MID-SOUTH REGIONAL RESILIENCE MASTER PLAN

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RESILIENT SHELBY

SASAKI

Ritchie Smith Associates

BLDG MEMPHIS

PIQUE

SMALL PLANET WORKS, INC.

POWERS HILL DESIGN

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Plan Communities

Shelby County, TN

DeSoto County, MS

Fayette County, TN

Marshall County, MS

Memphis, TN

Bartlett, TN

Collierville, TN

Southaven, MS

Germantown, TN

Olive Branch, MS

Horn Lake, MS

Hernando, MS

Lakeland, TN

Arlington, TN

Millington, TN

Oakland, TN

Byhalia, MS

Piperton, TN

Walls, MS

Gallaway, TN

Rossville, TN

Braden, TN

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Shelby County Resilience Council
Shelby County Emergency Management and Homeland Security
DeSoto County Fire and Emergency Management
Memphis Urban Area Metropolitan Planning Organization (MPO)
Shelby County Public Works Division
Shelby County Stormwater Program
Memphis – Shelby County Office of Sustainability
Memphis – Shelby County Division of Planning & Development
Shelby County Regional Geographic Information Systems (ReGIS)
Shelby County Roads, Bridges, and Engineering
Shelby County Housing Department
Shelby County Health Department
Shelby County Schools
DeSoto County Road and Bridge Department
DeSoto County Engineering Department
Memphis-Shelby County Airport Authority
Memphis Area Transit Authority (MATA)
Memphis Housing and Community Development
Memphis Office of Comprehensive Planning
Memphis Parks & Neighborhoods
Memphis City Engineers Office
Memphis Public Works Division
Tennessee Department of Environment and Conservation (TDEC)
Mississippi Department of Environmental Quality (MDEQ)
US Army Corps of Engineers
US Environmental Protection Agency (EPA)

Private Companies and Utilities

FedEx
Memphis Light, Gas, and Water (MLGW)
Entergy

Universities

The University of Memphis (Center for Applied Earth Science and Engineering Research, CAESER)
Christian Brothers University
The University of Tennessee

Nonprofit Organizations

Wolf River Conservancy
Shelby Farms Park Conservancy
The Sierra Club
The Greater Memphis Chamber of Commerce
The American Red Cross
The American Association of Engineering Societies

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BLDG Memphis
Pique
Small Planet Works
Powers Hill Engineering

Table of Contents

INTRODUCTION

Introduction

In the spring of 2011, record rainfall caused historic flooding along the Mississippi River that devastated many of the communities throughout the Mid-South: 345,000 residents lost power, 198 homes were flooded, and the cost of the flood damage exceeded $2 billion. In May of 2017, straight line wind uprooted trees and knocked out power for 190,000 households, which was the third largest power outage in Shelby County history.

Events like these are becoming more common and highlight major regional vulnerabilities that need to be addressed. This plan—the Mid-South Regional Resilience Master Plan (RRMP)[i]—is a comprehensive step toward addressing these challenges and laying out a roadmap to achieve a more resilient future for the Mid-South. The RRMP was funded through the HUD National Disaster Resilience Competition[ii] and uses HUD's definition of resilience, which is the following:

> *"Resilience is the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience."*

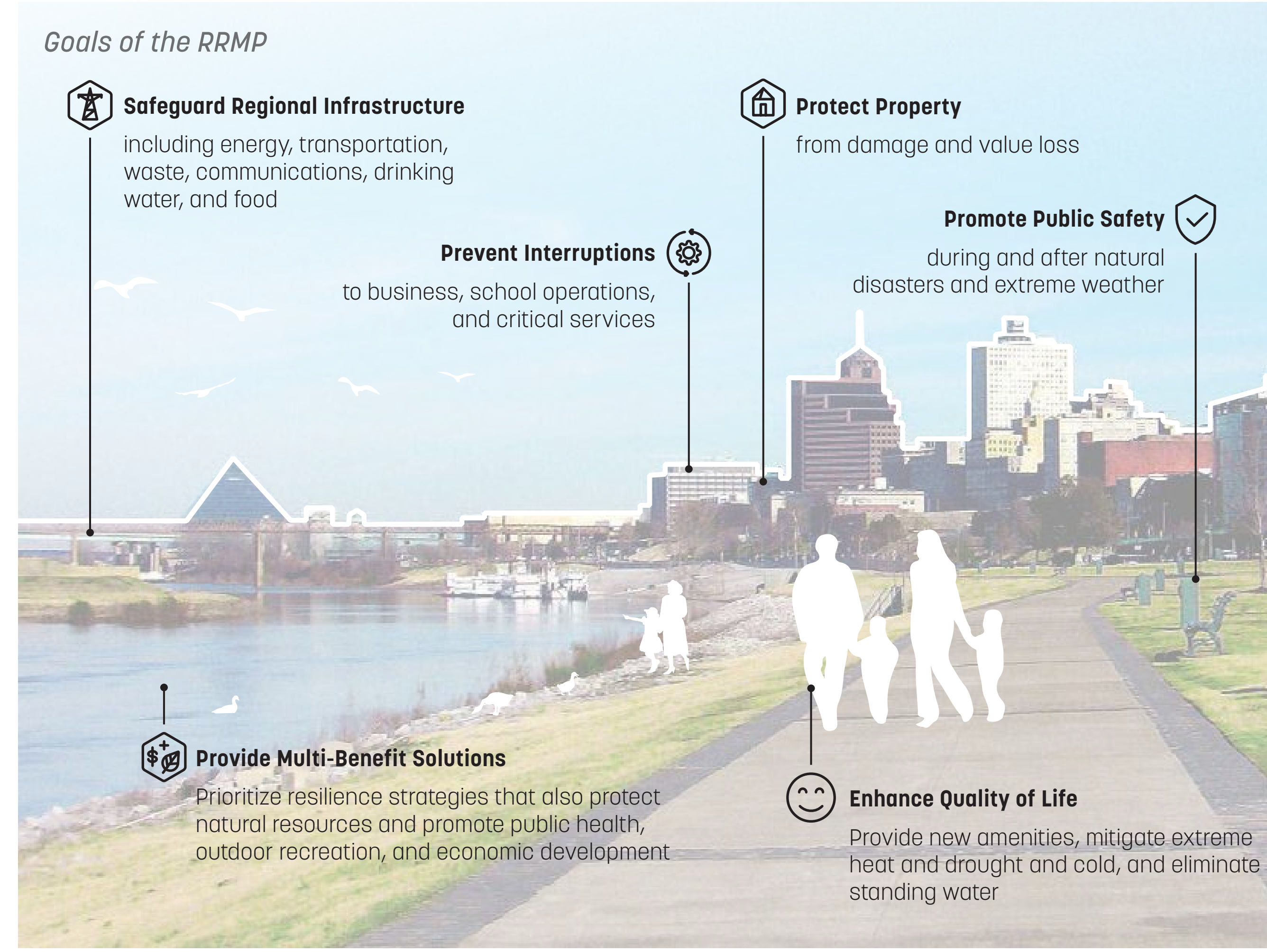
Resilience is vitally important to every single person living in the Mid-South. Climate and weather related shocks and stressors have major impacts on safety and quality of life for all residents, regardless of age, income, race, community, etc. Mitigating these threats and building the capacity to bounce back quickly from disasters will keep residents safe and comfortable, save money and protect property, ensure the continued operation of critical services and infrastructure, and provide beneficial new public amenities.

The value of the RRMP is in breaking down this large and complex topic (resilience) into a manageable set of options for a better pathway forward. It aims to understand the Mid-South's greatest resilience needs, research and select from current best practices to address them, set an agenda for prioritizing future action, and provide the resources to begin the process of implementation.

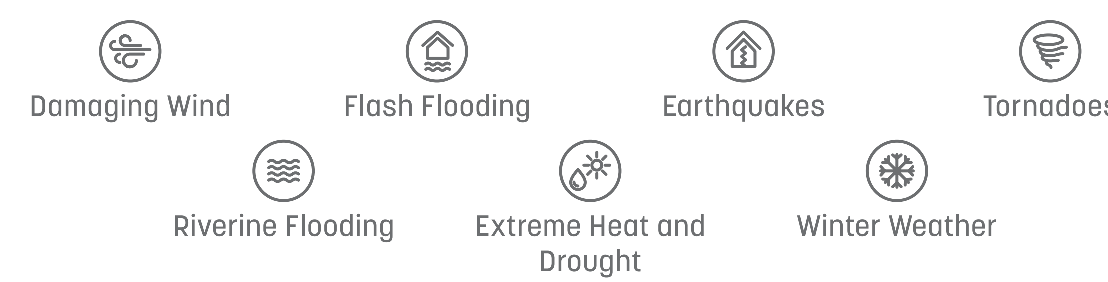
The heart of the RRMP is a set of recommendations that function as a curated toolbox of resources organized by theme and purpose. They should be approached like a reference manual, where readers focus on the sections that are most relevant or interesting to them. The RRMP was structured this way out of necessity, since it is written for a variety of audiences that include elected officials, planners, engineers, the emergency management community, private businesses, property owners, and the general public. All of these entities have a vested interest in regional resilience and play a role in implementation, and therefore they must all be addressed to some degree. This also means that the recommendations are necessarily broader than they would be otherwise if they were written for only one of these audiences, and not all sections will be relevant to everyone. To help the reader navigate the recommendations, suggested implementation leads for each are indicated later in the Introduction, and individual jurisdictions are matched with their highest priority recommendations in the Technical Appendix.

The contents of the recommendations are as diverse as the audiences they seek to address. They include physical design, site suitability, legal and regulatory considerations, partnership opportunities, funding, cost information, benchmarking, aspirational metrics, case studies, and more. They aim to provide a full toolkit of resources needed to select, design, and implement these strategies.

i Shelby Resilience Plan, https://resilientshelby.com/overview/resilience-activities/resilience-plan/
ii HUD National Disaster Resilience Competition, https://www.hudexchange.info/programs/cdbg-dr/resilient-recovery



Threats Addressed by the RRMP



As the name of the project suggests, the RRMP is regional in scope and scale. This means that the recommendations take a regional lens in terms of research, analysis, and design. They do not, for example, recommend specific dimensions for resizing local culverts or designate the detailed boundaries of a proposed water detention area. Instead, they seek to identify resilience opportunities that can only be achieved when planning at a regional scale, such as watershed or aquifer management. Even with this caveat about spatial scale, the recommendations do attempt to be site specific wherever practical and pair recommendations with specific jurisdictions, agencies, and collaborators whenever possible.

The RRMP also takes a long-term view and draws primarily from the planning and design disciplines. It is not meant to be a guide for emergency management and operations. It does not, for example, recommend a protocol for flood evacuation—this is something that the local emergency management communities provide, and they do so in a highly effective manner. Instead, the RRMP identifies strategies that would prevent the flood from happening in the first place.

One of the core concepts underlying much of the RRMP is the idea of the intersecting systems forming the basis for regional resilience. This includes social systems like neighborhoods, cities, towns, interpersonal networks, and economics; ecological systems like streams, rivers, floodplains, wetlands, forests, watersheds, aquifers, and fault lines; and infrastructural systems like roads, bridges, airports, the electrical grid, storm and sewer systems, water treatment, telecommunications, flood barriers, and emergency shelters. Each of these systems affects, and is affected by, climate and weather related shocks and stressors. Moreover, these systems are interrelated, meaning that an intervention in one can improve resilience in another, and a disaster affecting one will likely have downstream effects on other systems. This means that resilience is a multi-system and multi-variate problem. While documenting threats and offering solutions, the interrelationships between these different systems and the opportunities for synergy among them is always considered and articulated explicitly whenever it is relevant.

As the region works toward implementing these recommendations, it is important to remember that resilience is a process rather than an end state. This is because the characteristics of the threats evolve and the systems that they interact with change. For example, precipitation patterns are changing over time, and this means that storm design specifications of infrastructure must change in response. The advent of new systems also presents new vulnerabilities and opportunities. For example, the expansion of air shipping has led to incredible growth for the Mid-South through its logistics economy, but it has also brought with it new systemic vulnerabilities like preventing airport shut downs and maintaining essential services and infrastructure that power the logistics sector. Most of the recommendations presented in the RRMP are evergreen in the sense that they represent best practices whose underlying concepts will continue to be valid and relevant even as systems and technology evolve.

It is also important to reframe resilience as a productive investment, rather than as simply an expense or sunk cost, as it is often perceived. This is true for several reasons. First, it is usually less expensive to prevent a disaster than to recover from one. Furthermore, the threats and vulnerabilities that cause disasters usually lead to multiple and recurring issues, not just a single event, so the trade-off can be viewed as a single, often smaller, upfront payment (investing in resilience) versus a recurring, often larger, on-going payment whenever disaster strikes. To give a tangible example, improving the health of the region's streams and watersheds would be expensive, but it would be much less expensive, over the long run, than the current cost of flood recovery that the region incurs on a near-annual basis. Recommendation 7.5 offers strategies to monetize this cost efficiency and translate it into upfront capital that can be used to support resilience investments.

Second, the money spent on resilience often addresses issues that needed attention anyway. For example, retrofitting hospitals to be more flood and earthquake proof not only makes them more resilient but also presents an opportunity to replace aging building systems and materials.

Third, many of the recommendations in the RRMP represent win-win solutions in the sense that they also provide some public good beyond their specific resilience-related objective. The classic example of this is a new park that provides flood mitigation while also functioning as a recreational amenity for the community.

Fourth, the process of becoming more resilient represents an incredible economic development opportunity, since many of the RRMP recommendations require an expansion of the current labor force. There is an entire chapter of the report dedicated to this idea (Recommendation 7.4).

In terms of process, the RRMP was development over 2 years from 2017 to 2019 and has included 3 major rounds of public workshops. The first round occurred in January 2018 and covered threats and vulnerabilities. The second round occurred in May 2018 to solicit input on preliminary resilience strategies. The third round occurred in May 2019 and presented the full set of recommendations detailed throughout this report. Additional information about these events can be found on the Resilient Shelby website.

To provide an overview of the structure of this document, the RRMP begins with an introduction to regional planning and a composite map that synthesizes all of the key systems and spatial recommendations in one place. If the RRMP were distilled down to a single image, it would be the composite map. After this, the reader can find a preview of the themes and recommendations found throughout the report. At the end of the Introduction is a reference table summarizing all the RRMP recommendations.

The second major section of the report documents each of the 7 climate and weather related threats addressed by the RRMP, including descriptions, causes, impacts, trends, typical events, and extreme events. At the end of the Threats section is a chart that summarizes the current and future severity and frequency of each of the 7 threats.

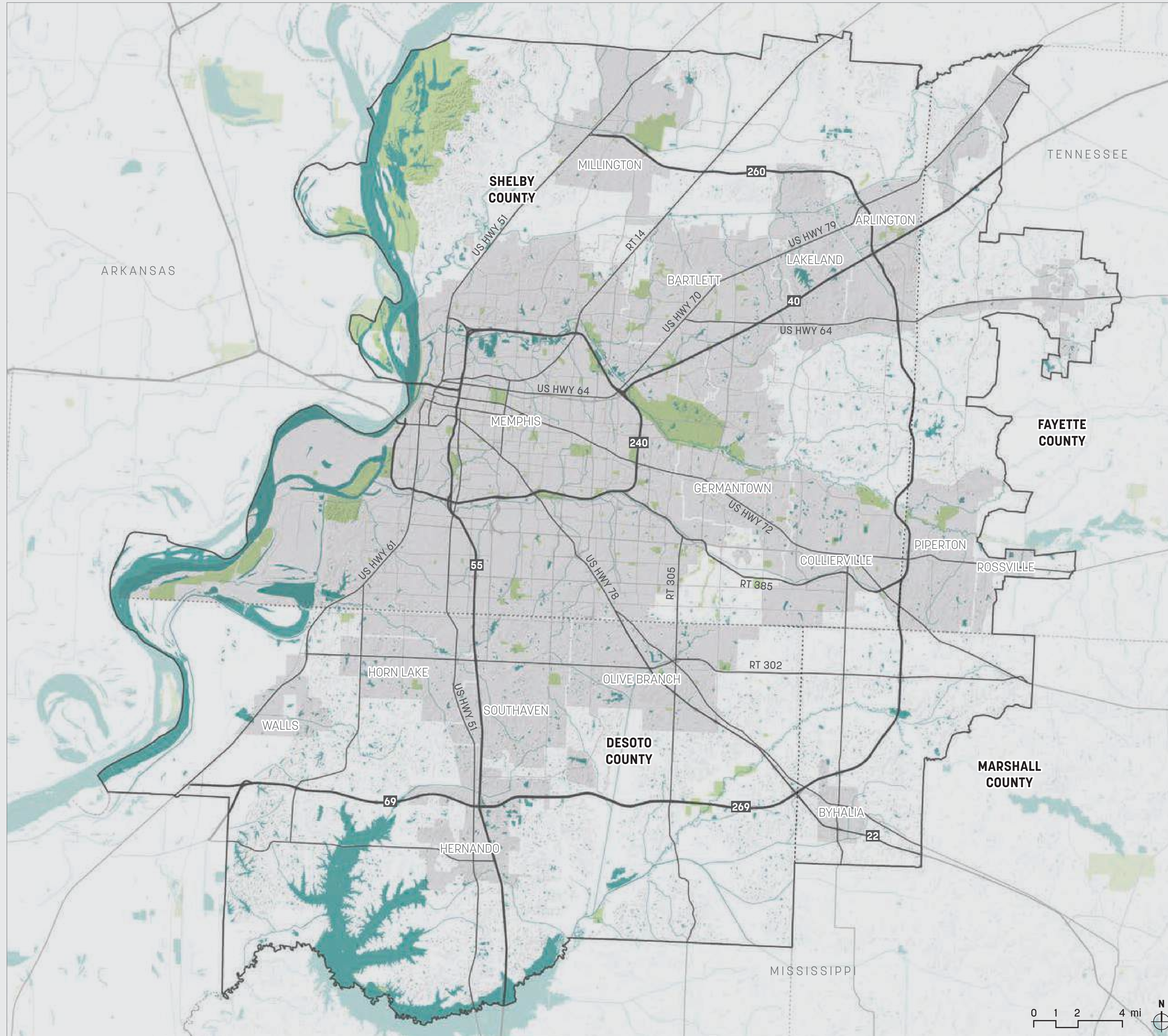
The third major section is the Recommendations, grouped by theme, which collectively represent the core of the RRMP.

Finally, at the end of the report is a Technical Appendix, which includes a table of frequently used acronyms, a list of case studies, a GIS data inventory, jurisdiction-specific summaries and recommendations based on field interviews, and an overview of a HEC-RAS hydraulic model that was developed as a resource for engineers implementing the RRMP.

Regional Context

The Mid-South Regional Resilience Master Plan uses the same boundary as the Memphis Urban Area Metropolitan Planning Organization (MPO), which is shown on the map to the right. This aligns the project area with the jurisdiction of the MPO and ensures that datasets will match up geographically. Conceptually, this area represents the Memphis metro area and commuter shed east of the Mississippi River.

The region includes parts of Shelby County and Fayette County in Tennessee as well as DeSoto County and Marshall County in Mississippi. While Memphis is the regional urban hub, there are several other jurisdictions within the region, including Millington, Bartlett, Lakeland, Arlington, Germantown, Hernando, Southaven, Collierville, Olive Branch, Rossville, Walls, Horn Lake, Byhalia, Oakland, Gallaway, Lynchburg, Braden, Piperton, Somerville, and Bridgetown. The region is characterized by relatively flat terrain with the Mississippi River to the West and several tributaries that flow generally East-to-West. There are also several highways that radiate from Memphis outward and two major ring roads: I-269 and I-240/I-40.



Thinking Regionally

Every community is located within a larger regional context. While many resilience plans look at local conditions where infrastructure investments may be devised in detail, a critical part of resilience planning includes a zoomed-out view to larger-scale systems. Transportation, energy transmission, and other infrastructure that impact local conditions are functions of larger networks. Many residents have experienced frustration and sometimes danger when the power goes out or they are stuck in traffic on the highway. These are both experiences likely driven or exacerbated by regional infrastructure conditions. What happens in one community several miles away may impact another at large distances. This is particularly true when it comes to environmental risk. For example, flooding in a particular area is a function of large-scale hydrological systems. Water flows across vast distances and the physical environments that accommodate this flow can either make it flow in ways that prevent hazards to communities, or exacerbate water accumulation in certain areas. At the watershed scale, the Mid-South is located within the larger Mississippi watershed which includes catchment areas far North as well as to the West and East, encompassing an immense area nearly a quarter the size of the contiguous 48 states of the US. The map to the right illustrates these expansive areas of the watershed that cross multiple state lines. Significant rainfall and flooding upstream in the Midwest and West often have direct consequences downstream.

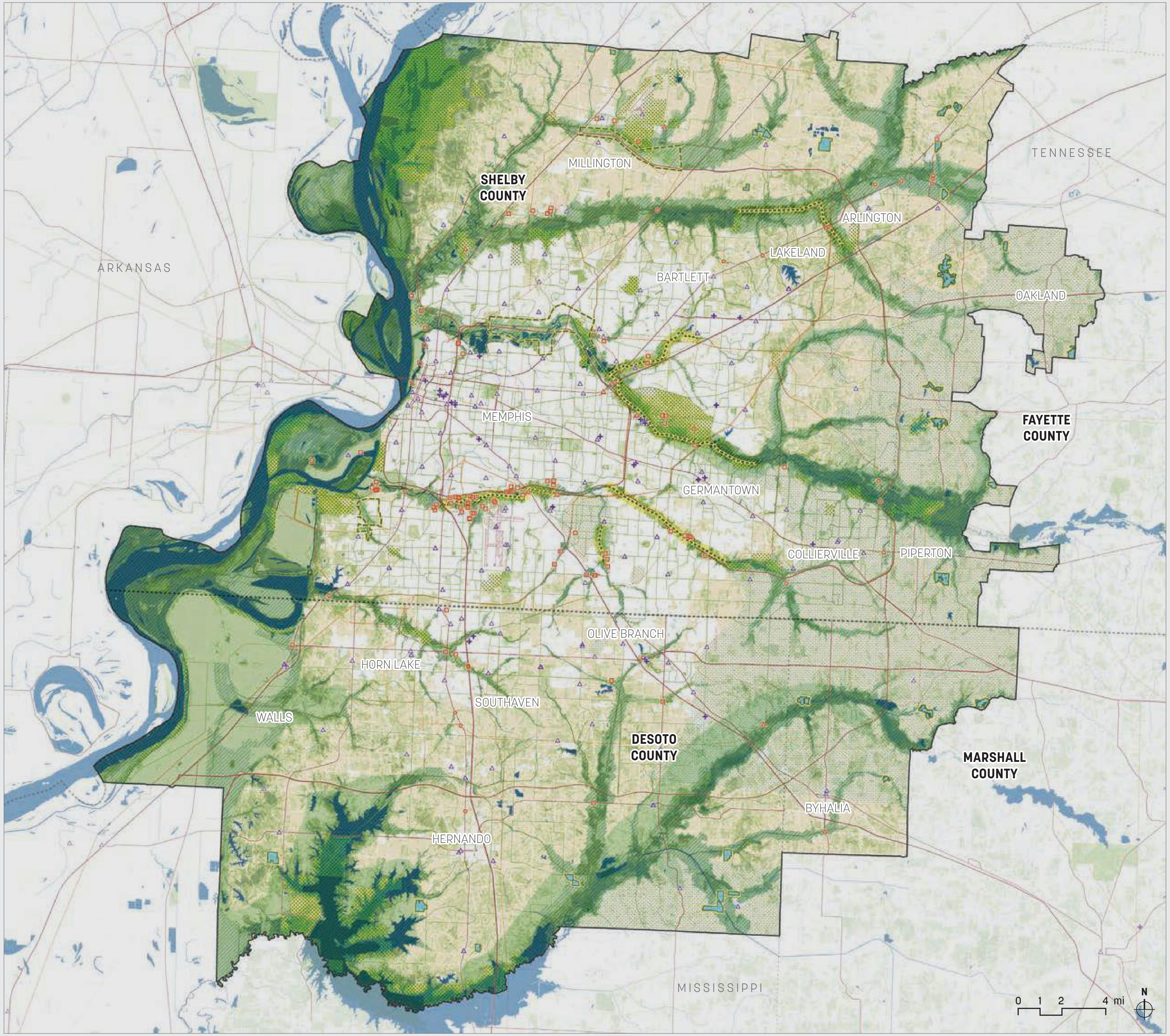
While many hazards are experienced locally, it is important to think about these systems regionally, as some of the most effective ways to reduce risk can only be undertaken at a larger scale and through collaboration between organizations and governments across the region. Additionally, many large-scale systems have important relationships that can only be illustrated through regional mapping. Population changes within a region can indicate new pressures on infrastructure and hydrological systems leading to changes in commuting patterns or new trajectories of water flow and flood hazard. Using data available in GIS, mapping helps to identify overlaps of critical spatial data as part of an analysis of key hazards and the areas under threat, the potential vulnerability of certain communities relative to these threats, and suitable sites for resilience project implementation.

Effective resilience planning in the Mid-South lies at the intersection of social, ecological and infrastructural systems. Each is an element that refers to the holistic capacity of communities to resist and recover in the face of natural disasters. This guidebook lays a foundation for action and cooperation throughout the region.

Composite Map

The composite map to the right illustrates several key layers—overlaying ecological layers with critical infrastructure, buildings, and key assets and facilities identified in subsequent recommendations throughout the RRMP. Through overlaying information, useful overlaps can be identified between various systems, such as the location of critical facilities located in the floodplain. These critical facilities provide important functions in cases of disaster or in the management of particular hazards. If flooding were to incapacitate these facilities, the critical functions they provide would be one less element that may help to mitigate the threat to the health and safety of residents that flooding alone would have.

The next several pages provide an overview of the themes depicted in this composite map as well as a broad introduction to the thematically organized recommendations found in the later chapters of the RRMP.



Map Legend

Ecological Layers

- Parks and Protected Open Space
- Conservation Priority Areas
- Ecological Sensitivity
- Non-urban Areas
- Trails
- Aquifer Recharge Area
- 500-year Floodplain
- Water
- Current Restoration Projects

Infrastructure

- Highways and Major Roads
- Airports
- Levees
- Pipelines
- Electric Corridors

RRMP Proposed Projects

- Parks with High Mitigation Value
- Large-Scale Water Detention Sites
- Stream Restoration Corridors

Critical Facilities and Infrastructure

- Healthcare Facilities
- Emergency (Police, Fire, etc.)
- Emergency Facilities in Floodplain
- Hazardous Sites in Floodplain (Waste, Contaminated, etc.)
- High Risk Bridges

Summary of Key Themes and Recommendations

1 Waterways

In nature, riparian corridors act as sponges, soaking up and containing floodwater before it spills over onto dry land. Riparian corridors are comprised of surface water, river banks, wetlands, and floodplains. Ideally, riparian corridors have absorbent soils to soak up excess water and ample vegetation to process water through evapotranspiration. Chapter 1 provides in-depth descriptions, analyses, implementation guidance, and case study information on the primary methods of flood control at the riparian level.

Development across the country and in the Mid-South has encroached on riparian corridors, and in some cases forced rivers into channels, culverts, and pipes. This kind of development has major negative consequences. First, there are now people and structures in areas that are likely to flood, inevitably resulting in risks to safety and property. Second, reducing the floodplain causes flooding to become more frequent and intense. Two major strategies to reduce flood damage with riparian corridors include restoration and building flood barriers.

Section 1.1 River and Stream Restoration includes strategies for strengthening natural infrastructure: increasing floodplain capacity, bank stabilization, and ecological restoration. Restoration is a great opportunity to increase recreational opportunities and access to nature for surrounding communities. The map "Landscape Systems" on the opposite page highlights several stream restoration corridors with overlapping benefits related to other recommendations within the RRMP.

Section 1.2 Flood Barriers include flood-mitigation strategies such as levees, flood walls, and floodgates. This hard infrastructure is appropriate in densely developed areas with no other viable options. While hard infrastructure has a smaller footprint than alternative solutions, it provides fewer ecological and community benefits and may increase flooding downstream.

