcomes.

7 Summary

While levees can help reduce the flood risk, it is important to remember that they do not eliminate the risk. Even levees which are well maintained and operated can overtop or breach when flood hazards exceed the design of the levee.

Flood risk to the leveed area can also come from high intensity or excessive amounts of rainfall directly to the leveed area. This flood source, as well as groundwater flooding that can occur from levee underseepage or from other natural conditions, can exceed the capacity of interior drainage systems meant to evacuate water within the leveed area, thus trapping it behind the levee.

For those living or working near levees, it is important to understand the flood risk and be aware of steps that can be taken to reduce the risk on a community level, as well as an individual level. An iterative process of understanding risks, exploring options to reduce risk, prioritizing, and implementing those options, and evaluating and adapting to changing conditions is essential to building community resilience to flooding. This process revolves around continuous engagement that is inclusive, equitable, and community-driven to help ensure all those affected by floods and flood risk management decisions are part of the planning and decision-making process.

A variety of flood risk management options are available to communities; however, the environment is ever changing from precipitation patterns altering flood hazards, O&M deficiencies altering levee performance, and human behavior and policy changes altering the socio-economic environment of a community. As flood risk changes, a resilient community will monitor, evaluate, and adapt to new information, ensuring their capacity to effectively recover from the next flood, with the same quality of social well-being, economy, and environment as existed before.

Related content associated with this chapter is included in detail in other chapters of the National Levee Safety Guidelines as described in Table 12-10.

Table 12-10: Related Content

Chapter	Chapter Title	Related Content
1	Managing Flood Risk	• Flood risk management strategies • Climate change impacts
2	Understanding Levee Fundamentals	• Levee fundamentals • Potential failure modes
3	Engaging Communities	• Community engagement
4	Estimating Levee Risk	• Potential failure modes • Estimating consequences • Social vulnerability
5	Managing Levee Risk	• Taking actions to reduce risk • Building risk awareness
6	Formulating a Levee Project	
7	Designing a Levee	
8	Constructing a Levee	
9	Operating and Maintaining a Levee	• Access corridor
10	Managing Levee Emergencies	• Emergency preparedness • Evacuation planning
11	Reconnecting the Floodplain	• Floodplain restoration
12	Enhancing Community Resilience	