2 Watersheds

Controlling flooding also relies on responsible management of the entire watershed, not just rivers and streams. The watershed includes all of the land in the basin that drains to a river, from the upland headwaters to the low lying delta. Development and land use changes within a watershed can increase the amount of water flowing downstream, resulting in more frequent and intense flooding. Chapter 2 focuses on effective strategies to manage excess water at the regional scale. In the Mid-South, these strategies include dispersed water management, protecting land surrounding water bodies, and controlling stormwater runoff.

Section 2.1 Large-Scale Water Detention emphasizes dispersed water management techniques, a strategy where low-lying fields are configured to hold large volumes of water and control its release. This technique is very cost-effective: simple detention ponds start at $0.07 per gallon. For the Mid-South, a target system size could be as large as 1,500 acres across dozens of sites. The map on the opposite page highlights several large-scale water detention sites identified in this section.

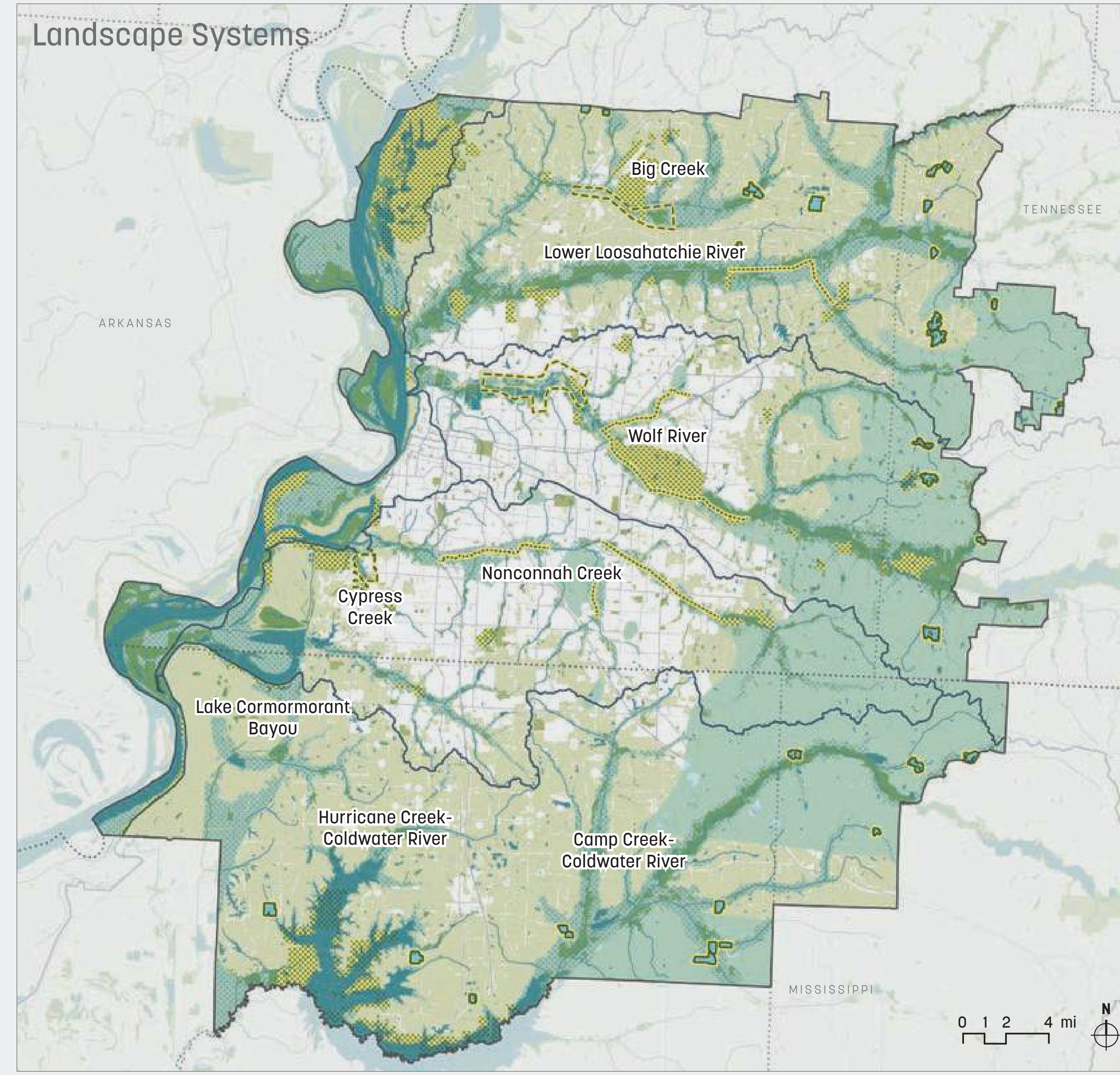
Section 2.2 Watershed Conservation focuses on protecting valuable natural assets within the watershed: primarily wetlands and aquifer recharge areas. Zoning strategies based on proximity to the watershed are common and effective ways to ensure long-term protection. Zoning can establish regulations on building and land development within 100 to 500 feet of the sensitive watershed assets.

Section 2.3 Low Impact Development describes the benefits, types, and funding of low-impact development (LID) techniques. Incentivizing the widespread use of LIDs across the watershed will lower the potential impact of continued upstream development on regional hydrology.

Section 2.4 Open Space Strategies emphasizes the use of land within the floodplain for both recreation and emergency floodwater storage. GIS analysis reveals that the Mid-South has nearly 10,000 acres of open space that meet preliminary criteria of large, flat, public open spaces within the floodplain. Further study of these sites is necessary to determine the appropriateness for use as temporary floodwater storage areas. The map on the opposite page highlights several major parks and open spaces with high flood mitigation value.

3 Buildings

Regional resilience can also be improved at the building level. As the map below titled "Urban Expansion 2001-2011" shows, urban expansion has resulted in significant construction encroachment on the floodplain. Building owners and operators can



Mapping Landscape Systems

This map illustrates several key spatial layers identified within the set of recommendations related to landscape and ecological assets for the region. These systems are intertwined through an interconnected network of water flows that shape the regional landscape. Both the Mississippi and its tributaries play a major role in the ecological resilience of local communities. Flooding events are tied to the functioning of these hydrological networks. Open space networks and trails are important to consider together as these assets provide space for risk mitigation and recreational opportunities for communities throughout the region. Also illustrated are the aquifer recharge areas which are integral to sustaining sources of drinking water. The 500-year floodplain is yet another critical reference layer to understand the risks posed to building and infrastructure located within or near it.

Map Legend

Ecological Layers

- Parks and Protected Open Space
- Non-urban Areas
- Aquifer Recharge Area
- 500-year Floodplain
- Water
- Current Restoration Projects

Infrastructure

- Highways and Major Roads

RRMP Proposed Projects

- Parks with High Mitigation Value
- Large-Scale Water Detention Sites
- Stream Restoration Corridors

take action to prevent floodwater and other damage to protect and improve a building's operational capacity to handle emergency events. There are also a range of subsidies, grants, loans, and other implementation information that would prove useful for building owners and operators to protect and retrofit existing buildings. Special emphasis is placed on buildings that support critical public services including fire houses, police stations, hospitals, and community shelters. An overview of selected critical facilities is illustrated on the map on page 22. Improvements to these buildings protect the critical services they provide in times of emergency, which further protects the health and safety of all members of the community.

Section 3.1 Floodproofing Buildings outlines flood protection strategies, with particular attention on reducing the amount of damage caused by floodwaters. Strategies include barriers and floodproofing.

Section 3.2 Earthquake Resilient Buildings proposes ways to increase a building's resistance to earthquakes caused by movements along the New Madrid Fault. Strategies include both technical and non-technical solutions concerning important facilities such as the Memphis International Airport, shelters, and hospitals.

Section 3.3 Emergency Shelters focuses on proactively identifying buildings that can act as emergency shelters in order to equip them with the necessary technology and retrofits. Within these buildings, temporary flood barriers, backup power systems, shelf-stable food, social services, and beds can be distributed long before disaster strikes.

Section 3.4 Roof Design describes the benefits of green roofs for individual buildings and the surrounding area. Green roofs reduce the energy load to heat and cool buildings, reduce flash flooding by storing stormwater, and mitigate urban heat island effect.

Section 3.5 Green Building Retrofits promotes the use of several different green building technologies, including Solar Photovoltaics, Solar Thermal, gray water recycling, insulation, moisture barriers, efficient windows, LED lighting, right-sized HVAC systems, and appliance replacement.

4 Land Planning

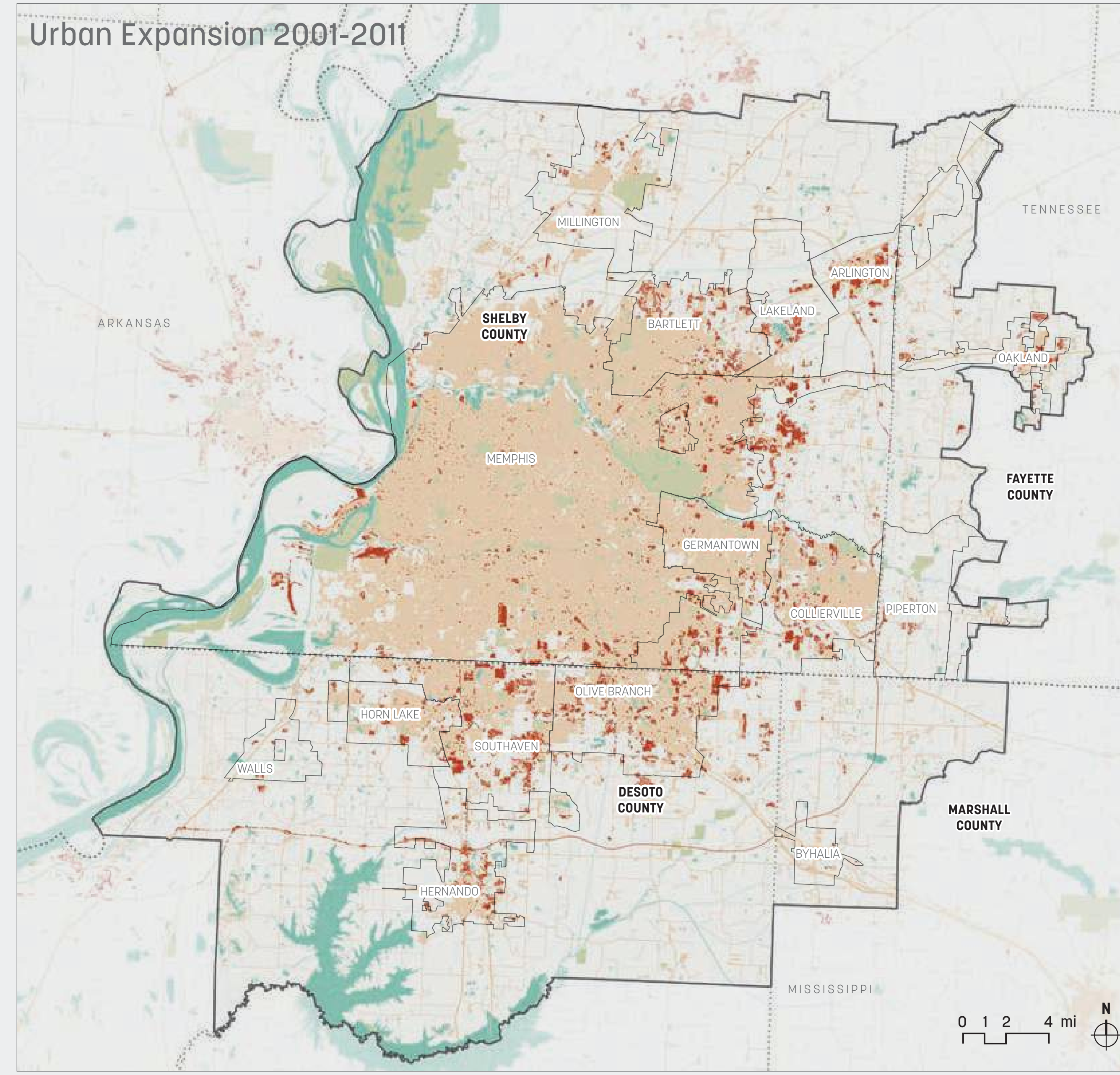
Prevention of damage through proactive hazard-mitigation can go a long way to promoting community health and safety and save on post-disaster recovery costs. A recent study by the National Institute of Building Sciences found that for every $1 spent on hazard mitigation, $6 in costs resulting from a future disaster could be saved.[i] Prevention and hazard mitigation also extends to land planning. This means adopting smart land-use planning practices that help keep people, property, and infrastructure out of harm's way.

Many contemporary development practices increase the risk to human health and safety from natural disasters. The map "Urban Expansion 2001-2011" on the opposite page illustrates the expansion of built structures into the floodplain that may have been prevented by proactive planning. Planning that does not consider the impact on and from natural systems can have detrimental effects to communities that continue to endure the impacts of natural hazards. Of chief concern for the Mid-South, flood risk is increased by the heavy runoff facilitated by urban sprawl. At the same time, allowing development in the floodplain puts more people, property, and infrastructure in the path of rising floodwaters. Chapter 4 addresses land planning best practices that help reduce flooding and the risk of damage from flooding. At the same time, these recommendations support compact communities that are more amenable to public transit and the preservation of scarce resources for emergency response.

Section 4.1 Resilient Sites promotes site resilience factors that can be integrated into zoning and development approval decisions. This includes strategies to improve the planning of multi-modal transit systems and the promotion of walkability, planning mixed-use developments, and shifting density towards existing urban cores and high-ground.

Section 4.2 Smart Growth outlines strategies to limit urban sprawl, which inevitably increases flood risk and damage. Typical practices include encouraging compact development and urban infill in areas with low-risk of flooding. This practice is in line with

i Natural Hazard Mitigation Saves Study, (National Institute of Building Sciences, 2017) https://www.nibs.org/news/381874/National-Institute-of-Building-Sciences-Issues-New-Report-on-the-Value-of-Mitigation.htm.



Urban Areas as of 2001
Urban Expansion 2001-2011
Parks and Protected Open Space
Water

Memphis 3.0, which aims to anchor future growth around the City's core. To achieve this type of development, some jurisdictions in the Mid-South can use the existing Unified Development Code with the addition of design guidelines, zoning overlays, form-based codes, and transit-oriented development.

Section 4.3 Flood Smart Development addresses how to mitigate flood damage with more robust floodplain development regulations. In addition to the toll on the health and safety of residents, flood damage currently comes with a huge price tag that is subsidized by tax payers. The National Flood Insurance Program (NFIP) sets minimum program requirements—steps communities and homeowners must take in order to get affordable flood insurance. Compliance with NFIP standards is a necessary first step. Still, there are even more effective regulations and strategies to reduce flooding costs such as increased transparency about the risk to renters and buyers and moving public facilities outside of the floodplain.

5 Infrastructure

The boundary of the City of Memphis has continued to expand over the past 40 years, as the population moves further away from the urban core. The map on page 18 illustrates urban expansion between 2001-2011. This sprawl means that the region's infrastructure must expand outward to accommodate population dispersal, which leaves behind older infrastructure near the center of the city with fewer direct users. Services like water, sanitation, electricity, and waste management, which are key to quality of life, become more expensive to cover larger areas with a lower population density. This can lead to underfunded services or a dependency on subsidies to cover the higher operations and maintenance costs of older and expanding systems.

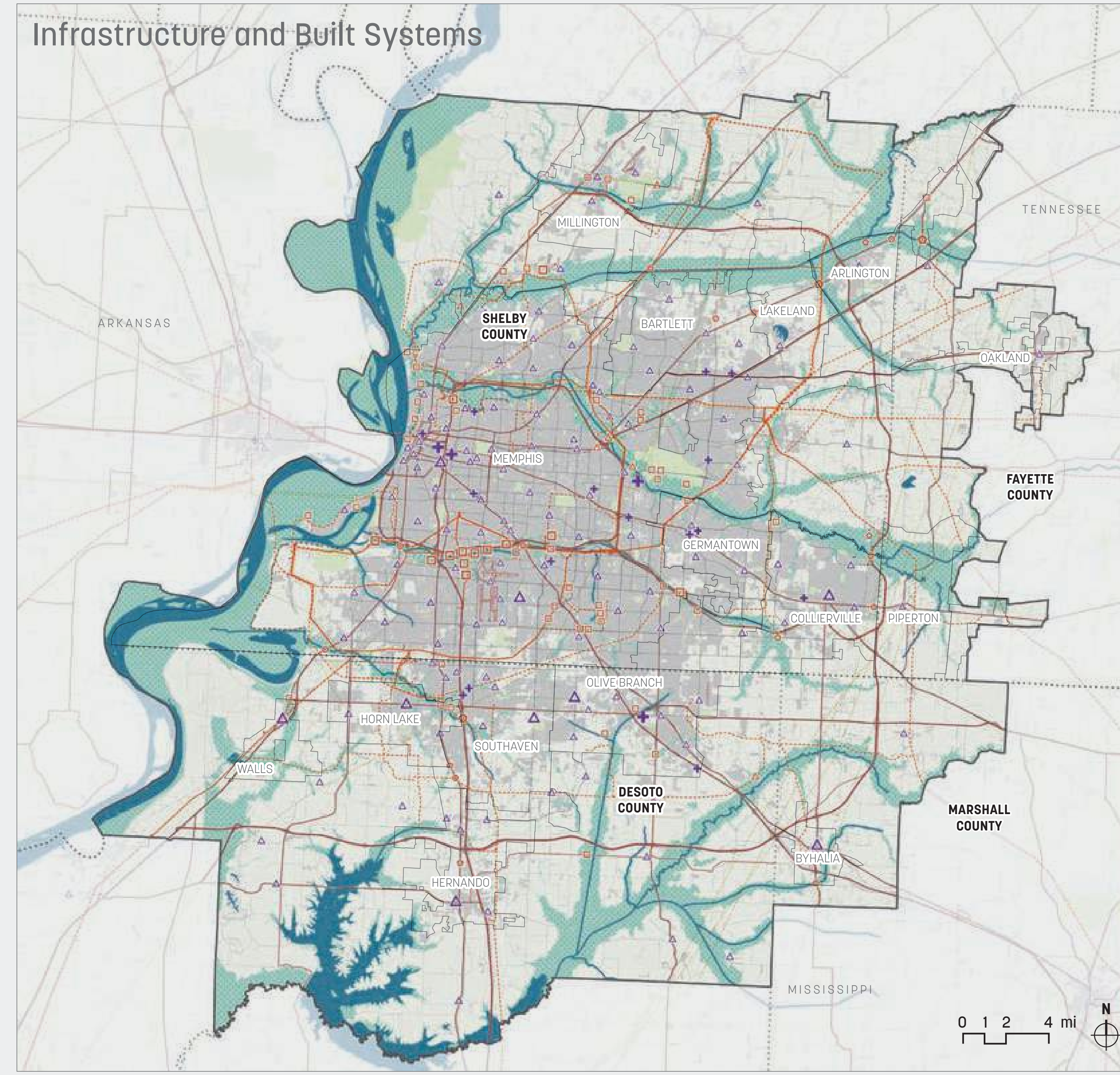
Infrastructure is the physical backbone of resilience and affects environmental, social, and economic systems. It is includes communications, drainage, water, waste, energy/power, and transportation, among others. Maintaining quality infrastructure through continued monitoring and maintenance is important for resilience anywhere. This is especially true for the Mid-South given the importance of logistics for its economy.

Section 5.1 Critical Infrastructure Planning emphasizes that the protection of key facilities is paramount to the functioning of many regional systems. Planning should be undertaken to create a Critical Facilities Protection Plan (CFPP) to safeguard critical infrastructure nodes like substations and water treatment facilities. There has already been robust planning addressing some of these issues during recent hazard mitigation planning efforts. For instance, the 2016 Shelby County Hazard Mitigation Plan proposed many improvements to address these hazards. The map "Infrastructure and Built Systems" on page 20 illustrates a selection of these critical facilities and infrastructure.

Section 5.2 Drainage Systems focuses on the overlapping concerns of water and drainage systems and their relationship with other critical infrastructure. For instance, roadways are generally comprised of large areas of impervious paving from which water must be directed to prevent flooding. Both stormwater networks and water delivery systems may be threatened during storm surges and riparian flooding. This can lead to the back up and flooding of critical transportation networks. To protect existing infrastructure systems and prevent failure due to flooding, it is recommended to enhance and maintain the regional stormwater conveyance network to meet current and future stormwater needs.

The resilience of the region's power grid impacts many other infrastructure systems. For instance, gas stations need electricity to function, and these facilities dispense fuel for evacuation and recovery in times of emergency. Traffic signals need electricity—the lack of which results in traffic backups or accidents. These and other communications systems are essential in times of disaster and often overlap with transportation systems and the power grid. Transportation systems provide a means for repair crews to access downed power lines, phone lines, cell towers, and fiber optic cable networks. Important transportation systems rely on communications systems for their operations. Airports use communications to relay information about scheduling to passengers, coordinate logistics, and communicate with air traffic control. Buses and public transit systems rely on communications systems to coordinate scheduling. Highways rely on Intelligent Transportation Systems (ITS), which utilize fiber optic cable networks to manage traffic flow around areas of backup and respond to emergencies.

Section 5.3 Power Lines outlines strategies for selectively burying overhead electrical wires and requiring in-ground utilities in new developments. This



Mapping Infrastructure and Built Systems

The above map illustrates several key spatial layers identified within the set of recommendations related to infrastructure and built space. These layers of overlapping systems are integral to the urban and infrastructure processes involved in the assessment of risk and strengthening of regional resilience.

Map Legend

Ecological Layers

- Non-urban Areas.
- Urban Areas
- 500-year Floodplain
- Water

Infrastructure

- Highways and Major Roads
- Airports
- Levees
- Pipelines
- Electric Corridors

Critical Facilities and Infrastructure

- Healthcare (Hospital, Clinic, etc.)
- Healthcare (2+ Cluster)
- Emergency (Police, Fire, etc.)
- Emergency (2+ Cluster)
- Emergency Facilities in Floodplain
- Emergency Facilities in Floodplain (Multiple in Vicinity, 2+)
- Hazardous Sites in Floodplain (Waste, Contaminated, etc.)
- Hazardous Sites in Floodplain (Multiple in Vicinity, 2+)
- High Risk Bridges
- High Risk Bridges (Multiple in Vicinity, 2+)

will help reduce power disruptions due to wind and winter weather, improve neighborhood aesthetics, and support critical emergency services.

Section 5.4 Smart Grid promotes newer technologies that allow more dynamic management of the power grid for increased resilience. A smart grid has distributed automation switches to mitigate and contain future power outages with precision and speed and improve power reliability.

Section 5.5 Community Energy illustrates the benefits of decentralization as an effective measure to mitigate systemic failures through distributing control and ownership over localized systems. Pilot projects for community-based ownership models of energy and water systems can help improve reliability and increase public awareness about these options.

Section 5.6 Snow and Ice focuses on the damage snow and ice may cause to the functioning of transportation, drainage, energy, and communications systems. Funding additional resources for post-storm snow and ice removal can improve the safety of transportation networks and improve the resilience of communications and energy systems.

Section 5.7 Trees looks at the management of tree planting in terms of the resilience benefits of effective selection, planning, and implementation. Modifying street tree planting and maintenance programs to offset the urban heat island effect can increase biodiversity and minimize falling branches that cause power outages.

6 Post-Disaster Opportunities

No matter how prepared a community is, the days, months, and years following a disaster are and will always be challenging. However, advance planning can help prepare a region for a more rapid and effective recovery. Chapter 6 presents three recommendations that should be considered now in preparation for the inevitable next disaster event. These include having resources and training in-line for post-disaster clean-up, a plan for housing displaced residents, and a way to compensate and relocate those who cannot reasonably return home.

Section 6.1 Voluntary Buyouts looks at how to prevent future property and home loss to reduce risk to human life as well as the cost of rebuilding. The process begins with identifying repetitive loss properties (those that have flooded multiple times) and properties with high risk of damage from future floods. The government (local, state, or federal) then offers to buy the property from the homeowner, working with the homeowner to find new housing if needed. People with high social vulnerability are of particular concern due to the additional challenge of moving or rebuilding after a disaster. Post-buy out, the original owner may vacate the property or live on the property with development restrictions. While homeowners may decline or object to the idea of a buy-out, it is worthwhile for communities to have the discussions around disaster risk and holistic cost-benefit analysis.

Section 6.2 Debris Recycling looks at the volume and diversity of material debris resulting from natural disasters. In the aftermath of a disaster, millions of cubic yards of debris must be cleared quickly and efficiently before residents can start rebuilding. Pre-disaster planning, education, and equipment purchases allow towns to increase rates of reuse and recycling of debris. By reducing trash loads, towns and residents save money spent on waste hauling and tipping fees. By collecting and sorting reusable materials, towns may be able to provide inexpensive supplies for local rebuilding. This section focuses on creating sorting, pick-up, and recycling systems that are straightforward and benefit the community.

Strategy 6.3 Temporary Housing focuses on pre-disaster preparation of emergency shelters and the provision of post-disaster housing. Recent Hurricanes such as Sandy and Katrina generated public and professional interest in developing post-disaster housing that is sturdy, cost-effective, and lasts for as long as needed. The Mid-South would benefit from reviewing new options for emergency shelters, temporary stays, and long-term housing. After this survey, the region should make pre-disaster arrangements that guarantee timely delivery and set up when disaster strikes.

7 Governance

Proactive governance can improve regional resilience in such a way that disasters are less debilitating. Through data collection, public outreach, and strategic pre-disaster funding arrangements, the region will be better able to withstand and bounce-back from the next storm event. Chapter 7 outlines the concrete steps Mid-South municipalities can take, from maintaining quality, robust public data to ensuring funding for recovery projects.

(Left) The Hernando De Soto Bridge with Memphis in the background. Transportation infrastructure provides vital service functions in times of emergency and recovery.

Section 7.1 Resilience Database recommends maintaining public, up-to-date records that interested parties can use to coordinate planning. This data should include information about threats, climate projections, and critical systems.

Section 7.2 Outreach emphasizes that information sharing is as important as data collection. Many people want to prepare themselves and their properties for storms but do not have the resources or funding to do so. This section calls for a public information campaign that reaches out to residents, homeowners, and businesses. The campaign could operate in conjunction with a one-stop-shop for information on disaster preparation and recovery.

Section 7.3 Vulnerable Communities gives special consideration to investments in vulnerable communities. These communities have some socially-determined characteristics that may make them less able to recover from a large disaster. This includes a range of factors such as low-median income, low English literacy, lack of car ownership, and many others. These areas of vulnerability may be addressed through programs that address the roots of social vulnerability such as workforce training, childcare programs, and accessible notifications, among others.

Section 7.4 Economic Development makes the case that resilience and job creation go hand-in-hand. Making the region more resilient will necessitate the creation of many new jobs to address needs such as the construction of stormwater LIDS, stream restoration, solar panel installation, and much more.

Section 7.5 Capital Market Funding promotes the ability of local governments to pre-fund disaster mitigation and recovery through the use of catastrophe and resilience bonds. This is an appropriate step to take if disaster insurance will be unable to fund the full amount needed for recovery. With catastrophe bonds, investors contribute to a principal which can be used by the municipality if a qualifying disaster strikes. If not, the investors continue to collect interest on the bond. This is beneficial for investors because the risk of qualifying event is currently low (3.3%) and the investment is not tied to the stock-market. Resilience bonds leverage insurance companies to fund projects that reduce the risk of damage from a natural disaster, resulting in reduced municipal insurance rates and other long-term savings.

Recommendations Matrix

Recommendations	Threats Addressed							Cost			Implementation Complexity			Potential Leads
	Damaging Wind	Riverine Flooding	Flash Flooding	Extreme Heat	Earthquake	Winter Storms	Tornadoes	$ Low	$$ Medium	$$$ High	• Low Internal Matter	•• Medium External Partnership	••• High Regional Cooperation	Public, Private, Non-profit
1 Waterways														
1.1 River and Stream Restoration Mitigate Flooding by Improving Waterway Health		✓	✓							$$$		••		Municipalities, Counties, Conservancies
1.2 Flood Barriers Construct Barriers to Protect Against Flooding		✓	✓							$$$		••		Property Owners, Municipalities, Counties
2 Watersheds														
2.1 Large-Scale Water Detention Store Water Upstream to Mitigate Flooding Downstream		✓	✓					$					•••	Property Owners, Municipalities, Counties
2.2 Watershed Conservation Protect Critical Watershed Assets		✓	✓	✓					$$		•			Municipalities, Counties, State, Federal
2.3 Low Impact Development Encourage Development that Supports Healthy Watersheds		✓	✓	✓				$			•			Property Owners, Municipalities
2.4 Open Space Strategies Use Parks, Trails, and Other Open Space to Protect Against Flooding		✓	✓						$$			••		Municipalities, Counties, State, Federal
3 Buildings														
3.1 Floodproofing Buildings Retrofit Critical Buildings for Flood Protection		✓	✓					$			•			Property Owners
3.2 Earthquake Resilient Buildings Update Codes and Building Stock to Provide Seismic Resilience	✓				✓				$$		•			Property Owners
3.3 Emergency Shelters Ensure Adequate Emergency Shelter Capacity	✓	✓	✓	✓	✓	✓	✓	$				••		Municipalities, Counties, Non-profits, EMAs
3.4 Roof Design Encourage Green / Cool Roofs for Thermal Regulation and Resource Efficiency		✓	✓	✓				$			•			Property Owners
3.5 Green Building Retrofits Support Retrofits that Improve Building Performance and Resilience	✓	✓	✓	✓	✓	✓	✓	$			•			Property Owners, Municipalities, Counties
4 Land Planning														
4.1 Resilient Sites Incorporate Site Resilience Factors into Land Planning Decisions		✓	✓	✓	✓			$					•••	Municipalities, Counties
4.2 Smart Growth Encourage Selective Compact and Infill Development		✓	✓	✓				$				••		Municipalities, Counties
4.3 Flood Smart Development Exceed the Minimum Requirements of the National Flood Insurance Program		✓	✓					$			•			Municipalities, Counties

Recommendations Matrix (continued)

Recommendations	Threats Addressed: Damaging Wind	Riverine Flooding	Flash Flooding	Extreme Heat	Earthquake	Winter Storms	Tornadoes	Cost: $ Low	$$ Medium	$$$ High	Implementation Complexity: • Low Internal Matter	• • Medium External Partnership	• • • High Regional Cooperation	Potential Leads: Public, Private, Non-profit
5 Infrastructure														
5.1 Critical Infrastructure Planning Create Critical Facilities Protection Plans	●	●	●	●	●	●	●	$			•			Municipalities, Counties, States
5.2 Drainage Systems Enhance the Capacity of Waste and Stormwater Systems		●	●							$$$		• •		Municipalities, Counties, Utility Companies
5.3 Power Lines Selectively Bury Overhead Electrical Lines	●			●		●	●			$$$		• •		Municipalities, Counties, Utility Companies
5.4 Smart Grid Implement a Smart Grid System to Mitigate Power Outages	●			●		●	●	$				• •		Municipalities, Counties, Utility Companies
5.5 Community Energy Expand Cooperative and Community-Based Energy Systems	●			●	●	●	●		$$				• • •	Non-profits, Municipalities, Counties, States
5.6 Snow and Ice Fund Additional Resources for Post-Storm Snow and Ice Removal						●		$			•			Municipalities, Counties
5.7 Trees Modify Tree Programs for Improved Resilience and Ecological Health	●	●	●	●				$			•			Property Owners, Municipalities, Counties, Utility Companies
6 Post Disaster Opportunities														
6.1 Voluntary Buyouts Implement a Voluntary Buyout Program for High Risk Sites		●	●						$$		•			Property Owners, Municipalities, Counties
6.2 Debris Recycling Recover and Recycle Post-Storm Debris	●	●	●		●	●	●	$			•			Property Owners, Municipalities, Counties
6.3 Temporary Housing Prototype Rapid, Temporary Post-Disaster Housing Solutions		●	●		●	●	●	$			•			Property Owners, EMAs
7 Governance														
7.1 Resilience Database Maintain Up-to-Date Resilience Data and Projections	●	●	●	●	●	●	●		$$			• •		Municipalities, Counties, States, Institutional Partners, Utility Companies
7.2 Outreach Expand Resilience-Related Public Outreach and Engagement Efforts	●	●	●	●	●	●	●	$				• •		Municipalities, Counties, States, EMAs
7.3 Vulnerable Communities Identify Resilience Strategies for Vulnerable Communities	●	●	●	●	●	●	●	$			•			Municipalities, Counties, Non-profits
7.4 Economic Development Align Job-Training Programs with Resilience-Related Workforce Needs	●	●	●	●	●	●	●	$				• •		Municipalities, Counties, States, Non-profits, EMAs, Private Companies
7.5 Capital Market Funding Fund Disaster Mitigation and Recovery Through Private Capital Markets	●	●	●	●	●	●	●		$$				• • •	Municipalities, Financial Institutions

THREATS

Damaging Wind

Causes

1	**Air moving rapidly from a high pressure system to a low pressure system**

Relevant Recommendations

- 3.2 Earthquake Resilient Buildings
- 3.3 Emergency Shelters
- 3.5 Green Building Retrofits
- 5.1 Critical Infrastructure Planning
- 5.3 Power Lines
- 5.4 Smart Grid
- 5.5 Community Energy
- 5.7 Trees
- 6.2 Debris Recycling
- 7.1 Resilience Database
- 7.2 Outreach
- 7.3 Vulnerable Communities
- 7.4 Economic Development
- 7.5 Capital Market Funding

Definition

Wind is defined as straight line, horizontal motion of air past a given point.[1] The National Weather Service considers wind storms to be severe if winds are greater than 58 miles per hour. Strong straight line wind gusts cause significant damage to property and infrastructure in the Mid-South. The most disruptive effect of wind storms is the frequent and occasionally extended power outages experienced by residents and business owners.

(Right) Strong wind gusts are powerful enough to topple utility poles.

Causes

High Pressure Air System Meets a Low Pressure Air System

Differences in atmospheric pressure create wind. When air in a high pressure system collides with air in a low pressure system, the air moves from the high pressure area to the low pressure area, and the resulting flow of air results in wind. Wind speeds are higher if the difference in pressure between the two colliding systems is higher.

Colder air systems have higher pressure, while warmer air systems have lower pressure. As temperatures rise, hot air rises, and leaves an area of lower pressure behind, inviting high pressure cooler air to come into that space. As global temperatures change, wind patterns are also expected to change. Research is ongoing to determine local impacts.

(Above) A common hazard resulting from damaging winds are collapsed trees that block roads and may damage power infrastructure.

Impacts

Health and Safety

While wind storms do not typically result in significant numbers of direct casualties, they can indirectly cause deaths and injuries due to falling debris. During the period from 2007 to 2017, two deaths and 33 injuries were reported during wind events.[2] Strong winds can dislodge trees from the ground, toppling them onto people, cars, buildings, and transportation routes. This can be a direct cause of injury. Additionally, the fallen trees or branches can trap people in cars, block building egress routes, and obstruct roadways. This can indirectly lead to injury or death for people needing medical attention and particularly affects vulnerable populations.

Property Damage

Straight line winds rarely reach speeds to directly cause property damage to major structures or personal property. However, wind speeds reach speeds great enough to topple trees or lift other heavy objects into the air, which can cause significant damage to houses, vehicles, and other real property as they land.

Infrastructure

Some of the biggest impacts of wind events are to the infrastructure networks of the Mid-South. Strong winds can blow trees or branches onto roadways, train tracks, or airport runways, making them impassable. Due to the widespread nature of wind hazards, fallen debris from major wind events can quickly overwhelm local maintenance crews who must find and then manually remove obstructions from the right-of-way before it can be reopened. Strong winds can also disable traffic signals, leading to confusion or accidents for drivers.

Overground utility wires are highly susceptible to damage from wind or from falling trees or branches during wind storms. When wind gusts exceed 20-30 miles per hour, utility agencies report an increase in the number of power lines that are down. Though utilities send out maintenance crews the same day as a wind event, it often takes days before power is fully restored after a major event. In order to minimize damage to the electric distribution network, Memphis Light, Gas, and Water (MLGW) and Entergy send regular tree-trimming crews to trim trees and branches along utility rights-of-way. These programs are helpful, but in Downtown Memphis in particular, utility easements run along rear property lines and it can be challenging for MLGW to gain access. Utility disruptions are typically limited to electric services; there has not been a recent time when weather-related events caused gas service or water service to be hindered.

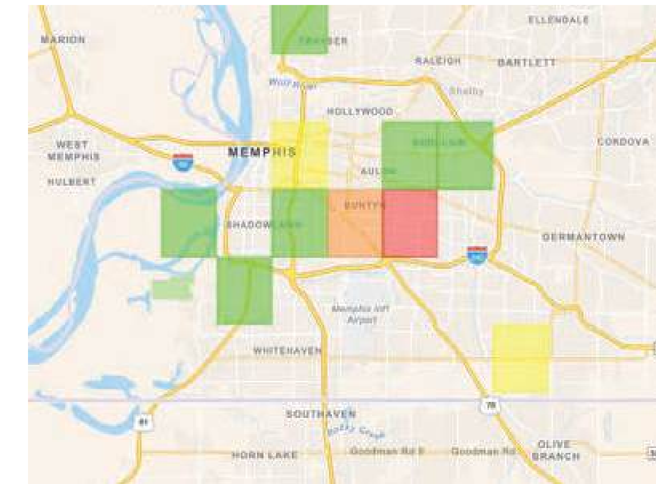
Continuity of Operations

Major wind events can disrupt business operations due to the frequent loss of power. Based on the frequency and duration of power outages, it is estimated that 3 or more businesses may close for a few months or indefinitely after each major wind storm.[3]

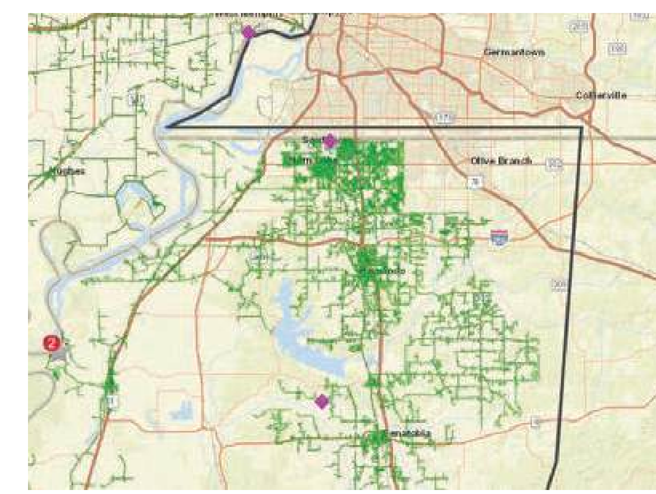
The Small Business Association can offer assistance to business owners to help them maintain operations through a major wind event, but this does not include compensation for lost revenue. Disaster Unemployment Assistance can help workers that lose paid employee hours due to wind-related disasters. Opportunity costs of business disruptions are not quantified, but Memphis is a national logistics hub and power outages in the Mid-South can have national implications for continuity of operations.

Quality of Life

Quality of life can decrease during wind storms in a number of ways. Due to associated debris, many sidewalks, roadways, and other open spaces may be impassable or unoccupiable. Most Mid-South residents experience, at best, an inconvenience following a wind storm, and often face more significant challenges to their typical quality of life. During power outages, including those associated with wind storms, crime rates can increase, including residential and business burglaries as opportunistic criminals do not fear the disabled alarm systems. Additionally, during power outages many people rely on alternative sources for light and heat; fires often occur due to inexperienced users attempting to use candles for light or fires for cooking or heat.



(Above) MLGW offers real-time updates about current power outages in their service area..



(Above) Entergy offers real-time updates about current power outages in their service area..

Frequency

Wind events are frequent in the Mid-South. Between 1956 and 2018, 528 wind events (where winds exceeded 58 miles per hour) were recorded by NOAA, averaging 8.4 recorded events per year. Evidence suggests that wind events are also becoming more frequent, likely due to global changes in weather patterns. For the ten year period between 2007 and 2017, 223 wind events of the same magnitude were recorded, averaging 20.2 events per year.[4]

Typical Wind Event

A typical major wind event in the Mid-South is one where wind gusts exceed 58 miles per hour but do not exceed 85 miles per hour. Property damage from the storm would be expected to range from $500,000 to $2 million, with most events causing approximately $1 million worth of property damage.

During a typical major wind event, one to two people may report injuries related to the storm, but it would be exceedingly rare for a typical major wind event to result in a fatality.

Power loss would be expected, but the number of customers affected and the expected duration would depend on the location of any outages. Generally, however, thousands of electric utility customers could expect to lose power for a few hours or days.

Magnitude

Wind events can range in magnitude from no property damage to tens of millions of dollars worth of property damage. The range often depends on the wind speed, as well as the value of any assets that are damaged. During most documented wind events, the Mid-South sustains approximately $1 million worth of property damage.[5]

Most residents and businesses experience power outages. On average, customers in the Mid-South lose power one and a half times per year, typically due to wind storms. These outages last for two hours and 45 minutes on average. These averages reflect MLGW's system averages, however, and can exceed or fall short of an individual customer's experience.

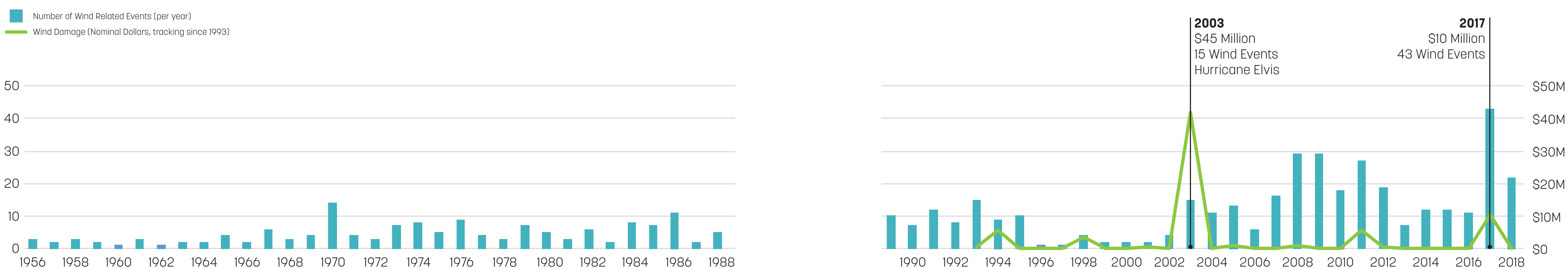
Worst Case Wind Event

The Mid-South Derecho of 2003, commonly referred to "Hurricane Elvis" in the Mid-South, is representative of the worst case wind event. During the storm, wind speeds of 102 miles per hour were recorded at AutoZone Park, and wind speeds of 77 miles per hour were recorded at the Agricenter.

The storm caused a reported $45 million worth of damage, in addition to 1.1 million cubic yards of tree debris.[6]

The intense wind gusts wreaked havoc on the region's infrastructure. Above-ground power distribution lines proved highly susceptible. In Shelby County alone, a reported 750,000 people lost power. After one week, 100,000 customers still did not have power. Additionally, the storm caused Memphis International Airport, one of the world's largest cargo airports, to close.

Historic Timeline of Damaging Wind Events



Endnotes

1 Noaa. “Glossary.” NOAA’s National Weather Service. November 01, 2004. Accessed July 09, 2019. https://w1.weather.gov/glossary/index.php?letter=w.

2 Ncei. “Storm Events Database.” National Centers for Environmental Information. Accessed July 03, 2019. https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=47,TENNESSEE#.

3 Ncei. “Storm Events Database.” National Centers for Environmental Information. Accessed July 03, 2019. https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=47,TENNESSEE#.

4 Shelby County Hazard Mitigation Committee. Shelby County Hazard Mitigation Plan. Report. Shelby County Office of Preparedness. TN, 2016.

5 Ncei. “Storm Events Database.” National Centers for Environmental Information. Accessed July 03, 2019. https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=47,TENNESSEE#.

6 Proseus, Erik. “Re-visiting the Summer Storm of July 22, 2003 - “Hurricane Elvis”.” MWN Blog. January 01, 1970. Accessed July 09, 2019. https://www.memphisweather.blog/2013/07/re-visiting-summer-storm-of-july-22.html.

Resources

MLGW Outage Map:

MLGW Outage Map. http://azimuth.mlgw.org/OutageSummary.php

Entergy Outage Map:

Entergy Outage Map. https://www.etrviewoutage.com/map?state=ms&_ga=2.206430682.854369056.1562937804-1162938053.1562937804

Riverine Flooding

Causes

1	**Increases in heavy rain events or snowmelt**
2	**Increases in impervious surfaces upstream**
3	**Degradation of riverbanks and floodplains**

Relevant Recommendations

- 1.1 River and Stream Restoration
- 1.2 Flood Barriers
- 2.1 Large-Scale Water Detention
- 2.2 Watershed Conservation
- 2.3 Low Impact Development
- 2.4 Open Space Strategies
- 3.1 Floodproofing Buildings
- 3.3 Emergency Shelters
- 3.4 Roof Design
- 3.5 Green Building Retrofits
- 4.1 Resilient Sites
- 4.2 Smart Growth
- 4.3 Flood Smart Development
- 5.1 Critical Infrastructure Planning
- 5.2 Drainage Systems
- 5.5 Community Energy
- 6.1 Voluntary Buyouts
- 6.2 Debris Recycling
- 6.3 Temporary Housing
- 7.1 Resilience Database
- 7.2 Outreach
- 7.3 Vulnerable Communities
- 7.4 Economic Development
- 7.5 Capital Market Funding

Definition

The 2016 Shelby County Hazard Mitigation Plan defines riverine flooding events as "when excess water from rivers and other bodies of water overflow onto riverbanks and adjacent floodplains."[1] Riverine flooding is generally understood as damage to a normally dry area due to high flow, overflow, or inundation of water. Inundation due to river flooding typically lasts days or weeks before water subsides.

Water levels on the Mississippi River are measured by river gages monitored by the Army Corps of Engineers. When water levels reach the "action stage," a mitigation action is needed to prepare for significant flooding. If water levels continue to rise to the "flood stage," there is an imminent hazard to lives, property, or commerce and flood advisories or warnings are issued.[2]

(Right) Photo of Beale Street in Memphis during the May 2011 floods.

Causes

Water levels in the Mississippi River and its tributaries rise as a result of increases in heavy rainfall and impervious land cover and decreases in riparian forests and floodplain meadows. When the water levels of the Mississippi River rise, its tributaries cannot sufficiently drain, even as the tributaries are also experiencing higher-than-normal water levels. This creates flood conditions throughout the Mississippi River's network of waterways in the Mid-South.

Increased Precipitation

Increases in frequency and duration of rain events in the Mid-South are part of global trends in precipitation changes and are commonly tied to increases in air and ground temperatures.[3] Both the increase in the annual amount of precipitation and the increase in the amount of precipitation per event are contributing to riverine flooding in the region.

Overall Increase in Precipitation

The region typically receives 53.67 inches of precipitation annually,[4] though there is a projected 5.29% increase in the amount of annual precipitation by the late 21st century.[5] More frequent and longer duration rain events saturate soils, creating increased runoff during subsequent rain events.

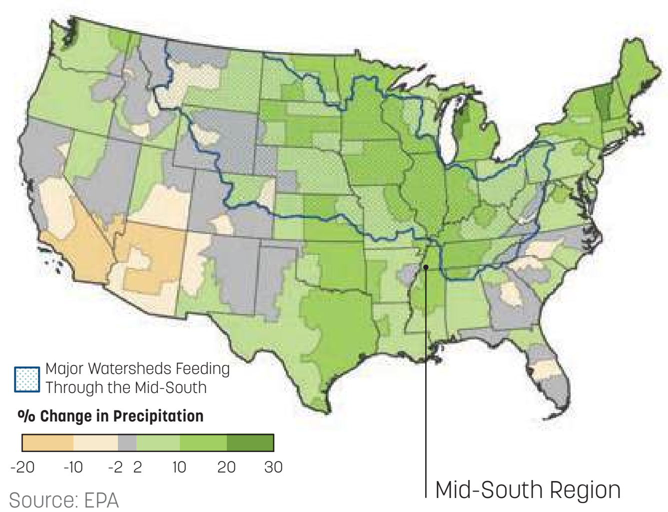
Projected increases in winter precipitation in states upstream on the Mississippi and Ohio Rivers means that more snow melt in the spring will find its way into the river channel.[6] This can be particularly problematic if snow melt is caused by a swift increase in temperatures after a cold winter, as the ground may still be frozen and snow melt runs directly to the rivers.

Increase in Precipitation Per Event

Over the last century, there has been a notable increase in the amount of precipitation experienced during a rain event in the Mid-South. Decadal averages of the annual number of days where precipitation exceeded 2.99 inches have increased from an average of 0.6 days from 1911-1920 to an average of 1.6 days a year from 2011-2015.[7] Events of more severe intensity can flood larger areas as the volume of water exceeds the capacity of the waterway during the event.

Heavy downpours can also accelerate stream bank erosion, which gradually creates a faster channel in the waterway, which in turn leads to more erosion and faster water flows for subsequent events. Higher velocity waters

Observed Precipitation Change



Source: EPA

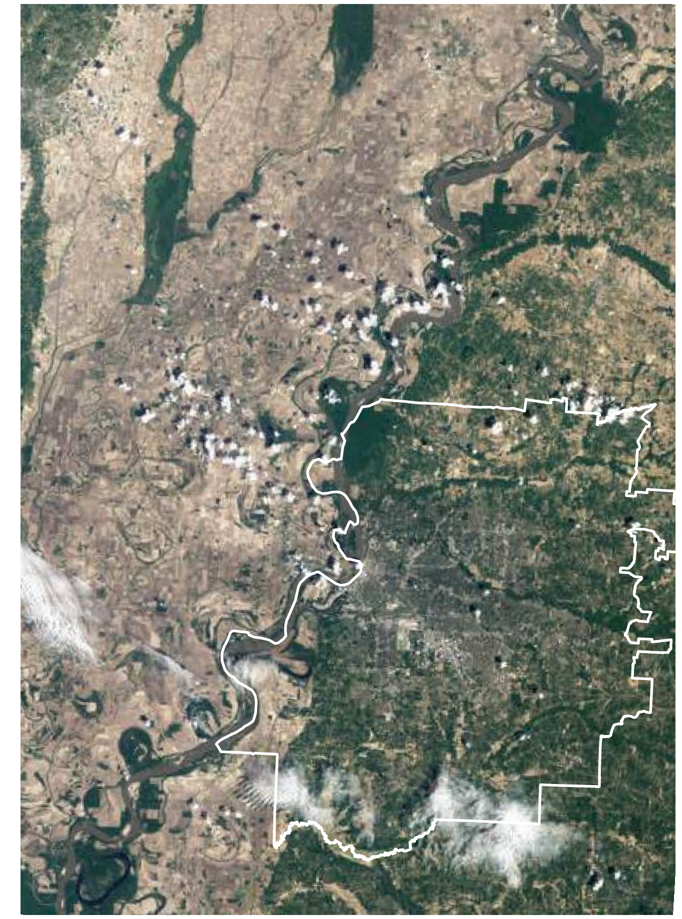
can also lead to flash flooding when rivers over-top their banks, which carries an extra set of risks; flash floods can harm people and property either through the force of water or by carrying destructive debris.[8]

Erosion also redistributes sediment along the waterway, contributing to riverine flooding. Sediment from the banks of a stream or river is eroded and redeposited along the riverbed (creating a shallower channel so less water is needed to over-top the banks), or within a wetland, spillway, or other water retention or detention area (reducing the water storage capacity of the basin).

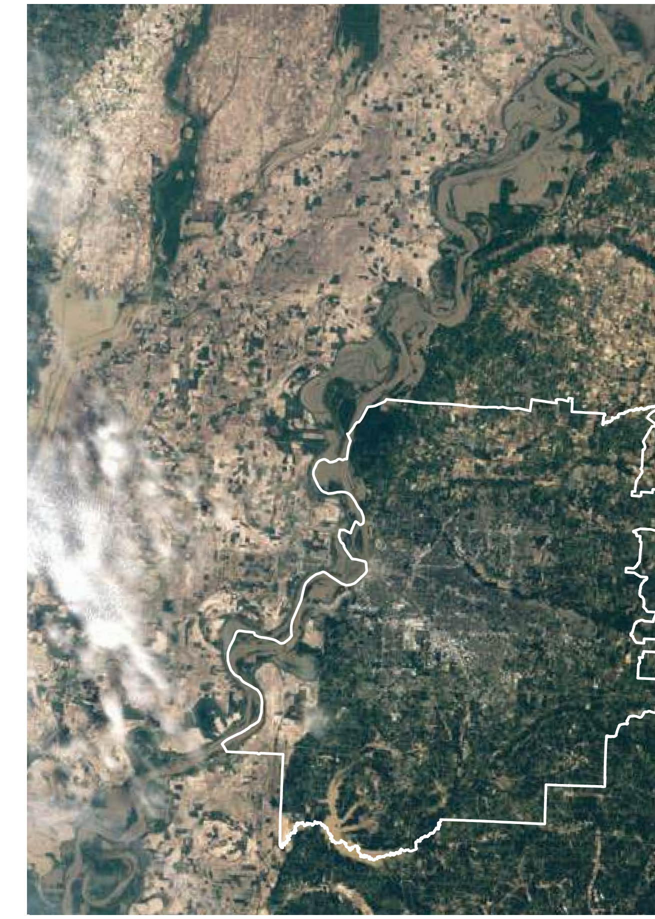
Increased Impervious Surfaces

There have been increases in impervious land cover upstream in the Upper Mississippi, Lower Mississippi, and Ohio River Watersheds and along their tributaries. Between 2001 and 2007, there was a 12.5% increase in impervious area in Tennessee, and a 10.7% increase in impervious area in Mississippi. Impervious surfaces absorb significantly less rainwater, creating runoff that flows quickly and directly into local waterways. This adds to the overall volume of water in the waterway during storm events.

In the Mid-South, most of the loss of pervious surface has been from loss of riparian forests and floodplain meadows. These types of land cover have significant water absorption capacities which exacerbates the flooding issue stemming from changes in land cover. This is both a regional issue due to development in the Mid-South and a larger watershed issue due to development upstream.

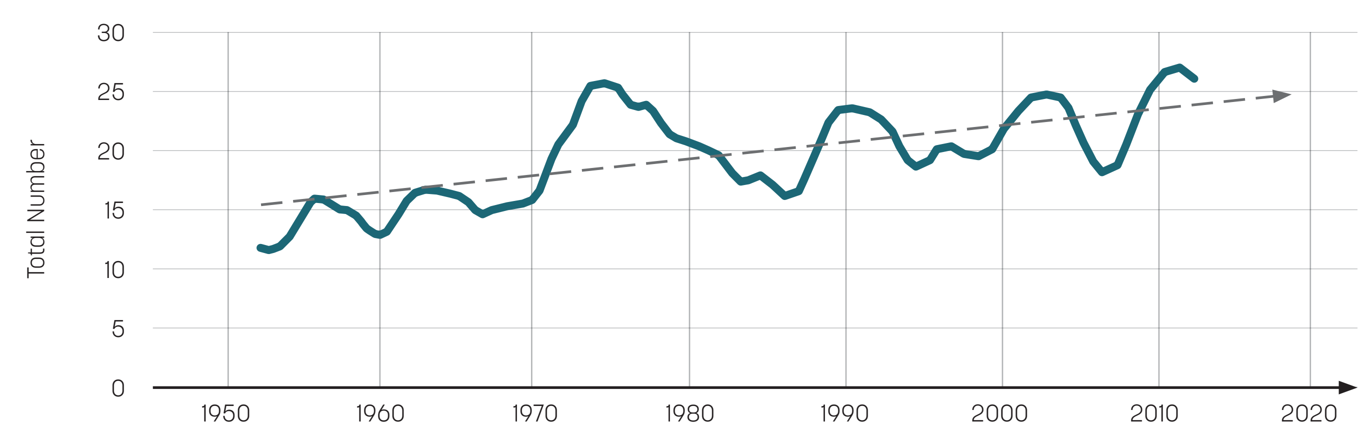


(Above Left) Satellite photo from November 11, 2011 showing normal conditions along the Mississippi River.



(Above Right) Satellite photo from November 30, 2011 showing flooding of the Mississippi River.

Number of Heavy Downpours in Tennessee[7]



Source: ClimateCentral.org

Impacts

Health and Safety

Flooding has direct and indirect impacts on health and safety. If high velocity waters over-top the waterway, they can sweep people into the flood or carry heavy debris into populated areas causing injury or fatality.

Indirectly, there are several health and safety concerns. When riverine flooding inundates roadways, emergency services vehicles may not be able to reach their service areas in a timely manner, if at all.

Flooding can also require short term and long term evacuation. Health service providers with facilities in the floodplain may need to evacuate patients, often with negative impacts on patient care. During the May 2011 floods, the Mid-South Health and Rehab Center had to evacuate 146 patients.[9] Other institutions that are in the floodplain may face similar challenges. During the May 2011 floods, the Millington Minimum Security Federal Prison was flooded and prisoners were transported to another site.[10] All manner of residential facilities in the floodplain may experience this type of disruption during flood events.

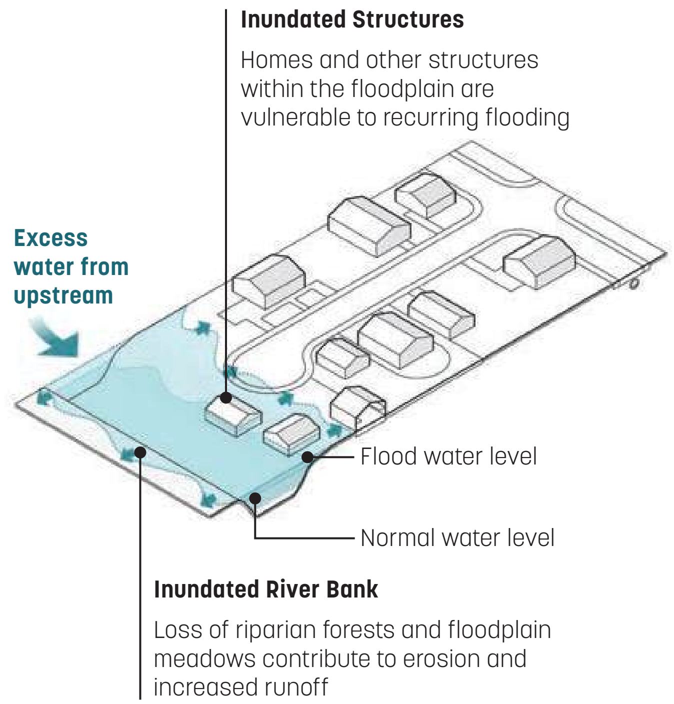
The aftermath of a major flood can have several impacts on health and safety. Physical health problems, such as respiration issues, stem from molding building materials left in inundated homes after the waters subside. Many people whose homes or businesses flood also experience anxiety and emotional issues as the deal with their loss.[11] In Shelby County, 198 houses were flooded during the 2011 storms, and approximately 1.6% of buildings in Shelby and DeSoto Counties have at least a 1% annual chance of flooding.

Property damage

Riverine flooding caused $2 billion in property damage in the Mid-South between 2005 and 2015, including the damage caused by the record-breaking floods of May 2011. During that flood event, 198 homes in Shelby County flooded.[12]

Infrastructure

According to a report conducted by the Tennessee Department of Transportation in 2015, Shelby County is in the most severe risk category for riverine flooding.[13]



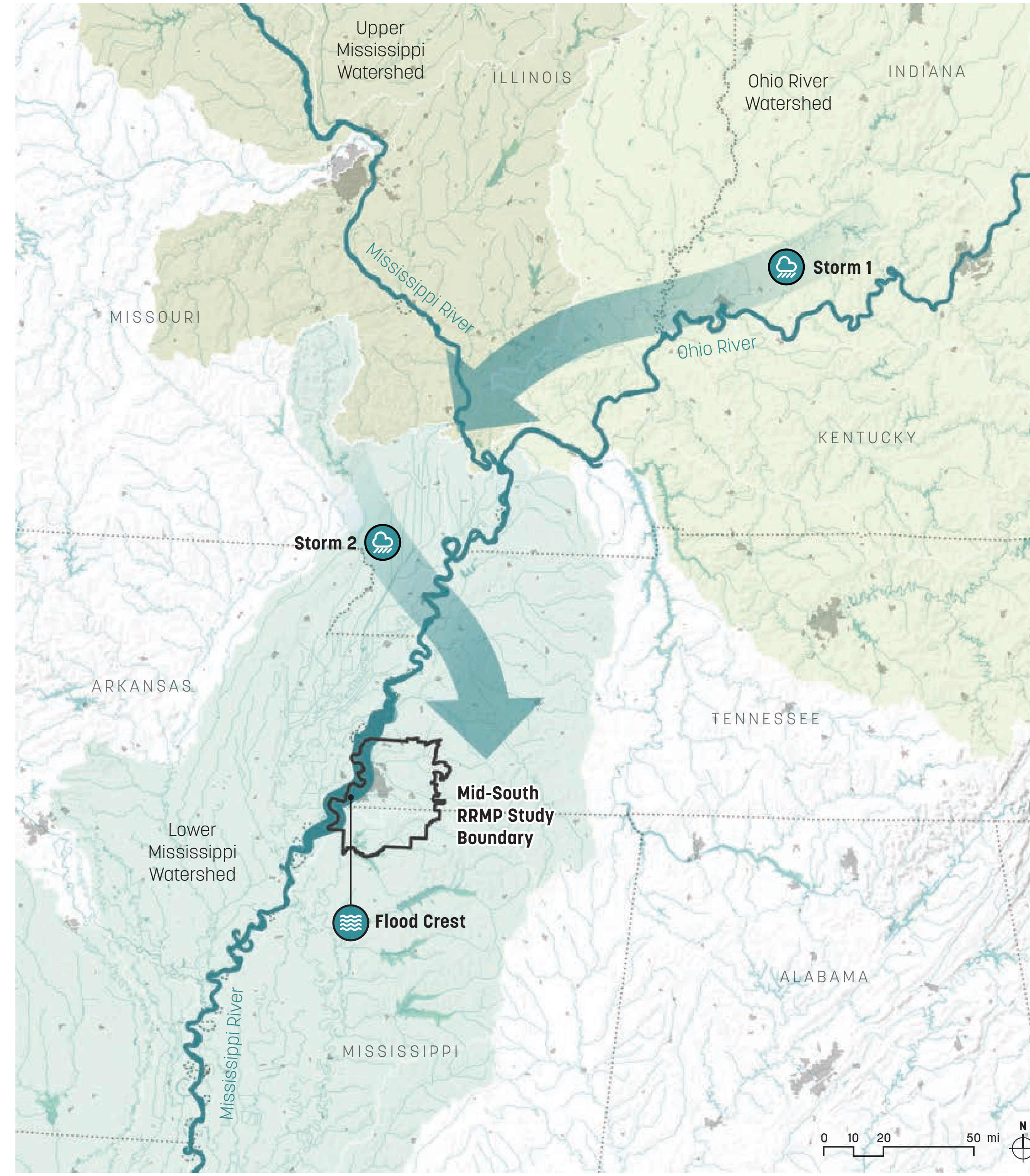
Roadways become impassable due to standing water, or can be washed out due to high velocity floodwaters. Riverine flooding can also erode the soil base for roads, railroads, and pipelines, causing them to destabilize and collapse.

Navigable waterways and ports are also at risk during riverine flooding events. When the water level exceeds the height of dams and locks, it isn't safe for barges to move along the river. This affects the movement of coal, building materials, and agricultural products. The entire Midwest depends on the Mississippi River for freight transportation, and 60% of U.S. grain exports are shipped on the Mississippi River.[14]

Ecological

Erosion, caused by riverine flooding, undermines slopes and causes bank destabilization and stream/creek bed damage. This affects nearby buildings that may face foundational instability and exacerbates streambank conditions that lead to flooding.

Additionally, when industrial sites flood, they can release contaminated materials or soils into waterways which has deteriorated water quality in several tributaries.



Understanding the 2011 Floods

Storm 1: April 25-27, 7.8 inches

A record storm dropped 7.8 inches of rain on Memphis in 3 days. At the same time, the Ohio River crested upstream in Louisville, KY.

Storm 2: May 1-2, 3.9 inches

Memphis saw almost 4 more inches of rain during this second storm. At the same time, the Mississippi River crested upstream on May 3 at Cape Giradeau, MO

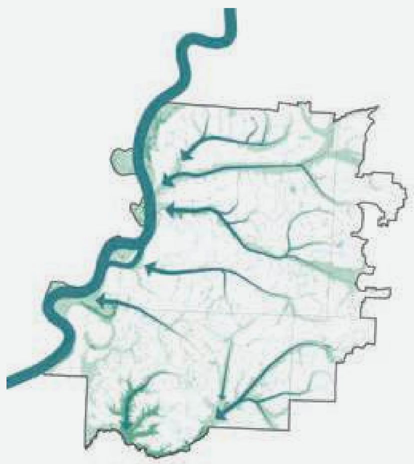
Flood Crest in Memphis: May 10, 2011

With all of this water from upstream converging on the already saturated Memphis, the Mississippi crested at 48.03′, the second greatest flood in Memphis' history.

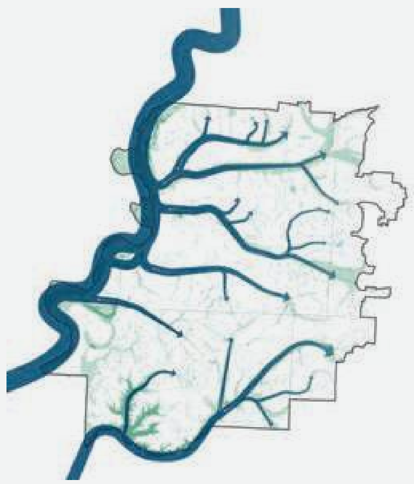
Riverine Flooding: Regional View

When the water level of the Mississippi River rises and exceeds the elevation of the outlets of the smaller tributaries, these tributaries are unable to drain, get backed up, over-top their streambanks, and flood adjacent areas.

For most of the Mid-South, the smaller tributaries are the main source of riverine flooding. The eastern banks of the Mississippi, including downtown Memphis, are protected by an elevated bluff.

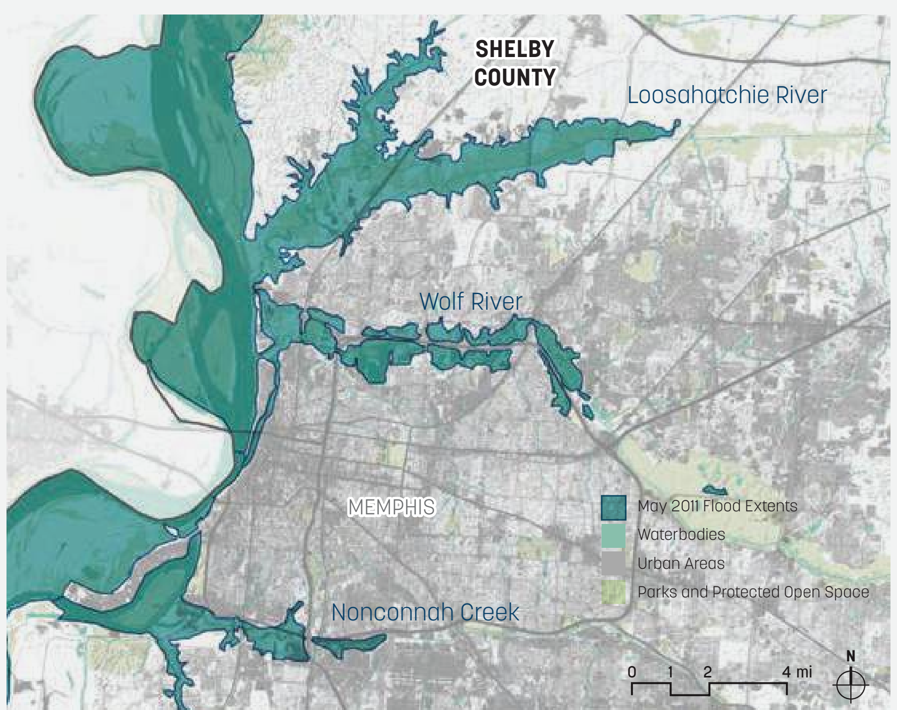


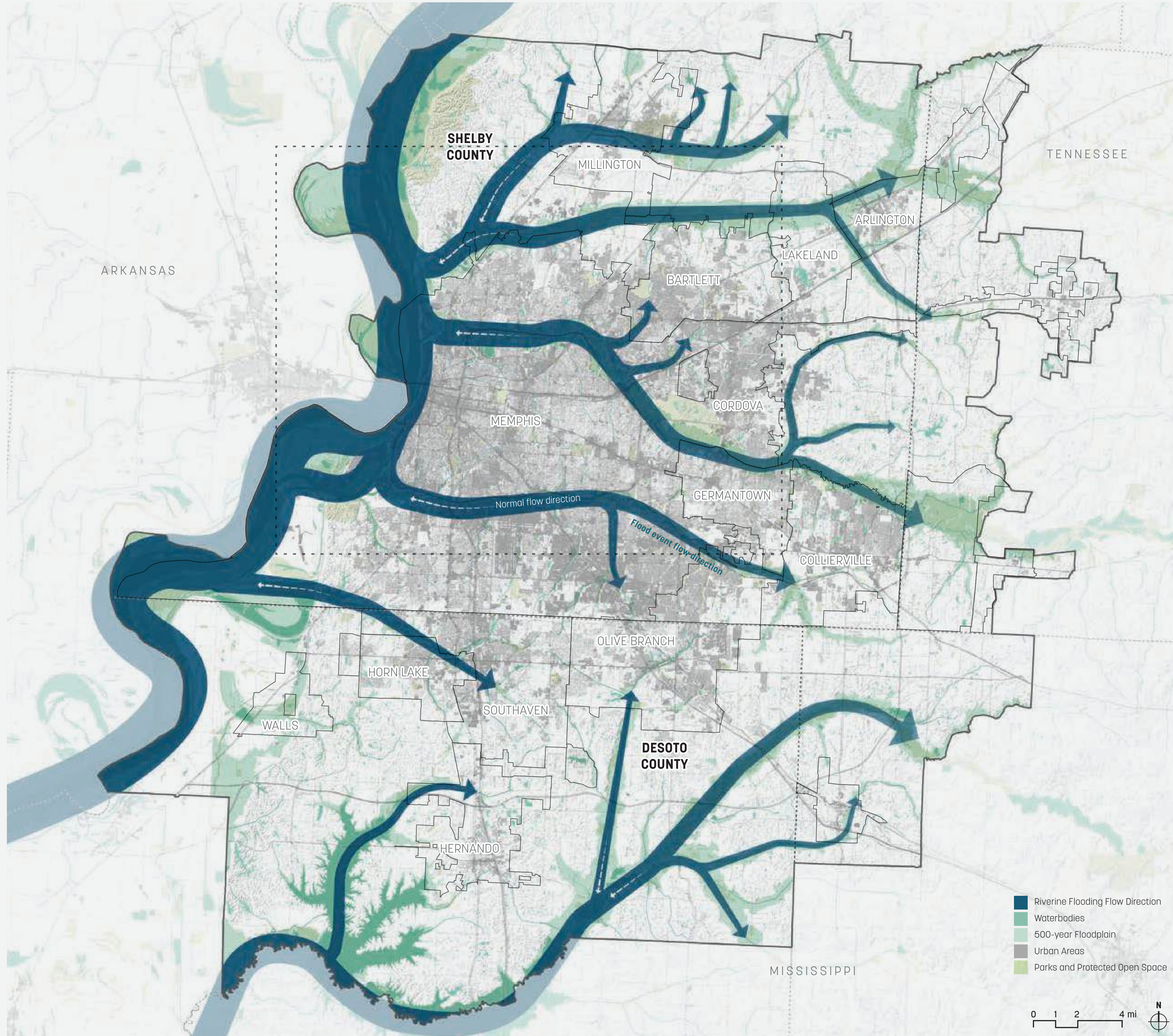
Normal River Flow



Riverine Flooding

May 2011 Mississippi Flood Extents





Frequency

Today, minor localized flooding is expected to occur more than 9 times per year in Shelby County.[15] Since the 1950s, the frequency of major flood events (over 34' flood crest) has increased. The first half of that period (1950-1985) shows 0.29 major flood events per year with a moderate increase in frequency over time. The second half of that period (1985-2019) shows 0.37 major flood events per year.[16] Moderate increases in precipitation in the Mid-South and in the Mississippi River watersheds (up to 10% increase in the amount of precipitation) could increase the frequency of major and minor flooding events in the future.

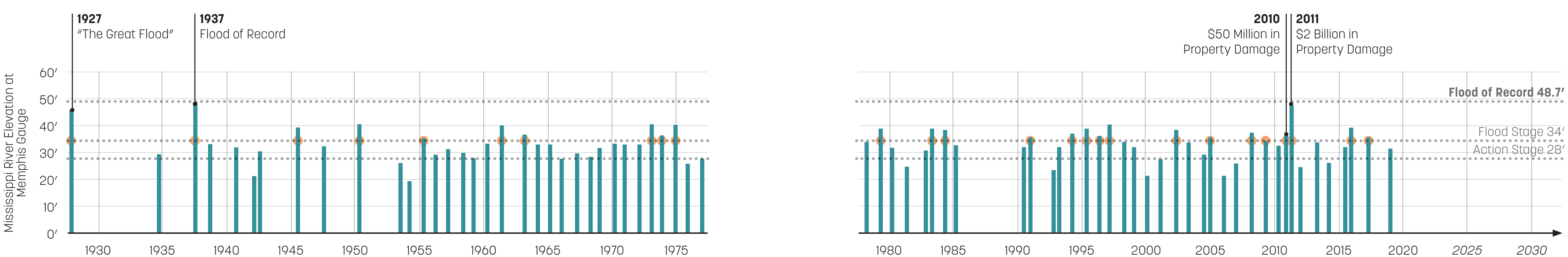
Typical Riverine Flooding Event

A flood in January, 2016 crested just below 40 feet. Most of the flooding occurred in agricultural areas and low-lying lands on the Mississippi River such as Mud Island.

Minor flooding was reported along Mississippi River tributaries. The Army Corps of Engineers deployed "Phase 1" flood fighting strategies, in which a few team members check levees and flood walls to ensure proper functionality.

Today, a typical riverine flooding event is cause for concern for property owners in low-lying areas and can be a nuisance for others who would attempt to pass flooded roadways in those areas.

Timeline of Riverine Flooding Near Memphis



Magnitude

Extreme precipitation events have increased in magnitude since 1950. The worst case scenario has been measured at 6 inches of rainfall per day, recently experienced in May 2010, or for water from the Mississippi River to rise above 45 feet, recently experienced in May 2011.[17] The change in magnitude of riverine flood events has not changed significantly over the past 50 years. However, from 2001 to 2011, over 4,700 acres of built space has expanded within the 500-year floodplain.[18] Close to 9,000 new single-family homes are currently located within the 500 year floodplain.[19] The expansion of buildings into the floodplain and adjacent areas puts more people and property at risk when higher magnitude flood events do occur.

Stream gauges measure river levels and record water levels over time (see timeline below for historic levels of the Mississippi at the Memphis gauge). There are five stages that characterize flood levels: Action Stage, Minor Flood Stage, Moderate Flood Stage, Major Flood Stage, and Record Flood Stage. The 'Action Stage' typically refers to water levels that are slightly above the top of the river banks, but no structures are flooded. Stages from 'Minor' to 'Record' refer to an increasing amount of flooding including more severe damage and threats to human safety.

Worst Case Riverine Flooding Event

The May 2011 floods were the second worst in Mid-South history. The Mississippi River crested at 48.03' in Memphis on May 10th. The crest was preceded by two major storms on April 25-27 and May 1-2, that collectively dropped 11.76 inches of water in Memphis (more than twice the April average). Cities upstream saw three to four times the average rainfall for April.

In the Mid-South, this storm caused more than $2 billion of property damage, flooded 198 homes, and caused more than 345,000 people to lose power.

Endnotes

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19 Shelby County and DeSoto County. Building footprints (Cartographic polygon shapefile). Using ArcMap.

Flash Flooding

Causes

1	**Increases in heavy rain events or snowmelt**
2	**Increases in impervious surfaces**
3	**Inadequate or non-functioning drainage systems**
4	**Failure of flood structures such as levees**

Relevant Recommendations

- 1.1 River and Stream Restoration
- 1.2 Flood Barriers
- 2.1 Large-Scale Water Detention
- 2.2 Watershed Conservation
- 2.3 Low Impact Development
- 2.4 Open Space Strategies
- 3.1 Floodproofing Buildings
- 3.3 Emergency Shelters
- 3.4 Roof Design
- 3.5 Green Building Retrofits
- 4.1 Resilient Sites
- 4.2 Smart Growth
- 4.3 Flood Smart Development
- 5.1 Critical Infrastructure Planning
- 5.2 Drainage Systems
- 5.5 Community Energy
- 6.1 Voluntary Buyouts
- 6.2 Debris Recycling
- 6.3 Temporary Housing
- 7.1 Resilience Database
- 7.2 Outreach
- 7.3 Vulnerable Communities
- 7.4 Economic Development
- 7.5 Capital Market Funding

Definition

Flash flooding is the result of excess precipitation that does not directly drain into the stormwater drainage system. The stormwater drainage system is comprised of man-made gray infrastructure such as roadside gutters, storm drains, pipes, and manholes, and man-made and naturally occurring green infrastructure such as swales, catch basins, ditches, lakes, ponds, creeks, and streams. The excess precipitation causes flooding when it hits impervious surfaces like asphalt and concrete and travels along that surface creating fast flows of water. Debris such as storm detritus and trash clogs stormwater drainage systems and exacerbates the issue by limiting the amount of water that can enter the system.

(Right) Photo of College Street and East Trigg Avenue in Memphis during Hurricane Harvey, August 2017.

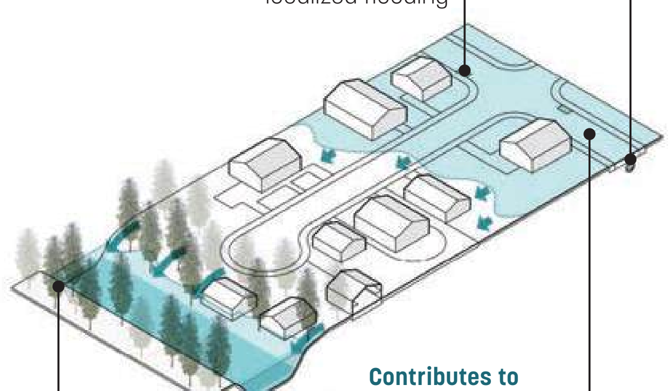
Major Causes

Flash flooding is caused in part by the same causes of riverine flooding, such as increased precipitation, failures of engineered barriers, and increases in impervious surface area. In addition, flash flooding can be caused by inadequate or non-functioning stormwater drainage capacity. This can include undersized infrastructure or clogs caused by fallen branches, sticks, and leaves that naturally occur or are the result of a storm, as well as trash that has been improperly discarded and made its way to the stormwater drainage system.

The existing drainage systems in the Mid-South vary widely across and within jurisdictions. The city of Memphis separated stormwater drainage systems from sanitary sewer systems by 1893 after several epidemics of yellow fever. Since then, design standards for drainage systems have been updated over time, most recently in 2006. The drainage systems themselves have been slowly upgraded but do not comprehensively reflect the latest design standards from 2006.[1] At the same time, the Mid-South has been developing outward and expanding the amount of impervious surface across almost all of the area's jurisdictions.

As of 2016, 19 of the drainage basins in Memphis have been studied for capacity, expected volume, and necessary upgrades and maintenance. A stormwater tax generates approximately $24 million of annual revenue that must be spent on drainage capital projects.[2] Over time, this revenue will help close the gap between existing capacity and current/projected volume.

(Above) Photo of Memphis stormwater street drain and debris.



Impacts

Health and Safety

One of the biggest impacts to health and safety posed by flash flooding is the risk of a person being swept away in fast moving water or of major debris being swept into fast moving water and colliding with a person. Since 1996, five people in the Mid-South region have died and six have been reported injured due to flash floods.[3]

During a flash flood, water depths of 6 inches may be enough to sweep away a person, water depths up to 12 inches may be enough to sweep away a car or sport utility vehicle, and water depths up to 18 inches can sweep away a larger vehicle.[4]

Flash flooding indirectly poses a threat to health and safety when evacuations result in disruptions to routines. Evacuations are stressful, and evacuees may not remember to bring or take necessary medication, causing an impact to their health and safety.

Property Damage

Property damage during flash floods is often limited to exterior items such as cars, lawn furniture, and landscaping and agricultural property. In the Mid-South, flash flooding causes damage to structures and interiors in only the most extreme scenarios (such as a car being swept into a building) or in the most low-lying areas (when a clogged street drain may cause backup to a building).

Infrastructure

Infrastructure can sustain damage during flash floods in a multitude of ways. During particularly swift-moving flash floods, earth under or along a roadway may be scoured, causing the road surface to fall. Flash flooding can also cause mudslides and sinkholes. These experiences can also threaten utility and transportation infrastructure.

Continuity of Operations

Road closures due to standing or moving water can impact the continuity of operations to varying degrees. When minor roads are closed, it is often reasonable for people to seek alternate routes. When major roads are closed, detours may be circuitous or impossible, halting "business as usual" until the water subsides. In many instances where flash flooding affects roads with commercial properties, those businesses must cease operations until the water subsides. Business owners may apply to the Small Business Administration for relief grants or loans, but workers are generally left to seek alternate sources of income or aid on their own.

Schools may close due to flash flooding, and this can be associated with road closures and lack of accessibility to some schools. This disrupts not only the school year, but often many working parents' work schedules as emergency childcare must be found.

(Right) Photo of Nesbit Road in DeSoto County following a mudslide caused by a flash flood.

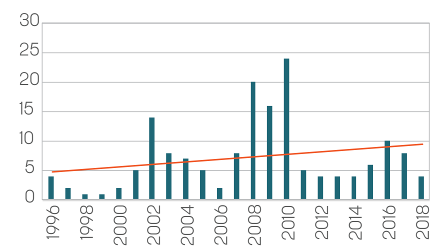
Frequency

The Storm Events Database, maintained by NOAA, has 148 documented flash flood events in Shelby County and DeSoto County since January 2007. This amounts to just over 12 flash floods per year. The database tracks storms with sufficient intensity to cause loss of life, injuries, significant property damage, or disruption to commerce. Over that time period, just over one flash flood per year had reported damage reaching or exceeding $100,000; most flash floods do not result in any recorded property damage.[5]

During that same time period, the National Weather Service recorded 204 flash flood advisories, watches, and warnings for the same area.[6]

Flash floods are increasing in frequency in the Mid-South. Since flash flood events started being routinely recorded in 1996, the average annual frequency has nearly doubled.

Flash Floods Per Year, 1996-2018

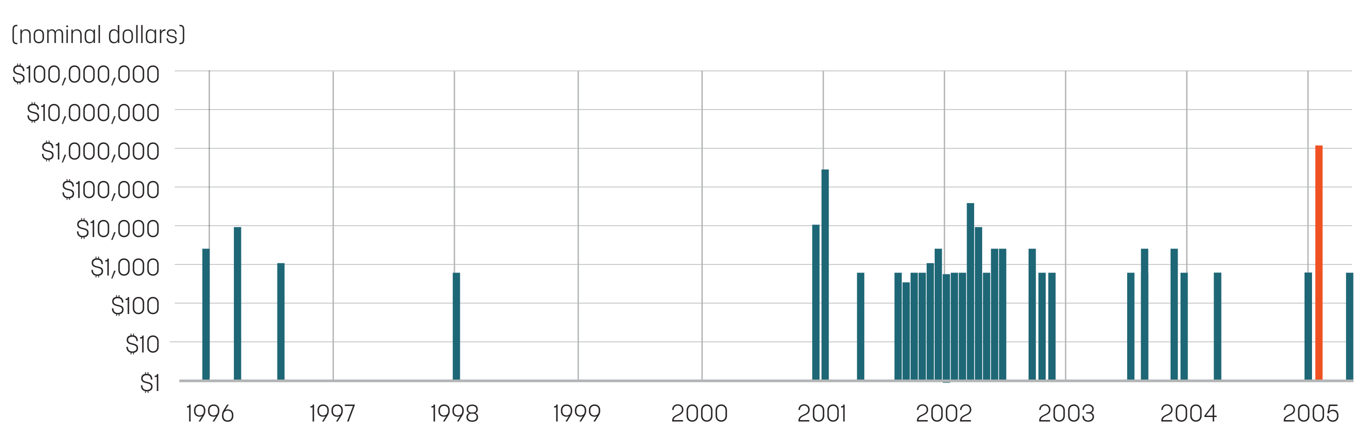


(Above) Flash flood events are increasing in frequency in the Mid-South since event recording started in 1996.

Typical Flash Flood

A typical flash flood would occur during a time when the water levels of the Mississippi River and its tributaries were at normal levels and most runoff entering the drainage system would be able to drain into the waterways. There would likely be a few minor road closures, closure of some open space water retention/detention areas, and nuisance flooding near building access points. Normal operations could generally function with limited modification or interruption.

Property Damage From Flash Floods, 1996 - 2017

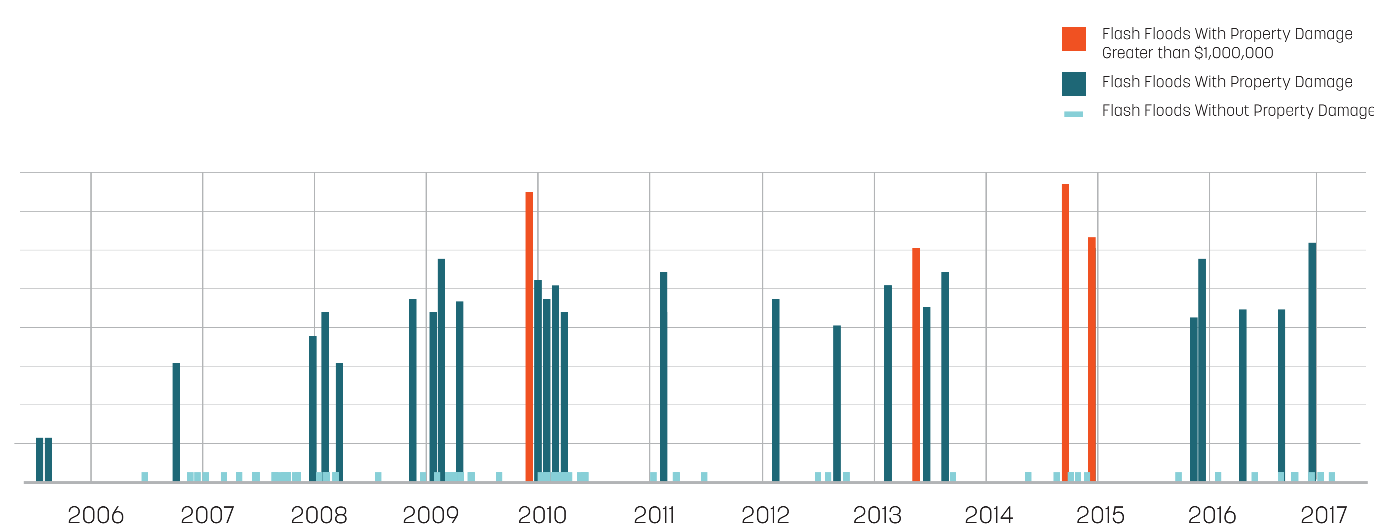


Magnitude

The magnitude of flash flooding events can vary widely based on current rainfall, recent precipitation levels, the water levels in the Mississippi River and its tributaries, and the amount of debris on the ground. Most flash flooding events in the Mid-South have minimal impacts: few, if any, health and safety impacts, reported property damage is less than $1,000 per event, and impacts to infrastructure and continuity of operations are very localized. Approximately 14 flash flood events since 2007 recorded property damages in excess of $100,000, and these events account for 99.5% of property damage ($86,450,000) due to flash flooding over that timeframe.[7]

Worst Case Flash Flood

A worst case flash flood event would be the result of a record-level precipitation event, where several inches of rain may fall in a 24 hour period (potentially exceeding the average total precipitation for the month). In this instance, roads and other transportation infrastructure may be closed or significantly damaged. Schools may be closed, residents may be evacuated from their homes, and ankle-deep or knee-deep water may encroach onto yards and sidewalks. Typically in the Mid-South flash floods encroach into structures only in the absolute worst case.



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Extreme Heat and Drought

Major Causes

1	**Meteorological conditions**
2	**Urban heat island effect**
3	**Greenhouse gas emissions**

Relevant Recommendations

- 2.2 Watershed Conservation
- 2.3 Low Impact Development
- 3.3 Emergency Shelters
- 3.4 Roof Design
- 3.5 Green Building Retrofits
- 4.2 Smart Growth
- 5.1 Critical Infrastructure Planning
- 5.3 Power Lines
- 5.4 Smart Grid
- 5.5 Community Energy
- 5.7 Trees
- 7.1 Resilience Database
- 7.2 Outreach
- 7.3 Vulnerable Communities
- 7.4 Economic Development

Definition

Extreme heat is defined in the 2016 Shelby County Hazard Mitigation Plan as temperatures that hover 10 degrees or more above the average high temperature for the region during the same time of year. Other indices measure extreme heat by the number of days where temperatures exceed 90 or 95 degrees Fahrenheit.[1] Excessive heat is the number one weather-related cause of death in the United States.[2]

Drought is defined as a deficiency of precipitation over an extended period of time. Drought does not typically cause significant harm to human health and wellness or to the environment, but it can have major implications for agriculture and power production.

(Right) Extreme heat and drought can affect the surrounding landscape across the Southeast. Source: Al Jazeera.

Major Causes

Urban Heat Island Effect

As described in the United States: Fourth National Climate Assessment, land cover changes impact local weather and climate by altering the flow of energy, water, and greenhouse gases.[3] In the Mid-South, recent development patterns are increasing impervious cover (which reflects heat into the air) and reducing pervious cover (which absorbs heat). Based on the U.S. Geological Survey's National Land Cover Dataset, there has been a 12.5% increase in developed land area in Tennessee and 10.7% in Mississippi between 2001 and 2011. The United States only saw a 5% increase in developed land area over the same period.[4] This increase in impervious cover absorbs more heat than pervious surfaces and reduces evapotransporation, creating a heating effect, also known as an "urban heat island." More detailed local information can be found on the following pages.

Greenhouse Gas Emissions

The average global temperature has increased by 1.5˚F since 1900 and is projected to rise 2˚F by 2100.[5] Average temperatures in the United States are projected to increase even more as a result of local human-induced greenhouse gas emissions. Specific temperature projections vary based on efforts to reduce greenhouse gas emissions, population change, and economic activity. Today, estimates indicate average temperatures will increase 4-8˚F by 2100 in the Southeastern US.[6] While the Mid-South can address greenhouse gas emissions locally, larger national and global trends will impact the climate in the Mid-South.

Among large nations, the United States has the highest per capita carbon dioxide emissions rate in the world, and carbon dioxide comprises 82% of U.S. greenhouse gas emissions.[7] Greenhouse gas emissions trap heat rising from the earth's surface, causing temperatures to rise and exacerbating the heat island effect. This also impacts precipitation patterns, causing both heavier downpours and more frequent or severe droughts.[8]

Meteorological Conditions

Meteorological conditions contribute to drought events. The same type of atmospheric conditions that lead to extreme heat also contribute to drought, causing high demand for water at a time when water is in relatively short supply. Meteorological conditions are the result of naturally-occurring and human-induced activities.[9]

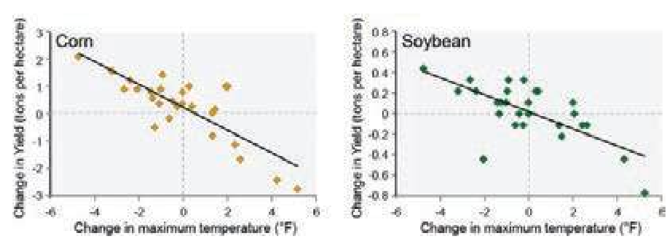
Impacts

Business Operations

Most business operations affected by extreme heat conditions are related to agriculture. While the cotton and soybean growing seasons will become longer, the corn and soybean yields plummet when temperatures increase above 84˚F.[10] There is a projected 10% loss in crop yields in Tennessee over the next 50 years. [11]

Extreme heat and drought affect livestock as well. There is increasingly high demand for hay in the winter as pastures are negatively affected, increasing feed costs to farmers. Additionally, cattle can struggle to find adequate water due to low river and lake levels, and can suffer from heat stress similar to humans.[12]

Crop Yields Decline Under Rising Temperatures[21]

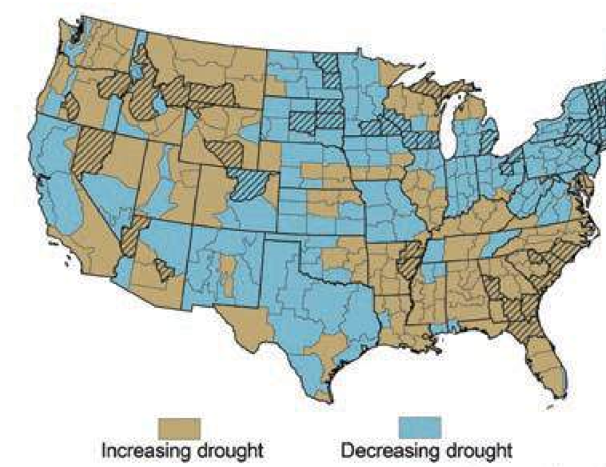


Additionally, other labor-intensive tasks that take place outdoors are also at risk during periods of extreme heat. Due to regulations and natural human systems, employee productivity declines sharply when temperatures exceed 84˚F.[13]

Risks to Human Health

Extreme heat can pose risks to human health and wellness. Heatstroke occurs when body temperatures reach or exceed 105˚F and can be dangerous. About 15% of heatstroke diagnoses in the United States prove fatal. Since 2012, there have been 12 fatalities explicitly attributed to excessive heat,[14] but heat is typically underreported as a cause of death. More often, cause of death is attributed to respiratory disease (which is triggered by the heat).Extreme heat also causes heat exhaustion, which is much less severe and can typically be treated with hydration and electrolyte re-balancing.

Observed Drought Trends 1958-2007[22]



Financial Burden

Memphis has the highest energy burden (percentage of household income spent on energy costs) among all cities in the United States.[15] This is partially due to the relatively low area median income of the region, and partially due to the number of heating and cooling days in the Mid-South. Increasing occurrences of extreme heat will increase the number of cooling days, and increase the overall energy costs to businesses and households.

Transportation Disruptions

An extreme weather vulnerability assessment was completed for transportation assets in the State of Tennessee in 2015. Shelby County was one of two counties with the highest category of average annual extreme weather events in the state. Droughts are expected to impact navigable waterways, including the Mississippi River, ports, roads, bridges, and pipelines. Extreme heat is expected to significantly impact railroads, rail yards, airport runways, locks, bridges, and pipelines.[16]

There are several weather event thresholds that impact the ground transportation network. These include the necessary slowing of trains once temperatures reach 90˚F (Memphis is expected to experience 72 days above 95˚F by 2065); road asphalt softens at 100˚F if there is no sufficient cooling at night (Memphis is expected to experience 23 days above 100˚F by 2065); and train tracks buckle at 110˚F.[17] In addition, airplanes have maximum operating temperatures from 118˚F for smaller regional jets to 127˚F for larger jets. Since 2010, Hernando has had maximum temperatures of up to 107.1˚F. In the future, the Mid-South's climate is expected to feel more like Nevada feels today.[18]

Energy

Coal power plants, nuclear power plants, and hydroelectric power plants all rely on access to significant quantities of cold water in order to produce power. During extended periods of extreme heat or drought, the cold water supply diminishes causing power production to decrease, often as demand for energy for cooling purposes increases. Drought conditions in the Mid-South are expected to decrease in frequency in the future, limiting the risk that local power plants will see a decrease in production.[19] However, the Tennessee Valley Authority (TVA), which controls power production for Shelby County and parts of Fayette, Marshall, and DeSoto Counties, relies on a broad network of coal, nuclear, and hydroelectric power plants in areas of the country with increasing drought conditions to supply power.[20] Because of this, power security in the Mid-South may be challenged due to broader dynamics beyond the boundary of the region.

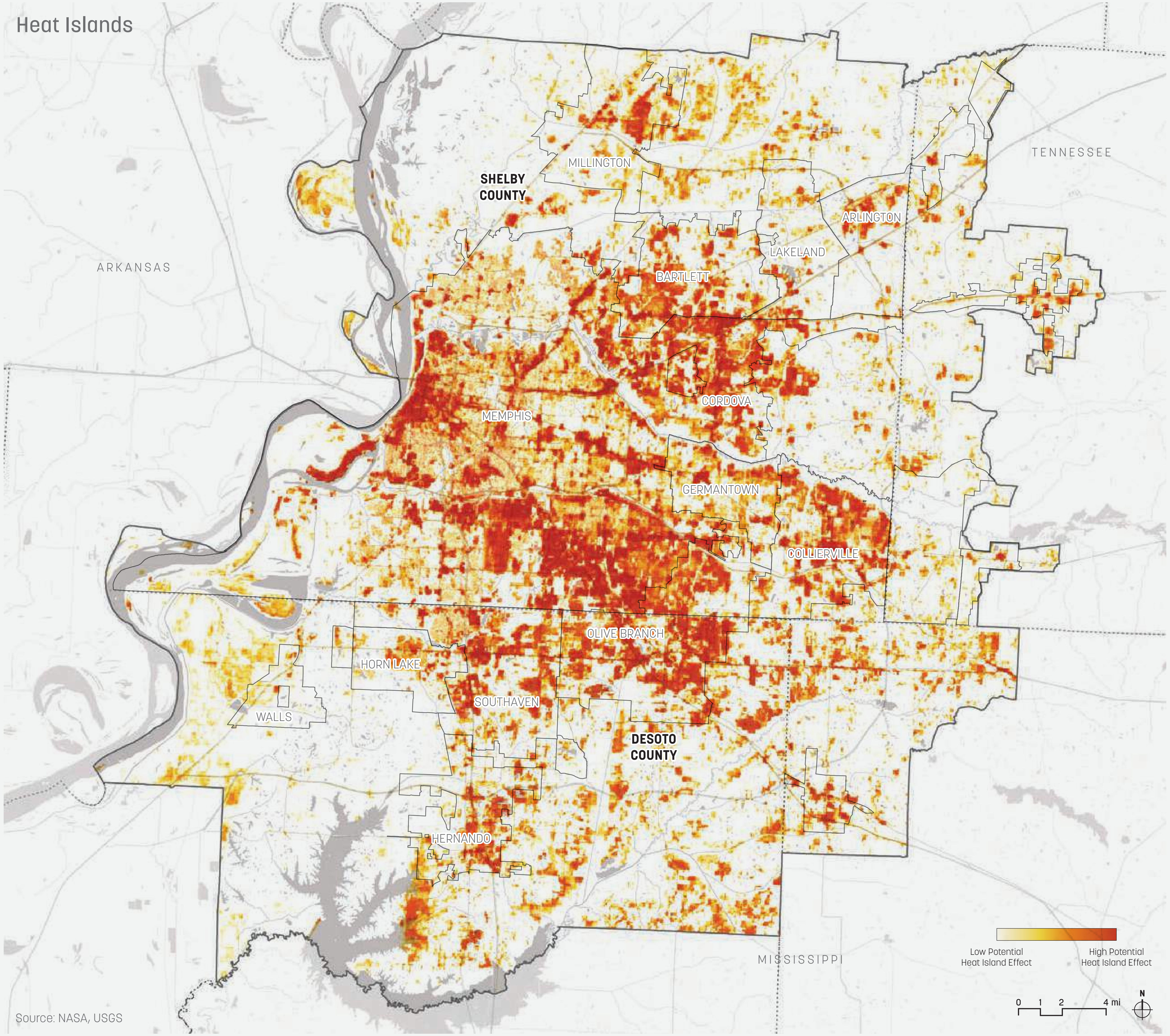
Impervious Cover

Impervious cover, especially in areas that lack tree canopies, can create a "heat island" effect. According to the United States Environmental Protection Agency, a heat island is a measurable increase in temperature in an area with impervious cover (such as an urbanized area) as compared with an adjacent area with pervious cover (such as a rural area).[23]

In Memphis, it can be up to 16˚F hotter compared to nearby rural areas; on average, summers are 3.4˚F hotter in the city. The heat island effect means that Memphis experiences 21 more days above 90˚F than rural parts of the region.[24]

Though heat islands are very local changes in temperature, the same temperature impacts of extreme heat still apply, including risks to health and wellness and high demand for electricity for air conditioning.

Heat Islands



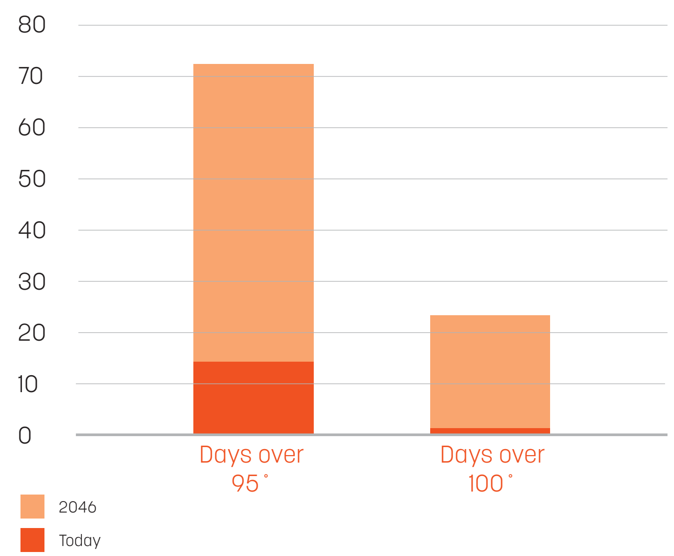
Source: NASA, USGS

Frequency

Over the past 70 years, the frequency of extreme heat has increased. This trend is expected to continue. Today, there are currently 15 days per year on average where temperatures reach or exceed 95˚F.[25] In Memphis, the highest average high temperatures are usually in the month of July. In Hernando, both July and August share the highest average high temperature.[26]

Drought events are expected to decrease in frequency and severity in the region. This is largely due to expected increases in precipitation for watersheds upstream of the Mid-South along the Mississippi River all the way to Minnesota.

Future Number of Hot Days



Magnitude

The magnitude of extreme heat events has also increased and is projected to continue increasing over time. More days of the year are reaching ever-higher temperatures. Today, the temperature can reach thresholds that soften road asphalt or necessitate slowing of trains, both of which are relatively temporary conditions that are mitigated once the temperatures cool. However, if temperatures continue to climb, it is possible that daily high temperatures will reach a threshold that exceeds the maximum operating temperatures for planes, especially due to the heat island effects exhibited at the Memphis International Airport.

Worst Case Scenario Heat Event

A heat wave in July would be considered an extreme heat event in the Mid-South. During this time, daily mean temperatures could reach several degrees above the average daily mean temperature or unusual humidity could create a spike in the heat index even as temperatures hover around average.

In 1980, a 26-day heatwave in Memphis in July saw daily mean temperatures 7˚F above average, though the overall number of days above 95˚F was fairly typical that year.[29] During the heatwave, 83 heat-related deaths were recorded (as compared with none the previous July), and there was a statistically significant increase in mortality rates, mostly in people over 60 years of age (heat can trigger other health and respiratory issues which are officially listed as the cause of death).[30]

Today, a typical heat event results in public announcement warnings and opening of cooling shelters.

(Above) A man waits for the bus in Detroit during the 1980 heatwave.

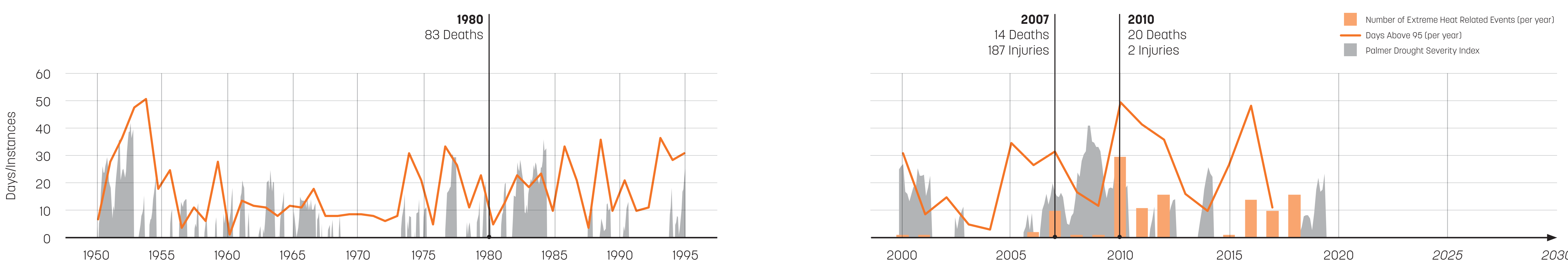
Worst Case Scenario Drought Event

The worst drought in Tennessee occurred during the summer of 2007.[27] The drought was so severe, all counties in the state were declared natural disaster areas by the U.S. Department of Agriculture. The drought caused significant issues with grazing grasses. In Fayette County, the drought monitor level was 4, the most severe classification.

The region experienced significant crop losses, including grazing pastures, and water shortages in reservoirs and wells. Because of the water shortage and the loss of grazing grasses, many cattle producers reduced their herd size, which impacts calf production in subsequent years.[28]

(Above) A 3-inch squash on the Howell Farm in Nashville would be standard size and ready to harvest but for the drought.

Historic Timeline of Heat- and Drought-related Events



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Earthquakes

Causes

1 Shifting tectonic plates

Relevant Recommendations

- 3.2 Earthquake Resilient Buildings
- 3.3 Emergency Shelters
- 3.5 Green Building Retrofits
- 4.1 Resilient Sites
- 5.1 Critical Infrastructure Planning
- 5.5 Community Energy
- 6.2 Debris Recycling
- 6.3 Temporary Housing
- 7.1 Resilience Database
- 7.2 Outreach
- 7.3 Vulnerable Communities
- 7.4 Economic Development
- 7.5 Capital Market Funding

Definition

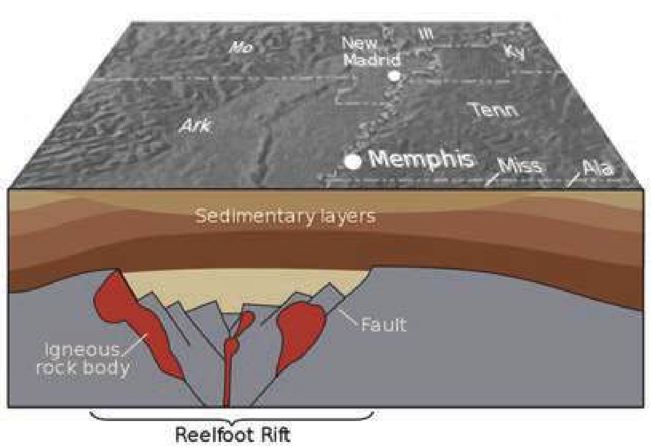
Earthquakes are a sudden and violent shaking of the ground as a result of movements within the earth's crust or volcanic action. The threat from earthquakes is largely based on the destruction of buildings and infrastructure that is caused by shocks and unstable soils that "liquefy" in the event of an earthquake.

(Right) Photo of the aftermath of an M7.5 earthquake in Palu, Indonesia. This is the same magnitude as the New Madrid earthquakes of 1811-12.

Causes

The New Madrid Seismic Zone is one of three in the central US known to cause earthquakes, and the most direct cause of earthquakes in the Mid-South. The New Madrid fault is 120 miles long, and sits at the intersection of Tennessee, Arkansas, Missouri, and Kentucky.

In general, causes of earthquakes are somewhat unknown. The most prevalent and widely-accepted understanding is that geologically old fault systems below the surface of the earth are reactivated during stress. The Mid-South is located on the interior of the North American plate, away from the plate boundaries. The best available understanding is that the stress in the Mid-South is caused by the continuous shifting of tectonic plates, inducing them to slide over and under each other. This shifting transfers through the layers of soil and sediment and is the source of the movement felt on the surface.



(Above) Diagram of the Reelfoot Rift in the New Madrid Seismic Zone. This was the origin of the 1811-12 earthquakes.

Impacts

Health and Safety

Since 1973, the magnitude of earthquakes in the Mid-South has been relatively low, not severe enough to negatively impact health and safety absent unique circumstances. However, the region experienced major earthquakes in 1811-12. If a similar sequence of earthquakes were to occur today, the affected area (extending beyond the boundaries of the Mid-South region) would experience 85,000 casualties, including 3,500 fatalities and 17,000 injuries severe enough for hospitalization.[1]

Property Damage

The earthquakes experienced in the Mid-South in the last several decades caused only minor property damage. Typically, the earthquakes are only detected by sensitive machines and are not felt by people. During the more intense earthquakes in recent history, the most significant damage reported includes cracked walls in single family structures and falling wall hangings.

In the worst case scenario, an earthquake similar in magnitude to the 1811-12 events could cause serious damage over large areas. Most residential properties would suffer at least slight damage, while many would suffer extensive damage. It is estimated that over 45,000 persons may need to seek temporary shelter in Shelby County.[2] Most commercial and industrial properties would suffer extensive or complete damage.[3]

Continuity of Operations

In the aftermath of the minor earthquakes that the Mid-South has experienced over the last two centuries, there have been very limited disruptions to normal operations.

In the event of a major earthquake with magnitudes exceeding 7.0, the projections for operations disruptions are significant. It is estimated that only 4.36% of hospital beds would be functional, that only 0.18% of police stations would be functional, and that only 0.29% of fire stations would be functional in the affected area. Communications sites would be 45.45% functional, and schools would be 0.12% functional.[4]

(Above) New Zealand residents approach an impassable roadway following a 7.5 magnitude earthquake in the region. This earthquake also caused landslides and soil liquefaction.

While it is unlikely that any schools would remain open in the event of a major disaster, the low rate of post-earthquake operational capacity means that schools would also not be available for emergency gathering or shelter space.

It is estimated that there would be significant economic losses due to damage to buildings, direct business interruption losses, and transportation and utility system damages. Direct economic losses due to building damages (not including business interruptions) would exceed $100 billion if the earthquakes of 1811-12 happened today.[5]

While it is forecasted that insurance payments would cover 60-80% of total economic losses, it may prove infeasible for most businesses to rebuild in the Mid-South due to the lack of supporting services or infrastructure.[6]

Infrastructure

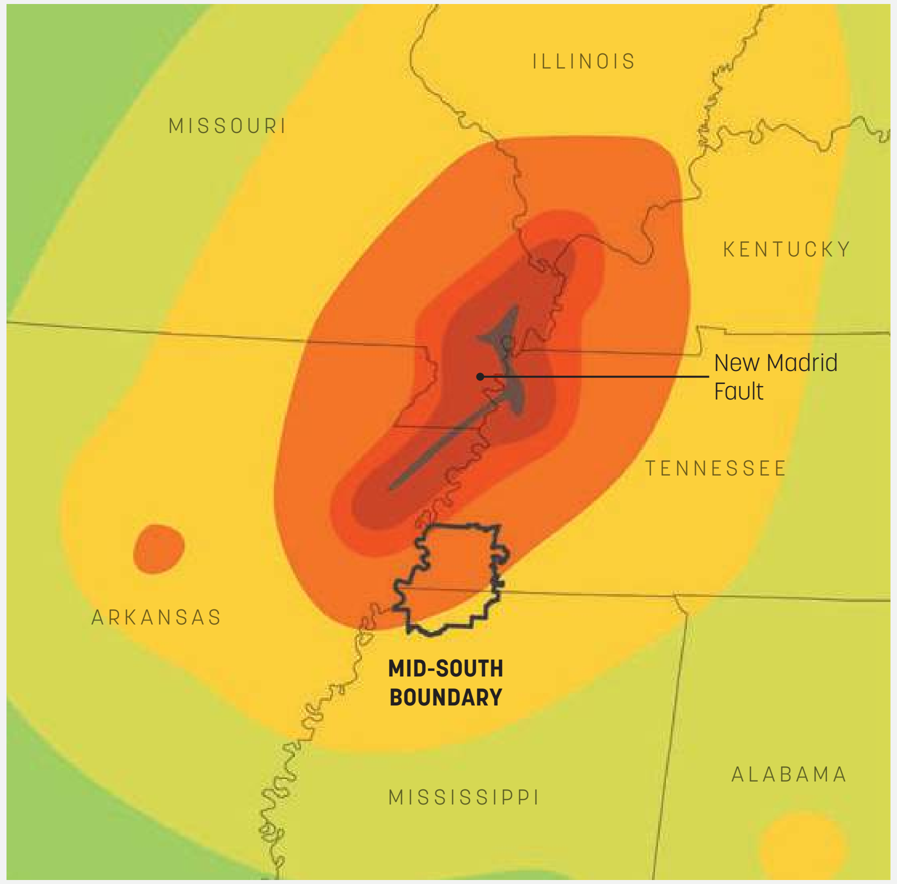
Significant damage to transportation infrastructure would be expected in the event of a major earthquake. It is estimated that 54.76% of bridges in the Mid-South would have extensive or complete damage.[7]

There would also be significant damage to the electrical grid that would affect consumers far beyond the Mid-South region. A major earthquake would create a blackout of the Eastern Connection, which is one of North America's two AC power grids. In more remote regions such as the Northeast, the power disruption might last a week, but in the Mid-South, it could last for months or longer.[8] It is estimated that after a major earthquake, approximately only 15% of residents in Shelby County would have power. Similarly, waste and potable water service would be disrupted; it is estimated that after a major earthquake only 5.51% of households in Shelby County would have potable water service.[9]

Finally, debris removal would be a significant task in the event of a major earthquake. It is estimated that over 50 million tons of debris would be generated.

Soil Liquefaction Very High Risk Zones

During ground stress situations such as during an earthquake, soils that are ordinarily solid can lose strength and stiffness and behave like liquid. Soils that are saturated are more susceptible to this phenomenon. Soil liquefaction can cause serious damage to buildings and infrastructure sited on those soils. Very high and high risk liquefaction zones are often adjacent to water bodies and overlap with floodplains. See the map to the right for an illustration of high risk liquefaction zones.



Peak Ground Acceleration Seismic Map

(10% in 50 years exceedance)

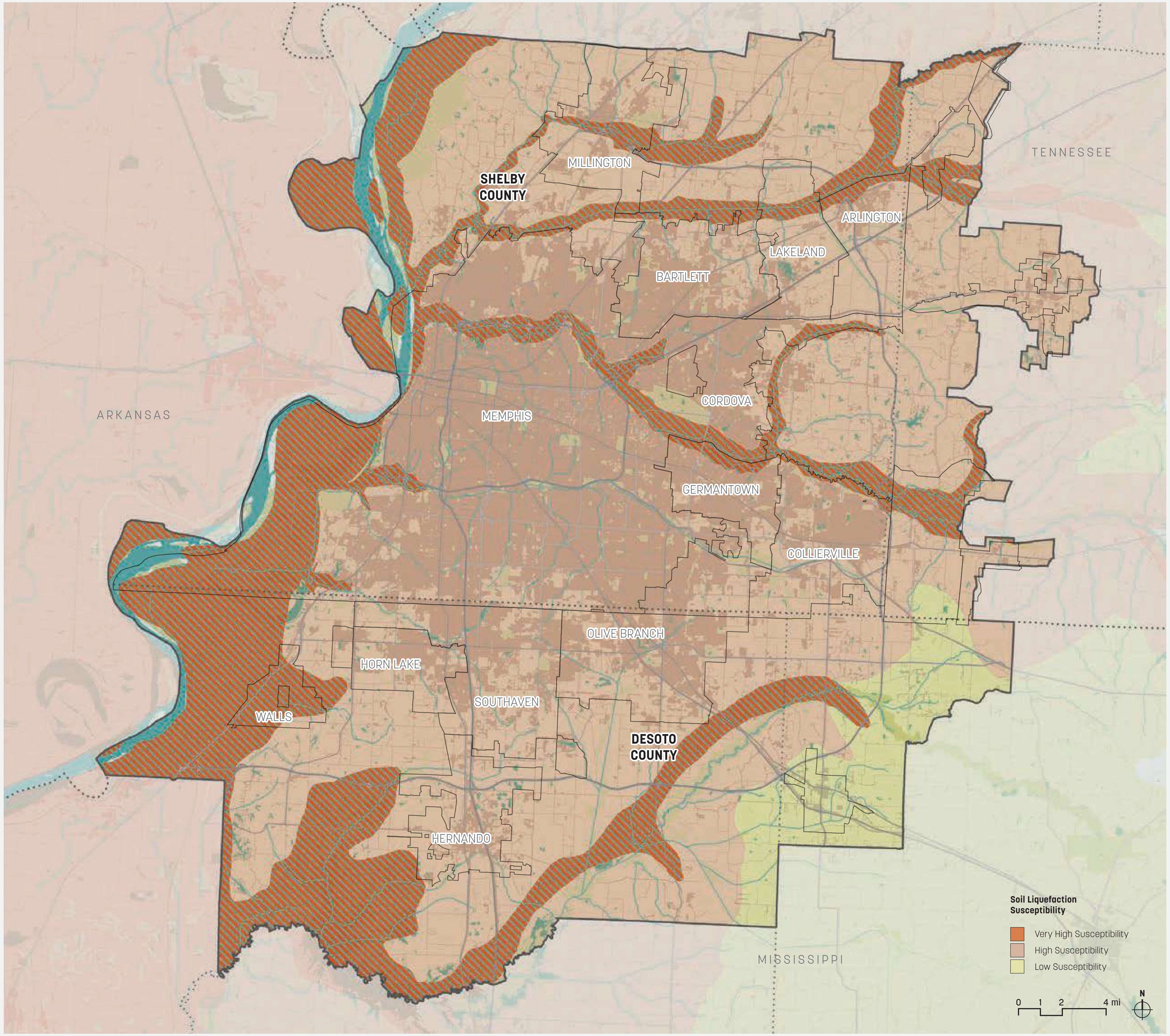
The U.S. Geological Survey (USGS) quantifies earthquake risk in the Mid-South Region based on distance from the New Madrid Fault. The concentric shapes represent peak ground acceleration (PGA) zones. PGA is the maximum ground acceleration that occurs during an earthquake - a measure of how hard the earth shakes at a given point.

PGA zones dissipate radially away from the fault. Most of the region lies within a "severe" zone, while the northwest corner has a "violent" designation and the southeast part of the region has a "very strong" designation from the USGS.

Peak Acceleration as Fraction of Standard Gravity (g)

- 0.4 (Extreme)
- 0.3 (Violent)
- 0.2 (Severe)
- 0.15 (Very Strong)
- 0.1 (Strong)
- 0.05 (Moderate)

Source: USGS



Seismic Hazard in the New Madrid Seismic Zone[10,11]

In 2012, Risk Management Solutions synthesized four alternative methods for quantifying seismic hazard. They are as follows:

Ground Motion Attenuation

Seismic hazard can be quantified based on the intensity of the ground shaking during a seismic event. The intensity of shaking decreases as you move further away from the source of the earthquake, so the seismic hazard also decreases as you move further away from the source of the earthquake.[12]

The quantified hazard is measured by a mathematical relationship between the distance from the earthquake source and the intensity of the shaking. Because there have been no major recent earthquakes in the New Madrid Seismic Zone (NMSZ), there is no reliable information about the intensity of the shaking during an earthquake at various points in the region. Thus, the mathematical relationships cannot be precisely quantified. Estimates about the intensity of shaking are drawn from earthquakes in other regions that are considered to be geologically and somewhat seismically similar to the NMSZ. This method was used in the production of the U.S. Geological Survey National Seismic Hazard Maps.

Using this analysis method, researchers suggest a 28-46% likelihood of a M6.0 or greater earthquake in the NMSZ, the highest chance for seismic activity of the four methods.

Earthquake Magnitude

Seismic hazard can be quantified based on the potential magnitude of the earthquakes produced from a particular fault. If a fault produces (or is capable of producing) earthquakes of higher magnitude, the regional risk is higher than if a fault produces earthquakes of a lower magnitude.

Earthquake magnitudes are now typically recorded by seismometers. Historically, earthquake magnitudes were estimated based on damage reports following an earthquake. After the 1811-1812 earthquakes in the NMSZ, the magnitude has been estimated to be between M6.6 and M8.1 based on damage reports.

Similar to the ground motion attenuation method, the earthquake magnitude method relies on seismometer readings from other large seismic events around the world. This is due to the lack of recent major earthquakes in the NMSZ.

Earthquake Recurrence Rate

Seismic hazard can be estimated based on how frequently earthquakes have occurred in a region over the course of history. Intense seismic activity causes ground failures (soil liquefaction). Geological studies have revealed sedimentary evidence of intense seismic activity in the NMSZ in 300 A.D., 900 A.D., 1450 A.D., and 1811 A.D., indicating that the region experiences a major earthquake approximately every 500 years. Other studies have shown evidence of large earthquakes over the last 10,000 years. Cumulatively, this indicates to researchers that the 1811-1812 earthquakes were not isolated incidents, and that it is likely the fault remains active.

However, researchers applying this method believe that seismic hazard in the NMSZ is declining. Earthquakes happen when tectonic strain is released through faults in the Earth's tectonic plates.[13] The seismic events in the NMSZ are thought by some to be caused by deglaciation, and the rate of earthquakes of the magnitudes seen cannot be sustained.[14] Recent regional measurements of strain in the earth's crust do not show that strain has been accumulating. This lead researchers using this method to conclude that the average time between earthquakes is either much longer than the 500 years implied by the geological studies.

Using this analysis method, researchers suggest that the fault is no longer active, the lowest chance for seismic activity in the NMSZ of the four methods.

Location and Geometry of Sources

Seismic hazard estimation often relies on knowledge of the location, size, and shape of a subsurface fault. Currently, the only geologic evidence of a subsurface fault in the NMSZ has been found beneath the fault ruptures of the 1811-1812 earthquakes. In addition, significant seismic activity can shift the tension and stress from one fault to another. Research that relies on the location and geometry of subsurface faults is only as accurate as the knowledge of the location and geometry of subsurface faults.

In the NMSZ, the Mississippi River would obscure subsurface faults. If faults were to exist below the riverbed, their risk would not be accounted for by researchers who rely on fault location and geometry to quantify seismic hazard in the region. Previous evidence of seismic activity does not indicate the location of the original active fault(s). Recent studies indicate that there are additional young faults within the region.

Frequency

Respected seismologists have been studying the New Madrid Seismic Zone for a long time. The magnitude of the 1811-12 earthquakes has been a source of interest for many in the field. Different research groups have projected different estimates for the frequency and magnitude of future earthquakes based on different methods for quantifying seismic hazard. On the low end, scientists analyzing the crustal strain in the region present evidence that there is a present-day end to seismic activity in the Mid-South. On the high end, other scientists believe that there is a 28-46% chance of an earthquake with a magnitude of 6.0 or higher occurring in the Mid-South in the next 50 years.[15]

Seismic activity of much lower magnitudes has been well documented in the Mid-South for decades. Lower magnitude earthquakes, generally less severe than 3.0 on the Richter scale, occur several times a year.[16]

Typical Earthquake

Typical earthquake events in the Mid-South rarely exceed magnitudes of 4.0. In 2015, an earthquake with a magnitude of 3.6 emanated from the New Madrid fault north of the Mid-South region. The ground movement was felt as far north as Illinois and as far south as DeSoto County. While the ground movement was felt by many, no injuries or damage was reported.

Magnitude

The magnitude of future earthquakes in the Mid-South is hard to predict based on the presently conflicting research. One of two future scenarios is probable.

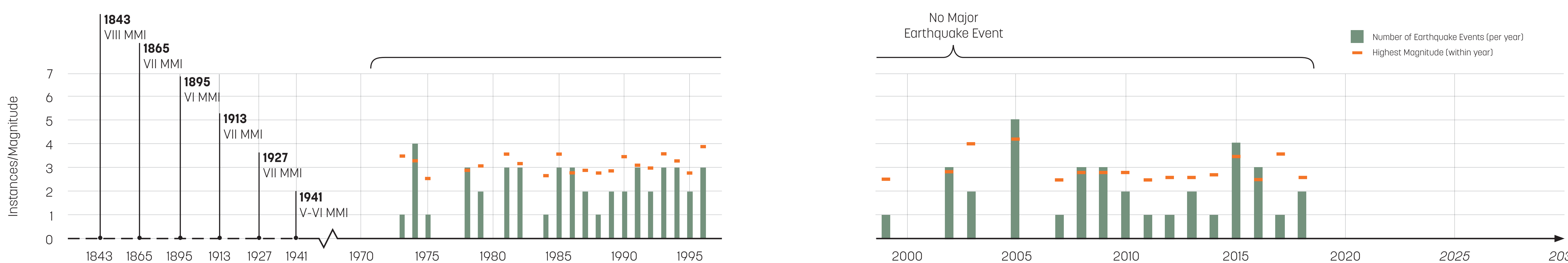
In the first scenario, earthquakes continue to occur frequently, but with magnitudes that range from 2.5 to over 4.0. Earthquakes with magnitudes of 2.5 are not felt except in rare circumstances. Earthquakes with magnitudes between 3.0 and 4.0 are generally only felt by people at rest on the upper floors of buildings. Earthquakes with magnitudes between 4.0 and 5.0 can be strong enough to be felt by everyone, and some fragile objects might be broken and some unstable objects might be overturned. Standing cars may noticeably rock.[18]

In the second scenario, the New Madrid Fault "reawakens" as an active seismic zone and the Mid-South begins to experience modern day moderate to major earthquakes, with magnitudes of at least 6.0. Earthquakes with magnitudes between 6.0 and 7.0 can see considerable damage in buildings that are poorly built or badly designed, and on the higher end, may see considerable damage in specially designed structures. Buildings can even shift off their foundations or partially collapse. For earthquakes greater than 7.0 in magnitude, few structures will remain standing, and bridges and railroads can be destroyed or badly damaged.[19]

Worst Case Earthquake Event

The worst earthquake in the Mid-South region was the sequence of three earthquakes between December 1811 and February 1812, with magnitudes between 7.3 and 7.5. Eyewitness reports state that sections of the Mississippi Riverbed were so elevated that the river began to run backwards for hours. Trees were upheaved from the ground, and geysers erupted in the Mid-South. Due to the small population of the region at the time, few fatalities were recorded and no official accounts of damage were tallied. Eyewitness accounts from Cincinnati, Ohio and Charleston, South Carolina report that the seismic activity caused chimneys in those cities to collapse and church bells to ring. Since 1812, the Mid-South has become intensely developed. A future earthquake or series of earthquakes of this magnitude would devastate the region.[20]

Historic Timeline of Earthquakes[17]



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Winter Weather

Causes

1 **Freezing temperatures**

2 **Winter precipitation**

Relevant Recommendations

- 3.3 Emergency Shelters
- 3.5 Green Building Retrofits
- 5.1 Critical Infrastructure Planning
- 5.5 Community Energy
- 5.6 Snow and Ice
- 6.2 Debris Recycling
- 6.3 Temporary Housing
- 7.1 Resilience Database
- 7.2 Outreach
- 7.3 Vulnerable Communities
- 7.4 Economic Development
- 7.5 Capital Market Funding

Definition

Winter weather is defined as blizzards, extreme cold, wind chill, frost, heavy snow, ice storms, and general winter storms, which may occur once temperatures are below freezing. While the Mid-South experiences fewer annual winter weather events than other regions in the United States, the impacts of these events can be felt acutely in the region. Individuals and municipalities often find themselves ill-equipped to manage snow and ice removal if accumulation levels require the use of snowplows, of which there are few in the region. These challenges are somewhat mitigated by the relative infrequency of winter weather events. Based on regional climate projections, winter weather events are expected to decline in frequency in the Mid-South.

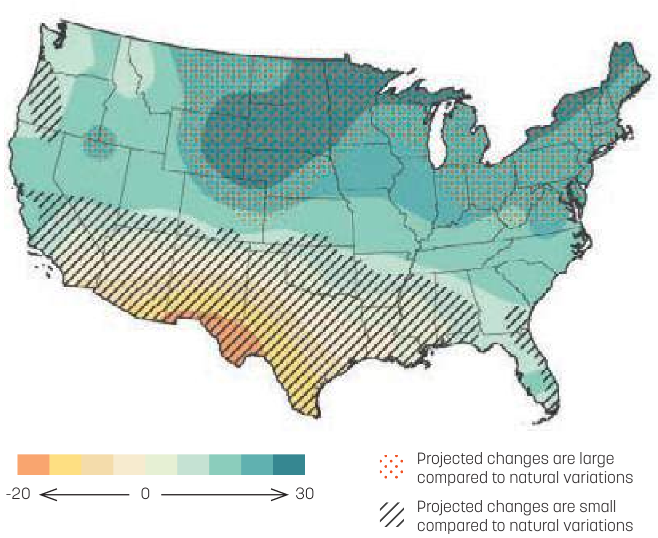
(Right) Winter weather conditions in Shelby County can impact major transportation infrastructure.

(Left) Memphis' homeless population struggle to find shelter during winter weather.

Causes

Cold weather in the Mid-South is part of the regular changing of seasons. Winter weather events that include snow or ice accumulations are caused by precipitation during cold weather months on days when temperatures reach or approach freezing. As global climate patterns evolve, documented increases in precipitation are causing increases in the number of snowfalls and the magnitude of snowfalls.[1] Over time, as average daily temperatures increase, this precipitation will manifest as rain and there will likely be fewer, less severe winter weather events.

Projected changes in winter precipitation during the 21st century (%)[6]



Impacts

Health and Safety

In the last five years, three deaths and one injury have been attributed to hypothermia in the Mid-South region.[2] Extreme cold is a serious threat to the homeless. During a 2017 Point In Time count of individuals experiencing homelessness in Memphis and Shelby County, 1,426 individuals were counted, including 79 who were unsheltered.[3] They are at significant risk of death or injury due to cold weather.

Snow and ice also pose a risk to residents of the region. In the last five years, there have been three deaths and two injuries from car accidents caused by winter weather.[4]

Property Damage

There is typically very little reported property damage associated with a winter weather event. An individual storm may cause damage to agricultural crops if an unseasonable storm affects the region during the growing season. Otherwise, property damage is typically limited to indirect property damage from motor vehicle accidents caused by poor road conditions.

(Left) Winter weather lead to motor vehicle accidents across the state of Tennessee in 2018.

Infrastructure

Two of the biggest areas of impact from winter weather are related to infrastructure. Many components of the transportation network are at risk during winter weather events. Roads, railways, and runways all become slippery with ice and snow accumulation, creating an accident risk for motor vehicles, trains, and planes. Frequently, there are temporary road closures due to snow and ice. The City of Memphis and Shelby County typically rely on surface treatments to prevent accumulation. This approach has declining marginal utility as precipitation accumulation increases beyond one-half inch to one inch.

The second threat to infrastructure due to winter weather is from the cold itself: some utility companies were unable to keep up with gas service supply during times of peak demand. Though this issue was sufficiently addressed in the 1990s, as the Mid-South population expands, it may become an issue in the future.

Gas heating demand can also be a problem for the region. A survey of 50 peer cities with similar geographies and utility company sizes revealed that Memphians enjoy a position in the top five for the lowest winter utility bills. In spite of that, the average winter energy bill for MLGW customers is $260.54, which can be a burden for many residents.[5]

Continuity of Operations

Winter weather can inhibit continuity of operations as schools, public buildings, and businesses close. These closures are largely safety measures put in place to reduce the number of vehicles on the roadways. In addition to this, many residents elect to stay home and inside during winter weather events. This can hinder daily life for the duration of the event (typically no more than a few days at a time).

Frequency

Today, the northern part of the Mid-South region experiences approximately 73 days per year when the temperatures go below freezing. By mid-century, this number will decline to an estimated 66 days per year, and by the end of the century, this number will halve to 36 days per year. These numbers are slightly lower for the southern part of the region.[7]

Even as temperatures in the region get warmer, which reduces the winter weather hazard over the long-term, increases in precipitation are posing challenges in the near-term. The average snow depth has been higher in the last decade than any decade since 1980. As the number of days below freezing declines, winter precipitation will more often be rain, rather than snow, reducing the hazards typically associated with snow and ice.

Typical Winter Weather Event

A typical winter weather event in the Mid-South region would include up to two days where temperatures stayed below freezing and snow accumulation reached one to two inches. Depending on total snow accumulation and daily high temperatures, the weather event could last between one to three days. With typical road surface pre-treatment, a one-inch accumulation would likely melt before there were significant disruptions to the transportation networks. With more accumulation, but higher-than-freezing daily temperatures, the same is likely true. During a typical winter weather event with two inches of accumulation and daily temperatures below freezing, more significant disruptions could occur, lasting for the duration of the freezing temperatures. In either case, there would likely be disruption to the continuity of operations, including school closures.

Magnitude

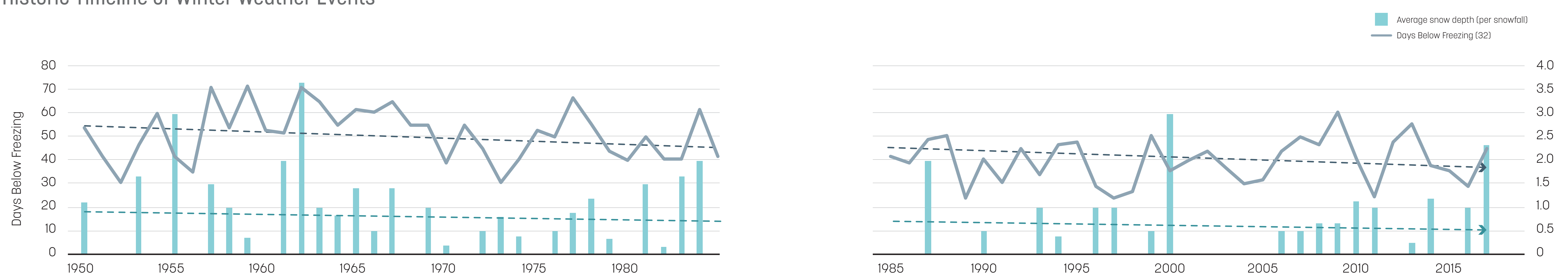
Worst Case Winter Weather Event

The biggest snow storm in the Mid-South region in the last century occurred from March 21-23, 1968. The storm yielded over 16 inches of snow accumulation. Temperatures dipped into the 20s, with high temperatures in the mid- to upper-30s creating a heavy wet snow that caused tree and utility line damage.

In the last 20 years, no winter weather event of this magnitude has occurred. Snow accumulation has not exceeded five inches in the last 30 years.

Since 1950, the Mid-South has experienced an average of just above three days of snow per year. In the last 20 years, that number has dropped to under two days of snow per year. Since 1950, the average total annual snow accumulation was three inches. In the last 20 years, that number has also dropped to under two inches per year. There is wide variability year-to-year, however. For example, in the last 20 years, there have been six years with no snow accumulation, but six years where total snow accumulation was greater than three inches.[9]

Historic Timeline of Winter Weather Events[8]



Endnotes

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Tornadoes

Causes

1 Air columns extending to the ground from rotating thunderstorms

Relevant Recommendations

- 3.3 Emergency Shelters
- 3.5 Green Building Retrofits
- 5.1 Critical Infrastructure Planning
- 5.3 Power Lines
- 5.4 Smart Grid
- 5.5 Community Energy
- 6.2 Debris Recycling
- 6.3 Temporary Housing
- 7.1 Resilience Database
- 7.2 Outreach
- 7.3 Vulnerable Communities
- 7.4 Economic Development
- 7.5 Capital Market Funding

Definition

A tornado is a violently rotating column of air extending from the base of a thunderstorm down to the ground. They are only visible when water, dust, and debris are collected in the rotating column of wind, which would otherwise remain invisible, much like straight line winds. Tornadoes are capable of completely destroying well-made structures, uprooting trees, and hurling objects through the air. They can occur at any time of day or night and at any time of the year.[1] Tornadoes typically occur over a shorter period and affect smaller areas than other extreme weather events that happen in the Mid-South.

Tornado strength is measured on the Enhanced Fujita (EF) scale, which ranges from zero (lowest strength) to five (greatest strength).

(Right) A tornado cloud passes over Memphis and the Mississippi River without touching the ground in May 2011.

Causes

While the causes of tornadoes are not fully understood, in the Mid-South they are typically formed in rotating thunderstorms (supercells) as warm, low pressure air systems collide with cool, high pressure air systems. The rotating column of wind must touch the ground to be considered a tornado.

(Above) A tornado warning was issued for northern Mississippi and southwestern Tennessee. The tornado landed in Columbus, Mississippi, reaching a strength of EF-3.

Impacts

Health and Safety

Since 1950, there have been 236 injuries and 7 fatalities in the Mid-South as the result of a tornado event. Though tornado winds are often strong enough to lift people in their path into the air, the biggest risk is being struck by flying or falling debris, destruction of occupied buildings, or overturning of occupied vehicles.[2]

The safest place for people at home is in the interior part of the basement, but many homes in the Mid-South do not have basements, so residents must rely on interior rooms aboveground for shelter. This leaves mobile home residents highly vulnerable to tornadoes.[3]

Improvements in tornado detection and warning systems have reduced tornado-related fatalities and injuries, as have increases in public awareness and communication of safety information.

Property Damage

Tornadoes can cause significant damage to all types of buildings, but large-spanned, big-box retail stores and mobile homes are particularly susceptible to damage from tornadoes. Typical events would cause between $500,000 and $2,000,000 in damage.[4]

Cars, trains, and other transportation vehicles are susceptible to damage if they sit in the path of a tornado. Boats and other aquatic vehicles, when in the water, are at less risk of damage, as water-based tornadoes are less severe in the Mid-South.

Crops and livestock are at risk during tornadoes as well. Due to agriculture's cyclical nature, this could be devastating for individual farm owners and operators. A tornado's relatively narrow path of destruction would likely leave the region's crops and livestock intact, with potentially few large-scale implications.

Continuity of Operations

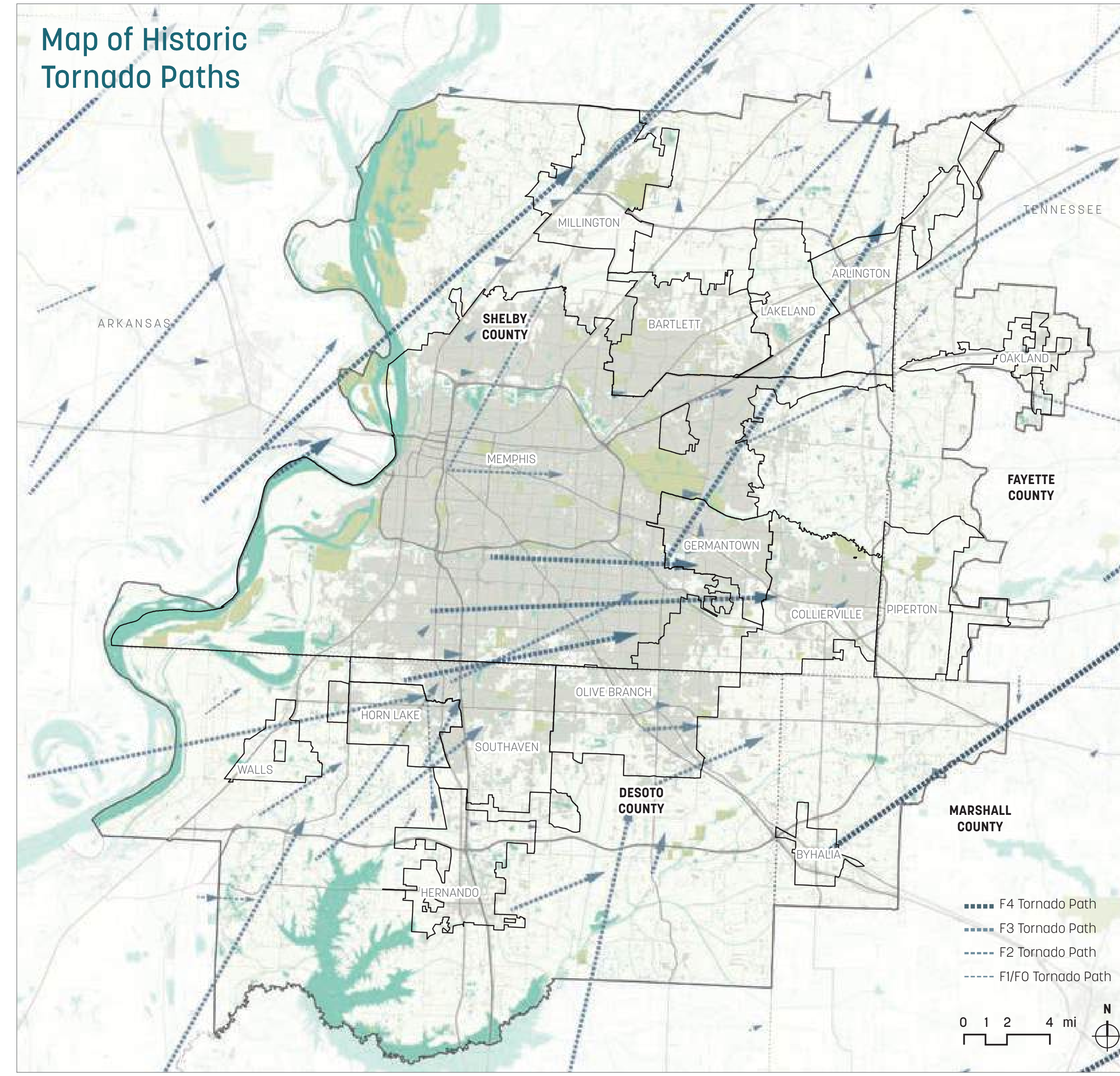
As with many hazards facing the Mid-South, the regional effects of a tornado can have negative impacts on the continuity of operations and quality of life immediately following the event. Tornadoes can have a very severe impact on a relatively small area within the region. Depending on its path, a tornado could completely destroy a college campus, forested area, or other community asset leading to huge impacts on quality of life.

The Shelby County Hazard Mitigation Plan indicates that roughly three or more businesses in the County would have to close temporarily or permanently as a result of a major tornado event. A significant number of regional commercial establishments are big-box retailers, which are more susceptible to damage from a tornado. However, specific parcels of land are not more at risk than others, so many of the national chains would likely reopen well-performing locations after repair or reconstruction.

Finally, tornadoes leave significant debris in their wake. Sidewalks or roadways may be impassable until cleared, particularly in low-traffic areas.

Infrastructure

Tornadoes could negatively affect most components of the transportation infrastructure network. Roads,



railroads, rail yards, airport runways, ports, locks, bridges, buildings, and other structural facilities would all be at significant risk if in the path of a tornado.[5]

Above-ground electrical lines are some of the most susceptible structures. Given their networked nature, it would be almost impossible for a regional tornado to avoid damaging several lines. Downed power transmission lines would affect a large number of people, while downed distribution lines would affect smaller numbers, depending on where they are in the network.

Above-ground components of waste and drinking water systems are also at risk for damage from tornadoes if they are located in the tornado's path.

Historic Tornado Paths

Each line represents a tornado event that passed through the Mid-South. The line thickness corresponds to the strength of the tornado, the line length indicates the ground path of the tornado, and the arrow indicates the direction of movement.

In the Mid-South, tornadoes typically travel from the southwest to the northeast. The paths can vary in length and width, and need not be continuous; tornadoes may lift from the ground, proceed along their path, and reconnect to the ground.

Tornado paths are not presently thought to be repetitive. Tornado risk is understood to be a regional hazard, and not locally specific to a site. Just because a building has been destroyed by a tornado in the past, it is not more likely to be destroyed by a tornado in the future when compared with other buildings in the region.

Frequency

Nationally, tornado events have become less frequent over the last two decades, measured by the decline in the average number of days with a tornado. However, the number of tornadoes per event has increased.[6] Contemporary research indicates that the shift in tornado patterns is the result of climate change, but scientists can not definitively or confidently project future changes in tornado frequency or magnitude at this time.[7]

Regionally, there has been a detectable increase in tornado risk, aligning with eastward shifts in climate zones. Research suggests that this may be correlated with an increase in temperature, which generates more energy for thunderstorms that produce tornadoes. However, more research is needed to understand if the increase in thunderstorms will lead to an increase in tornadoes.[8]

Since 1950, the Mid-South has experienced, on average, 1.23 tornadoes per year, causing approximately $2.8 million of annual property damage on years when tornadoes occur. There have been 7 deaths and 236 injuries related to tornadoes in the Mid-South since 1950.[9]

Typical Tornado Event[10,11,12,13]

Most of the tornadoes that make landfall in the Mid-South are rated as EF-0 or EF-1 magnitude events. These tornadoes have three-second wind gusts measured at 86-109 miles per hour. There have been 51 tornadoes of this magnitude in the Mid-South since 1950, causing a total of $8.3 million worth of reported damage.

During an EF-1 tornado event, roofs can be peeled off, glass in windows and doors can be broken, and vinyl and metal siding can be removed from single family homes, fast food-style restaurants, and big box stores. Attached garages may also collapse or be destroyed. Mid-rise buildings and institutional buildings such as hospitals suffer less damage; these buildings may experience some loss of roof covering, including damage to the penthouse roof and loss of rooftop HVAC systems. Larger tree branches can be broken, and smaller trees can be uprooted.

Magnitude

Tornado strength is measured on the Enhanced Fujita (EF) scale, which relates wind intensity to the damage caused by a tornado. It is the primary indicator of the magnitude of a tornado. The wind speeds used in the EF scale are estimated at the point of damage, and are different from the wind speeds measured by weather stations. Because the amount of damage can vary based on what objects are in a tornado's path, 28 damage indicators are used to guide classification, ranging from various building types to infrastructure components and trees.[14]

In the Mid-South, tornadoes typically range from EF-0 to EF-3 in magnitude.

Worst Case Tornado Event[15,16,17,18]

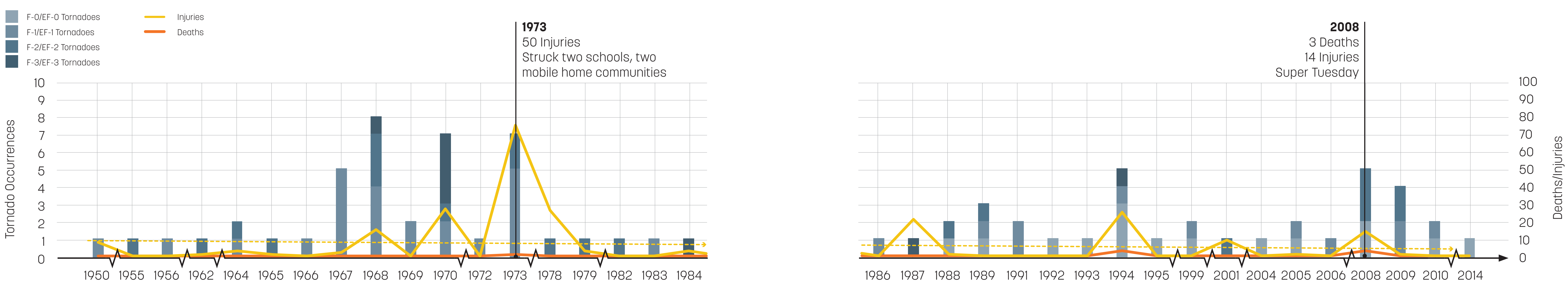
The likely worse case scenario tornado event in the Mid-South is an EF-3 tornado. Tornadoes of this magnitude see three-second wind gusts measured at 138-167 miles per hour. There have been eight tornadoes of this magnitude in the Mid-South since 1950, causing a total of $65 million worth of reported damage.[19]

During an EF-3 tornado event, large sections of roofs can be removed, walls will likely collapse, and the building can shift off the foundation of single family homes, fast food-style restaurants, and big box stores. Mid-rise buildings would experience significant loss of roof material, curtain wall damage, and significant damage to exterior walls. Institutional buildings would see significant loss to roofing materials, facade components torn from the structure, damage or collapse of exterior walls, and uplift of the roof structure. Large trees would be uprooted, snapped, and potentially debarked.

The 2008 Super Tuesday tornado caused $129 million worth of reported damage, 14 injuries, and 3 fatalities in the Mid-South. The tornado were rated EF-2 in Memphis, but reached EF-3 and EF-4 magnitudes elsewhere in the impacted area. The high reported damage is largely due to the tornado's path through a densely populated area.

Damage to Memphis International Airport included the lost roof from an airport hangar, airstair trucks being thrown 100 yards, and slight movements of a Boeing 737 plane.

Historic Timeline of Annual Tornado-related Events



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Threats Overview Matrix

This threats overview matrix indicates the frequency and severity of a typical extreme weather event in the Mid-South region today, as well as the expected frequency and severity of an extreme weather event in the future.

RECOMMENDATIONS

1

Waterways

1.1 River and Stream Restoration

Mitigate Flooding by Improving Waterway Health

Key Benefits

1 **Reduces floods through increased floodplain capacity**

2 **Improves ecological health along river corridors**

3 **Provides recreational amenities for nearby communities**

Overview

'Riparian Corridor' describes a river and its banks and floodplain as a single unit– the water, soil, vegetation, and adjacent wetlands. Riparian corridors serve a vital role in flood control and watershed function. When healthy and stable, riverbanks slow the flow of water through the watershed. Gently sloping banks support trees and shrubs that slow and filter and absorb runoff. Wetlands and floodplains along the river contain, remediate, and filter floodwaters. All the while, animals, such as birds and fish, thrive in the diverse habitats created by tree canopy, shrubs, grasses, gravel, and thick soil.

A catalytic step towards reducing flooding is to address the rivers, streams, floodplains, and wetlands that have been impacted by development. The resulting eroded, channeled, and straightened waterways directly contribute to flooding. These conditions also prevent the local community from using the river and cause poor water quality as well as loss of habitat.

Beyond their resilience value, attractive and vibrant riparian corridors are a significant community asset. Restoration projects can create recreational trails, build community programs, and provide access to the river for boating. These trails also give the community a window into the transformation that occurs during restoration, showcasing the regrowth of vegetation and reintroduction of birds, animals, and fish over time. The local community can also help with tasks such as invasive species removal and new plantings. Long-term, volunteer groups can serve an important role in maintaining the site by removing litter and invasive species on a regular basis and monitoring the area after construction is complete.

Given the direct reduction in flood risk and the benefits to the local community and ecology, restoring riparian corridors is a vital strategy for resiliency.

(Right) Invasive Vegetation and Erosion Along a Mid-South riverbank

1.1.1 Increase Floodplain Capacity

River flooding and flash flooding have increased over time largely because the natural floodplains and resilient riverbanks have been degraded by development. Development in the broader floodplain reduces the amount of overflow space for the river. Where rivers are covered, channeled, and straightened, they lose their natural meandering curves, absorbent slopes, and riparian wetlands. Overall, the result is higher flood risk and damaged ecosystems.

Specific issues beyond increased flooding include erosion and velocity. Channels, covers, and culverts that are too small create bottlenecks that cause erosion upstream. By contrast, large channels and straightened streams often move fast and can carry excess debris (sand, gravel, rocks, and natural detritus). Such water causes downstream problems including erosion in some places and debris build up in others. Fortunately, there are many ways to increase the natural flood-reduction capacity of a river. These are necessary first steps in riparian corridor restoration.

De-channelling the Kissimmee River (Example)

These before and after pictures show the difference between a straightened river and the reintroduced meanders (curves). The goal of this project was to repair the hydrology and ecology of the area.

Earthworks projects like this are usually expensive, requiring detailed planning, engineering, and site work. The total project was projected to cost $980 million dollars, with land acquisition making up one third the cost.[1]

2009

2010

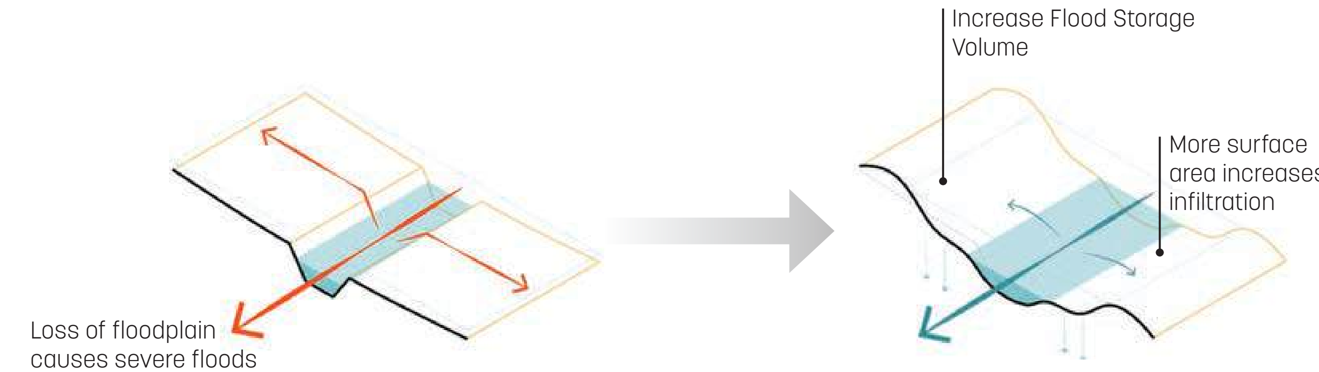
Source: North Star

Common Challenges in the Mid-South

1. Loss of floodplain exacerbates flooding
2. Development up to and over stream
3. Pollutants and litter drain to stream
4. Lack of riparian habitat
5. Heat pollution in shallow water
6. Impermeable surface precludes infiltration

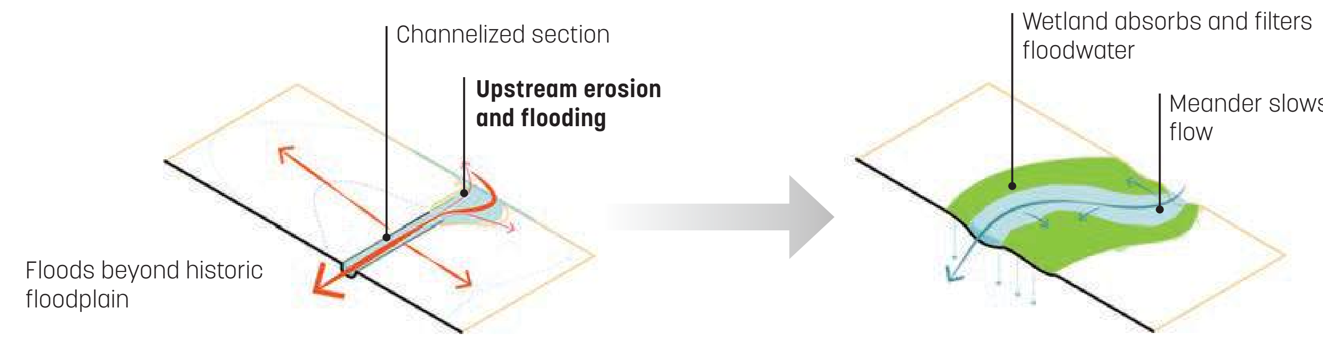
Remove Constraints and Lay-back Slopes

Daylighting is the process of removing the covers put over tunneled streams. Daylighting streams and laying back their slopes increase flood capacity.



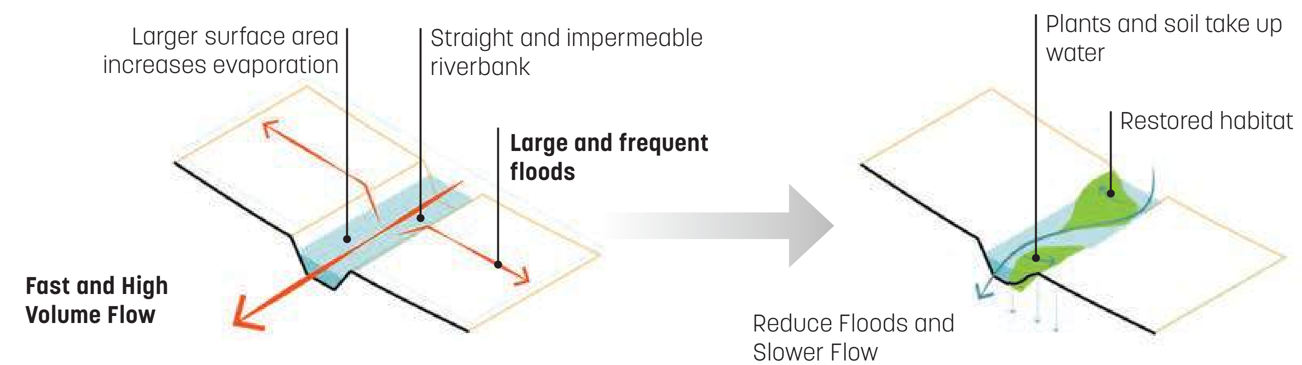
Reconnect or Introduce Meanders

Reconnecting old meanders and introducing new ones expands the floodplain and slows river flow.



Add Variation to Slow Stream Flow

Introducing variation on the stream bottom and banks creates obstacles that slow river flow and increase water infiltration.



1.1.2 Bank Stabilization

Higher river velocities and frequent flooding are the main causes of riverbank erosion. Straightened rivers, narrowing floodplains, and increased runoff from pavement and roofs can all stress riverbanks to their breaking point.

Eroded riverbanks are problematic for many reasons. The eroded soil washes away, causing silt to build up downstream. This can fill in boat channels, clog harbors, or cause algal blooms. Without soil, the eroded riverbank may not be able to support any vegetation–the very vegetation that helps reduce erosion. Exposed riverbanks are more susceptible to invasive species, as they can often tolerate harsh habitats better than native species. Exposed tree roots may lead to trees falling into the river, further altering water flow. Loss of the riverbank's integrity puts nearby structures at risk and makes the banks unusable for residents.

Fortunately, bank stabilization projects can successfully restore necessary riparian structure and function. The many different methods used in bank stabilization fall into two general categories. The first is soil bioengineering, which is planting new vegetation to collect silt and anchor soil. This is appropriate for smaller scale projects in low-flow, predictable settings. On projects where there is a lot of erosion, frequent flooding, and high water velocity, materials that are long-lasting, durable, and heavy must be used. This second method is called structural stabilization. Overtime, vegetation may grow within and on the structure.

Hudson River Bank Stabilization

The Hudson River restoration projects include old bulkheads that have worn down overtime and need replacement. In the case shown here, the bulkhead was replaced with natural looking rock revetement and woody trees and shrubs. Planners took the opportunity to include a recreational trail and rest stop.

Source: Natural Estuarine Research Reserve System, Scenic Hudson, and Creative Habitat Corp.

2004

2006

Common Challenges in the Mid-South

1. Vegetation loss
2. Subsidence
3. Undercut
4. Slope failure
5. Sediment loss /sedimentation

(Right) Mill Creek Erosion
Source: Clackamas Soil and Water Conservation District, 2012

Soil Bioengineering (Using Vegetation)

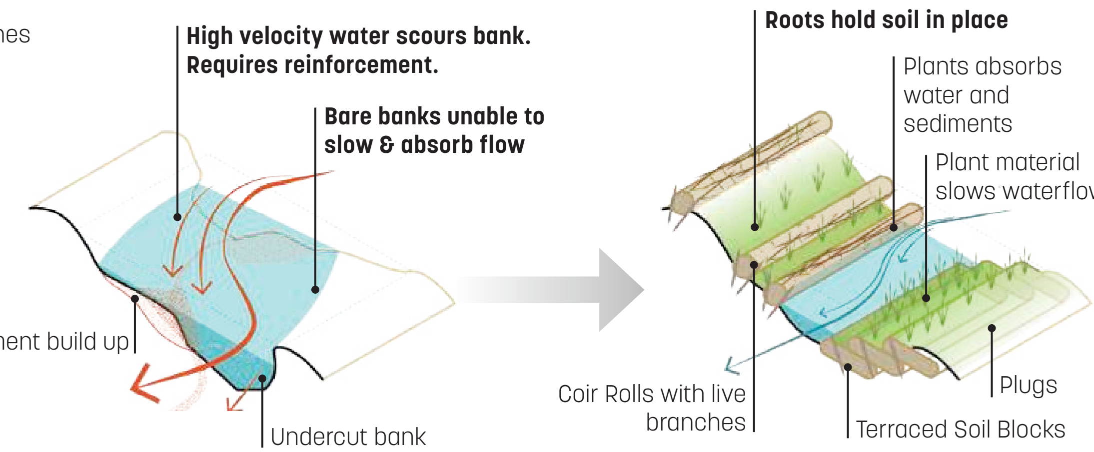
Plants and natural materials are used to rebuild eroded banks. Overtime, the plant root systems become deep anchors while new shoots stabilize and collect soil. This method requires maintenance throughout vegetation establishment. The image to the right illustrates alternating layers of soil-filled bags and live branches that add structure and vegetation to compromised slopes.

Despite its benefits, vegetation alone will not prevent undercutting and erosion if the water velocity is too strong.

(Right) Vegetated Geogrid.
Source: Almeda County Resource Conservation District

Materials

Live Stakes and Fascines
Vegetated Geogrids
Brushmattress
Live Siltation
Branchpacking
Reed Clumps
Coconut Fiber Rolls
Seeds

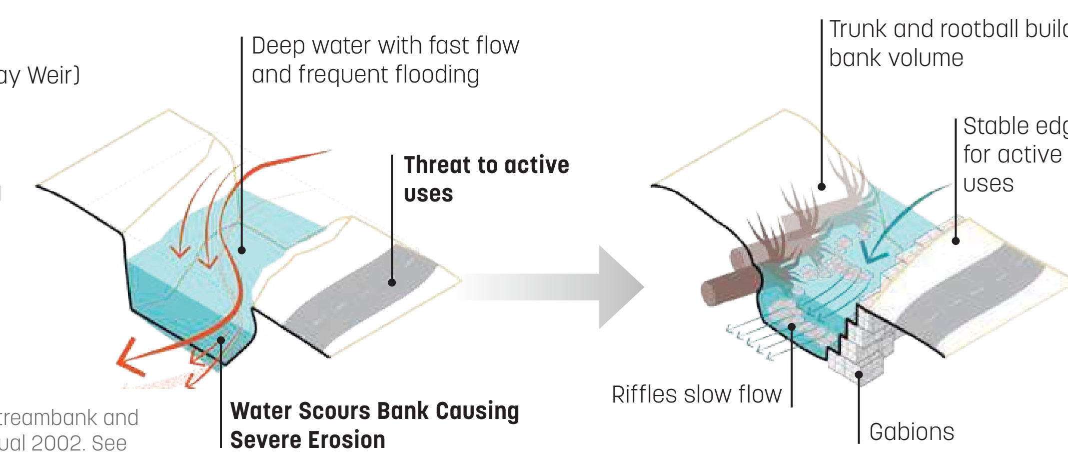


Structural Stabilization

Rocks and trees can be used to rebuild highly eroded banks. The materials are stable enough to withstand high water velocities and varying water levels. Planting can be incorporated within structural solutions.

Materials

Rock Riffle
Stream Barbs (Bendway Weir)
Tree Revetment
Log, Rootwad, Boulder Revetment
Dormant Post Planting
Rock Rip-rap
Rock Gabions



Materials lists From the Streambank and Shoreline Protection Manual 2002. See "Resources" on page 127 for citation.

Stabilization Materials in Use

Vegetation

Live stakes or branches are pieces of wood cut from living trees and shrubs. When the branches are exposed to water and soil, they will begin to sprout into whole new plants.

Woody trees and shrubs create strong root systems that help stabilize soil year-round.

Large tree branches, trunks, and stumps can be used as structures for restoration.

Woody Trees, Shrubs, and Coir Mat Stabilizes Soil. Source: UWSP

Downed Tree Placed for Sediment Accumulation, Creates Fish Habitat. Source: Lost Lake

Logjam made from local trees. Source: FEMA

Coir

Coir refers to a fabric-like mat made from coconut fibers. Coir comes in many forms, like mats, rolls, and blocks.

Coir mats can be laid over a slope to keep soil, seeds, and vegetation in place. Coir rolls are used to hold riverbanks in place. They come with live branches rolled into them. Coir blocks are filled with soil and are used to rebuild banks.

Pre-seeded Coir Mats, Pre-vegetated Coir Mat (at nursery). Source: North Folk Native Plants

Coir Roll Pinned with Wooden Stakes, Vegetation growing out of Coir Roll. Source: Water Care Partnership

Seeded Coir Blocks with Live Branches Sticking Out, Seeds Covered with Straw Source: Dakota County Soil and Water. Conservation District

Stone

Rip Rap refers to rough cut rocks which are typically laid out at or below water level to reduce the impact of high-velocity water.

Riffles are rock deposits that slow water flow, like a natural dam.

Gabions are cages filled with rock. The cages can be stacked to create walls in areas of steep slopes.

Rock Riffle Slows Water Flowing out of Culvert. Source: Frontier Environmental Services

Rock Gabions Stabilize Steep Streambank. Source: Gabion 1

Rock Riffles Replace a Dam, Includes Stone Revetment. Source: City of Santa Fe

Fast Results

Restoration projects typically take only a year or two to begin showing impactful results. As shown in the examples below, substantial vegetation growth typically occurs by the end of the first summer. Below the water surface, the roots systems quickly begin to stabilize the stream bank soil and absorb water. Above water, the rough texture of vegetation slows water flow and creates habitat for animals.

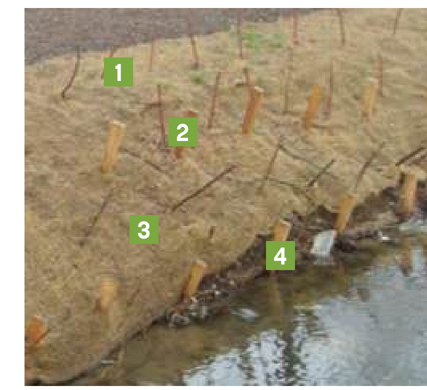
Images below are from the Wisconsin Lakeshore Restoration Project unless otherwise noted.[2] This is a good resource for additional information and before-and-after photographs.

Stakes and Coir Mat

Includes live willow branches stabilized with wooden stakes and coir mat. Image on far-right shows result one year later.

1. Ground Cover Seeds
2. Live Stakes
3. Coir Mat
4. Support Stakes

(Right) Example by Wisconsin Lakeshore Restoration Process



Brush Mattress

Brush mattress with live willow fascines (bundles branches). Image on far-right shows results.

1. Silt from Stream
2. Staking System
3. Fascine

(Right) Example by Bioengineering Associates

Vegetated Geogrid

Vegetated Geogrid with alternating layers of soil-filled bags and live stakes/ plants. Image on far-right shows results.

1. Revetment
2. Established Geogrid Slope
3. Revetment

(Right) Example by Envirolok

1.1.3 Ecological Restoration

Ecological restoration is a third major step for repairing riparian corridors and increasing flood capacity.

From a flood standpoint, vegetation can significantly reduce water volume through evapotranspiration. During the summer, each mature tree may use hundreds of gallons of water. Also, leaf litter and grasses slow water flow across the ground-surface, increasing infiltration rates. Low-lying wetlands both consume water and slow its flow. In addition, wetlands are ideal filters of pollutants and fertilizers.

Having a thickly vegetated riparian corridor can moderate water flow and reduce flood risk downstream. For more on the benefits of trees, see 5.7 Trees. 5.7

In addition, riparian corridors can be the most ecologically productive areas in a local ecosystem because they provide habitat and feeding ground for aerial, land, and aquatic species. This habitat is vitally important for the overall environmental health of the region.

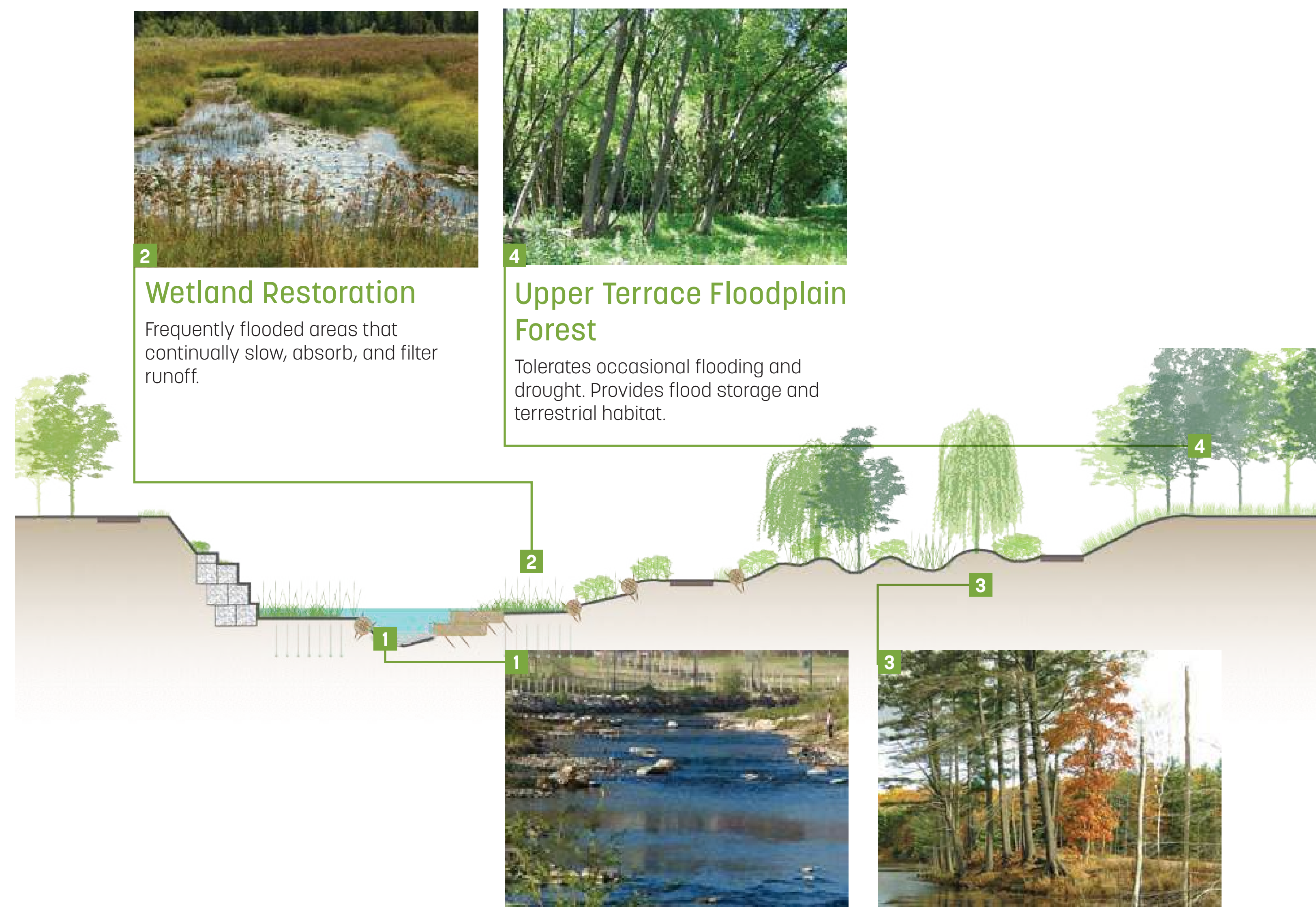
A large tree can consume 50 gallons of water per hour on hot summer days.

Common Challenges in the Mid-South

1. Native Species Loss
2. Habitat Diversity Loss
3. Barren Slopes
4. Invasive Species
5. Overheated Water
6. Loss of Aquatic Life

Increase Habitat Diversity

The riparian zone is a feeding and breeding ground for many types of wildlife. Terraced riverbanks hold a large volume of water in the event of flooding. When dry, these terraces can support human activity and a range of habitats.



Wetland Restoration

Frequently flooded areas that continually slow, absorb, and filter runoff.

Upper Terrace Floodplain Forest

Tolerates occasional flooding and drought. Provides flood storage and terrestrial habitat.

Aquatic Habitat

Rocks, rapids, and riffles are the breeding grounds and shelter for many fish and aquatic species.

Lower Terrace Floodplain Forest

Occasional flooding and wet soils.

1.1.4 Improve Community Access

Restoring riparian floodplains can provide substantial benefits to the local community. Access can be as simple as clearing a trail along the river and providing a boat launch. It is important to engage the community in the design process to understand what kind of access and amenities they would like to come along with restoration. The community can also play an important role in maintenance and programming.

All together, these improvements create a compelling asset for the local community. Where dangerous banks once posed a risk to the community, now recreational and educational opportunities abound.

1 Improve Recreation Access

2 Trails and Open Space

3 Event Spaces

Proposed Restoration Corridors

This map shows corridors identified as prime candidates for riparian restoration. Additional site-by-site analysis and due diligence would be required for final site selection and implementation. Similar projects have been successful in securing grant funding.

These sites were chosen because they exhibit several of the following criteria:

- Adjacent to, or shortly upstream from, areas that tend to flood during heavy precipitation
- High percentage of degraded stream length, as designated by state environmental agencies
- Adjacent to, or shortly upstream from, a high density of houses within the floodplain
- Adjacent to publicly owned or non-developed land that could receive a stream meander or widening
- Comparable in length to current grant-based stream restoration projects

	Creek	Jurisdiction	Miles	Impairment*
1	Loosahatchie River	Arlington, Lakeland, Shelby County, Bartlett	6.7	Sedimentation/siltation from site clearance, E. Coli from MS4 discharges, physical substrate habitat alterations due to channelization
2	Fletcher Creek	Memphis	5.3	Sedimentation/siltation, E. Coli from MS4 discharges, physical substrate habitat alterations due to channelization, and low levels of arsenic
3	Wolf River	Germantown, Memphis	8.9	Contaminated sediments and sedimentation from MS4 discharges
4	Nonconnah Creek-1	Memphis	5.8	E. Coli from MS4 discharges, physical substrate habitat alterations due to channelization, low levels of oxygen
5	John's Creek	Memphis	1.9	Siltation, E. Coli from sanitary sewer overflows and MS4 discharges
6	Nonconnah Creek-2	Shelby County, Memphis	6.9	E. Coli from MS4 discharges, physical substrate habitat alterations due to channelization, low levels of oxygen
7	Horn Lake Creek	Horn Lake, Southaven	2.7	Bank erosion and impaired life support from pesticides, nutrients, siltation, organic enrichment-low DO

*Impairment information retrieved from: Tennessee Department of Environment and Conservation, "Year 2016 303(d) List," 2016.

Implementation

Stream bank restoration projects are typically led by a project sponsor, which can be a government agency or department, a non-profit organization such as a conservancy group, watershed organization, foundation, or a private organization. For larger projects that affect major waterways, the project sponsor may partner with the U.S. Army Corps of Engineers which can provide design, engineering, and construction services in areas where it has jurisdiction (in this case, Waters of the United States, as defined by the Office of the Federal Register, National Archives and Records Administration). In this case, a project sponsor may identify a project within the Army Corps' jurisdiction and take the project through the design stage before presenting it to the Army Corps for consideration.

The Army Corps can approve projects up to specified dollar amounts on its own authority. For stream bank restoration and flood mitigation projects, these cost limitations range from $3,000,000 to $7,000,000 depending on the specific type of project. For projects with higher costs, Congressional approval is required and the project sponsor must contact their Congressional Representative to request authorization through the Congressional Public Works Committees.

Aspirational Targets

Create a plan for riparian restoration for the 28 miles of proposed corridor by 2025

Rate target streams with EPA Report Card every year to track water quality improvements

Restore 25 miles of stream bank by 2030

Process

1 Planning	Define project objectives: design criteria, site hydrology, ecological risk assessment, habitat and riparian needs, and project budgets Collect data (hydrologic and hydraulic modeling, upstream observation, context analysis).
2 Design & Permitting	Form multidisciplinary teams: river engineers, geomorphologist, ecologists, landscape architects, and planners Select a suitable method for restoration and develop a design Apply for federal, state, and local permits
3 Construction	Hire contractors to complete the work Manage contractors to ensure construction matches design drawings
4 Maintenance	Transfer maintenance to the Department of Public Works or local equivalent Coordinate volunteers for ongoing maintenance efforts or planned volunteer event days

1 Planning

The first step in any planning process is to define the project objectives. These could include flood protection, ecological preservation or restoration, and recreation opportunities. One or more of these drivers may be a sufficient justification for the stream bank restoration project in the first place, and that may determine specific project objectives and design criteria. For example, the stream bank restoration project may be tied to specific disaster recovery funds, in which case flood protection would serve as the main objective for the project and specific design criteria may be required, such as providing protection against a future 100-year storm event. When possible or practical, it is also a good idea to engage local stakeholders at this stage to identify additional opportunities or limitations and build community support for the project.

Next, a comprehensive site analysis is required to understand existing conditions. This includes site hydrology and hydraulics, observation of stream bank conditions, land use analysis, review of local development regulations, local habitat, ecological needs, and recreational amenities or deficits. Concurrent to the comprehensive site analysis, a risk assessment should be conducted to determine the appropriate design life of the project. If the stream bank restoration project is intended to directly protect critical assets, the risk assessment will establish the acceptable minimum level of risk protection that the project design must provide. The site analysis and risk assessment will help guide the selection of recommended interventions.

Identify Sites for Riparian Restoration

At the end of the planning phase, specific intervention sites along a stream corridor should be identified and accurate terrain data must be gathered. This data is necessary to begin the design and permitting stage and prepare construction drawings. Additionally, the necessary land should be acquired or an easement should be obtained, if necessary. Given that nearly all riverbanks can be improved in some way, choosing which site to work on is a negotiation of current needs, feasibility, and potential future expansion.

The proposed stream restoration segments presented earlier in this chapter are based on publicly available data from both Tennessee and Mississippi. Per Section 303(d) of the Clean Water Act, the Tennessee Department of Environment and Conservation (TDEC) and the Mississippi Department of Environmental Quality (MDEQ) have to publish a list of impaired streams, which accounts for both water quality and bank integrity. The map in this section, along with these lists, are a valuable starting point for choosing restoration sites.

Restoration typically occurs in shorter phased sections from 100 feet to 1 mile over time. Connected sections have major impacts on riparian function.

Criteria for Riparian Restoration Sites

Primary Criteria

- Large potential flood capacity
- Well-drained and stable soil
- Accessible for construction and maintenance
- No conflicting uses
- Adjacent land available for purchase, conservation easements, or voluntary improvements by owner

Secondary Criteria

- Connection to a corridor-scale project
- Proximity to sources of native flora and fauna (e.g., nature preserve, forest, etc.)
- Accessible for recreational use
- Supportive community group (e.g., conservancy, neighborhood organization, recreation department, etc.)

Mitigating flood risk takes priority over other criteria because of the immediate biophysical threat of flooding to the Mid-South. Prioritize sites that can both store large volumes of water in expanded floodplains and slow stream velocity.

The vegetation and drainage that help with flood mitigation depend on well-drained and stable soil.

Sites must be accessible not only for the initial phases of design and construction, but also for the ongoing monitoring and maintenance required to ensure the long-term success of the project.

Adjacent land should be surveyed to determine the suitability of a riparian project. There must be no conflicting uses along the bank, and there must be land that is either already set aside for conservation or available at a reasonable cost.

The most effective projects are part of a master plan for the entire stream corridor and watershed. Such plans are typically broken down into phased projects.

Sites that contain some existing habitat and vegetation can jump start the restoration work. As the banks improve, animals and vegetation will naturally expand their range and multiply. This reduces the financial burden and risk of buying and introducing plants and animals from off-site.

Sites that can create recreation opportunities accessible to the community should be prioritized. Trails, boat launches, parking and recreation areas can often be added to projects with minimal impact directly on the banks. People from the surrounding area need to be able walk, bike, or drive to a site in order for the trails to be used.

Finally, river restoration projects are usually most successful when there is a partnership group or community that will help with maintenance, management, and advocacy.

Potential Partners

The **US Army Corps of Engineers (USACE)** is a potential partner organization. When working with the Corps, costs are shared between the local jurisdiction and the federal government. The specific cost sharing ratios are outlined in a document published annually by the U.S. Army Corps of Engineers, and vary by phase of work. For the local share of the costs, this can be a local budget allocation, a state budget allocation, philanthropic funds raised by a non-profit sponsor, or philanthropic funds donated by a private project sponsor.

The **Tennessee Stream Mitigation Program** is a potential partner organization. They are an in-lieu-fee program that provides ecosystem restoration services. They accept project impacts and associated mitigation fees on the front-end of projects that require mitigation, pool mitigation fees within a watershed, and then identify stream restoration projects within that watershed. Federal regulations prevent the co-mingling of mitigation funds, so local funds or grants cannot supplement the stream bank restoration component of a project. In the past, the group has worked with local entities who provide additional funding to pay for other amenities, such as transportation or recreation additions to the stream bank restoration scope. Notably, the program requires a perpetual conservation easement to be obtained for the project intervention area. The easement prohibits mowing or tree-cutting, limiting waterfront access recreational opportunities. To achieve an economy of scale on the high cost of hydraulic design fees, the group limits work to projects greater in scale than 10,000 linear feet of stream. There is no formal process by which local entities propose projects; partnerships start with a phone call.

The most successful restoration projects have a mission driven group that supports maintenance, programming, planning, and funding.

Typical Cost/Benefit Factors

Bank restoration is one of the best ways to improve habitat, water quality, and recreational opportunities in an area. It can also be very effective at reducing downstream flooding, but only if there is ample room to expand the stream profile. It should be supported by Low-Impact Design (LID) practices along stormwater routes to the river (see 2.3 Low-Impact Development). The costs and benefits of riverbank improvements can be measured both directly and indirectly. Direct measurements relate to the area improved. Area may be the number of miles improved or the acreage of the watershed that is affected. Indirect measurements include effects such as water quality improvements, habitat restoration, and added recreational amenities for the community.

2.3

Typical costs for river restoration projects can vary based on location along the length of the river, jurisdiction, variable administrative costs depending on the agent involved in management functions, as well as various other factors involved in implementation, such as permitting, acquisition of property rights, pre-construction engineering, construction management, monitoring, maintenance, and stewardship. Even within the length of one particular river the cost can vary greatly. For example, the total cost of bank stabilization for several projects along Wind River in Skamania County, Washington range from approximately $8.70 to $42 per linear foot of river.[3] Costs also range based on local conditions and the intensity of restoration needed. For instance, stream restoration costs can be as low as $40 to $120 per foot for establishing a riparian buffer or rip-rap armoring of stream banks. A more moderate estimate has been calculated at $242 per foot for a range of urban, suburban, and rural projects in South Carolina,[4] while higher restoration costs in more-urban contexts have ranged from $500-1,200 per foot in Baltimore.[5] Easement and acquisition costs may also vary depending on land value along the river. Within a series of river restoration projects in Thurston, Washington between 1999 and 2016, costs for riparian restoration were estimated at $13,866 per acre on public land to around $23,323 per acre on private land. This meant that the average easement cost was $9,457 per acre.

While calculating costs, it is also important to include indirect measurements, such as the potential benefits of riparian restoration. In many cases, the benefits can outweigh the costs of implementation. In the Thurston, Washington example, ecosystem services and social benefits have been estimated to bring a benefit-cost ratio between 14.78 and 18.15—in other words, for every $1 spent on riparian restoration, between $14.78 and $18.15 is recovered in economic benefits measured through looking at the value of targeted redevelopment, preservation, flood reduction, habitat quality, and water supply.[6]

Factors involved in driving up costs also depend on how a project is planned and managed. For example, the fixed costs included in administration and equipment can be spread over larger projects, while multiple smaller projects spread over the entire site can drive up these costs overall. In the cost/benefit table on the next page, relative costs are illustrated as weighted against potential benefits. '$' and '+'are used to indicate the relative costs and benefits of implementation aspects involved riparian restoration projects. The more '$' or '+' in an aspect, the more costly or beneficial it may be as compared to others, and deserves considerable focus in minimizing costs or enhancing benefits.

Funding Opportunities

Riparian restoration is a widely accepted best practice. There are numerous governmental and non-profit agencies that will fund or partner on projects.

Cost/Benefit Factors

Typical Cost Aspect	Relative Cost
Administration Site identification, quality assurance, contract management, and accounting of funds	$
Permitting	$
Acquisition of Property Rights Purchase of either land or a conservation easement on land around a stream	$$$
Engineering & Design Feasibility analysis, watershed assessment, reach analysis, reference analysis, topographic study, flood study, creation of a restoration plan, final design	$$
Construction Management Includes all phases of construction, bidding and supervision of construction	$
Construction Mobilization, equipment, earthwork, planting, creation of drawings, labor	$$$
Monitoring Baseline monitoring, continued monitoring	$
Maintenance	$
Stewardship Inspection, enforcement of violations, and continued repair	$

Costs will vary based on location, area and intensity of restoration

Potential Benefits	Relative Benefit
Health and Social Benefits Increased recreation space, increased potential for park and trail development, etc.	+++
Habitat Restoration and Biodiversity	+++
Reduction of Pollution Mitigation Costs Riparian restoration can improve water treatment through nutrient removal, reducing the needs for costly active water treatment	++
Job Creation The added jobs involved in the restoration project, increased monitoring and stewardship positions, recreation-related jobs, etc.	++
Increased Land Value Land values may increase near areas of improvement, particularly including increase recreation and park space	+

Benefits will vary based on location, area and intensity of restoration

$$$ = High Cost Factor

$ = Low Cost Factor

+++ = High Viability of Benefits

+ = Low Viability of Benefits

Federal Funding Sources

The **FEMA Flood Mitigation Assistance Grant Program** offers a Pre-Disaster Mitigation grant. The goal of the program is to "reduce overall risk to the population and structures from future hazard events, while also reducing reliance on Federal funding in future disasters." The program is available for planning and project grants. Development of a Hazard Mitigation Plan is a pre-condition for receiving this funding. The state Emergency Management Agency (TEMA or MEMA) is responsible for the application, and only one Pre-Disaster Mitigation grant application will be accepted from each state. The maximum federal share for this program is $4,000,000 for mitigation projects and $400,000 for new mitigation plans (less for updates to existing plans). The grant generally requires at least 25% matching funds from a non-federal source.

The **US Fish and Wildlife Services (FWS) offers a Wildlife Restoration Grant Program** to restore fish and wildlife habitats. Eligible applicants include state and local governments. The grant requires at least 25% matching funds from a non-federal source, and the maximum award value is $5,000,000.

The **US Department of Housing and Urban Development (HUD) offers a Community Development Block Grant Disaster Recovery Program**. Following a Presidentially-declared disaster, Congress will approve a CDBG-DR appropriation and HUD will announce allocations to affected jurisdictions. State and local governments administer the grant program directly or distributes funds to sub-recipients.

State Funding Sources

The **Tennessee Department of Environment and Conservation (TDEC)** offers grants when funding opportunities become available. Future grants and requests for proposals are announced by TDEC. Likewise, the **Mississippi Department of Environmental Quality (MDEQ)** offers loans through the Water Pollution Control (Clean Water) Revolving Fund Loan Program. Non point Source Pollution Control Grants may apply depending on the restoration site and objectives.

Private Funding Sources

Grants from foundations, conservation groups, watersheds, or private, for-profit organizations are available to assist with stream bank restoration projects. These grants may specifically apply to the planning, design/permitting, or construction phases. In many cases, one grant may be used to cover the cost of project planning. The finished plan can then be used in another grant application to cover design/permitting and/or construction.

2 Design & Permitting

The design and permitting stage follows the planning stage. The first step in the design and permitting stage is the assembly of a design team. The most successful multi-benefit stream bank restoration project teams are comprised of qualified professionals from a variety of disciplines, including river engineers, geomorphologists, ecologists, landscape architects, and planners.

Together, the design team will create one or more concept interventions for the stream bank restoration. The selected concept design will be elaborated to include an erosion control plan to control sediment loss and erosion, a grading plan showing existing and proposed grade changes to the stream bank, and a planting plan that details specific soil preparations, plant selections, and planting locations. Additionally, the design team may identify and incorporate recreational amenities or floral and fauna habitat within the design. Though these components may not necessarily provide flood protection, they can add value to the community.

Once the final design is selected and schematic design drawings have been completed, the design is presented to governing agencies for review. After review, a governing agency may issue a permit or require changes to the design. Typically, a governing body reviews the design to ensure that the project will not interfere with natural or navigational functions of the stream and surrounding area, including during construction. Once the design is complete a final round of permitting must be complete before construction may begin.

3 Construction

Near the end of the design and permitting stage, a construction partner will need to be identified. For publicly funded projects, this likely means a public bidding process based on final design drawings. It is important to select a construction partner who has experience with the specific kinds of riverbank restoration detailed in the design. Bioengineering solutions are not ubiquitous, and contractors may not have experience with this kind of infrastructure.

Managing the construction process is a large responsibility and can be shouldered by a non-profit project sponsor, a contracted construction manager, a design firm involved in the design development and permitting stage, or by the U.S. Army Corps of Engineers.

4 Maintenance

Following construction, it will be necessary to implement a maintenance plan to ensure the continued success of the restoration project. Often, if the project sponsor is a non-profit organization or a private landowner, the project maintenance responsibilities will be transferred to the local Department of Public Works. It may take several years of maintenance before the stream bank restoration project realizes the full design benefits, as bioengineered solutions need time for plantings to mature and for ecosystems to re-establish.

One of the best ways to ensure the future success of a project is to involve the community and conservation groups in design, construction, and long-term care.

Case Study

Wolf River, Shelby County, TN

The Wolf River Restoration Project turned the damaged banks of the Wolf River into a recreational and ecological center for the region. The river damage was caused by a 22 mile channelization project in the 1960s. The channelization had caused erosion upstream and increased the amount of runoff, threatening wetlands and groundwater recharge. The Wolf River Conservancy and the U.S. Army Corps of Engineers partnered to complete the Project. The project was completed in 2009 and is part of a larger effort to protect and enhance the 90-mile long Wolf River watershed for recreation and ecological function. The Wolf River is a tributary to the Mississippi River and its watershed covers over 800 square miles across Tennessee and Mississippi.[7]

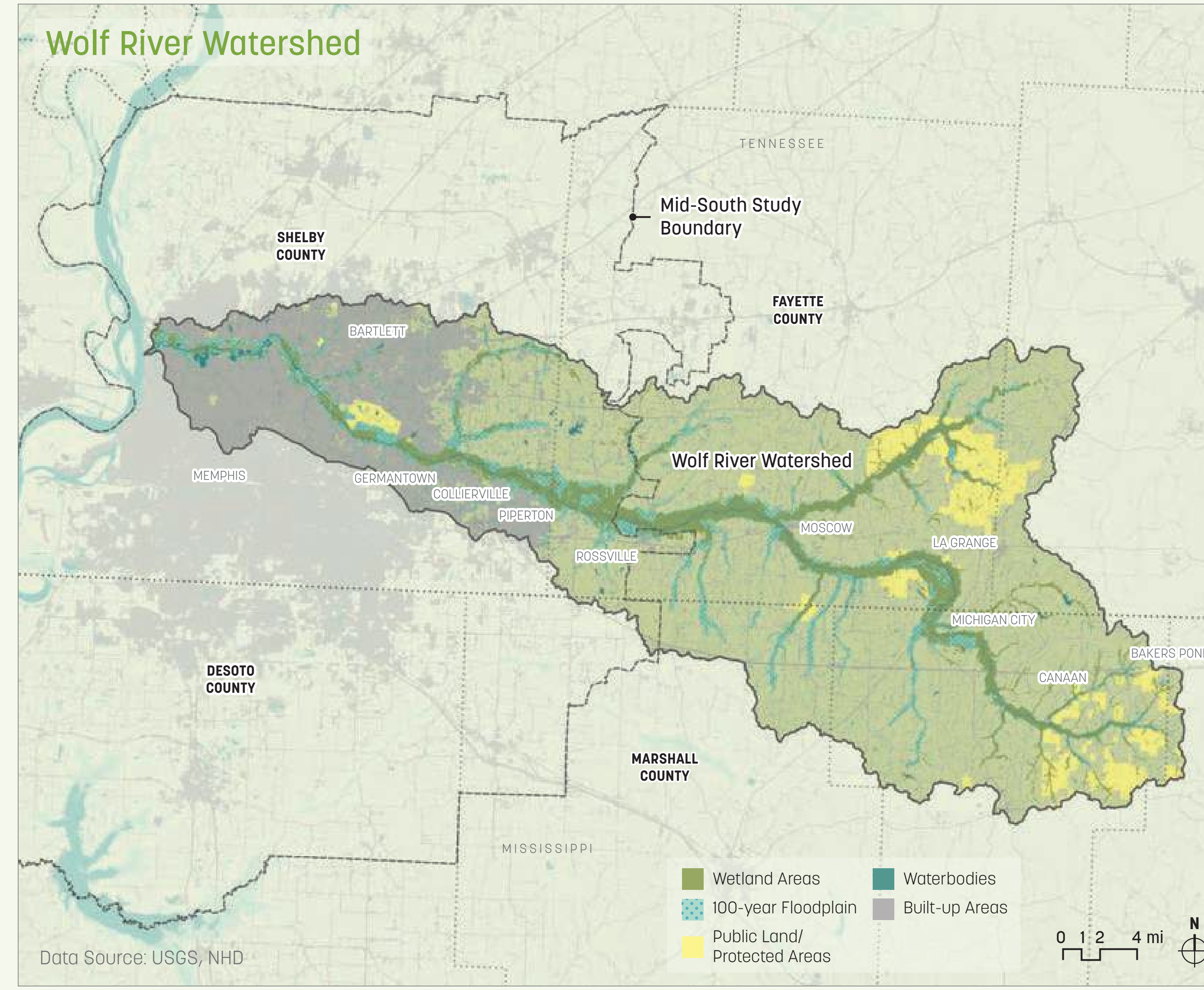
The Wolf River Conservancy existed for decades before undertaking the Wolf River Restoration Project. The Conservancy began in 1985 with an effort to block a new mine from being developed along the riverbank. Their overall work in the Wolf River Watershed covers 16,000 acres. Recently the Conservancy has mapped all of the sub-watersheds and rated them based on conservation value in order to prioritize areas for conservation.

As a land trust, the Wolf River Conservancy uses many methods to acquire or protect the river banks and flood plain. Some land is purchased outright, other land is donated. In some cases, the Conservancy negotiates conservation easements with private land-owners. The Wolf River Restoration Project itself was funded by congress.

The Wolf River Conservancy has protected 16,000 acres to date and aims to protect the full 90 mile Wolf River Corridor and watershed.

(Below) Wolf River before restoration.
Source: Wolf River Conservancy

(Below) Wolf River after restoration.
Source: Wolf River Conservancy



(Below) Kayaking tours on the Wolf River

Case Study

Crooked Creek, Hardin County, TN

The Crooked Creek Restoration Project[8] restored the natural creek channel, native buffers, and connections between the stream and the floodplain. The previously forested wetland area had been cleared and drained for agricultural use. Prior to the restoration, the riparian buffer consisted primarily of ten-foot wide strips bordered by fallow fields. As a result, Crooked Creek and several unnamed tributaries were severely channelized and experienced bank erosion with poor channel stability.

In 2006, the creek channel was restored to a more natural dimension, pattern, and profile, and the riparian habitat was re-established with native trees, shrubs, and herbaceous species. Additionally, in-stream structures maintain riffles and pools to improve aquatic habitat. The restoration project has led to improved water quality as sediment inputs have been reduced and aquatic and terrestrial habitats have been improved. During flood events, the reconnected floodplain provides additional storage capacity and the naturalized channel reduces water velocity.

The Tennessee Stream Mitigation Program sponsored the project, which ultimately restored 11,986 linear feet of streams for a cost of just over $789,122 by the end of 2006 ($66 per foot on average).[9] The project was completed in December 2006 and is part of a larger vision for the White Oak Creek Wildlife Management Area in the Upper Kentucky Reservoir Watershed. Additional work including monitoring of the restoration process brought the final cost of the project to just over $1 million by the end of 2011.[10]

The Tennessee Stream Mitigation Program is a an In-Lieu-Fee Program established in 2002. They provide a fee-based compensatory mitigation option for permittees seeking a third party to develop compensatory mitigation projects.

(Below) Crooked Creek before restoration.
Source: Tennessee Stream Mitigation Program

(Below) Crooked Creek after restoration
Source: Tennessee Stream Mitigation Program

(Above) Aerial photograph of Crooked Creek.
Source: Tennessee Stream Mitigation Program

Endnotes

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8 "Crooked Creek," *Tennessee Stream Mitigation Program* online, last modified 2018, https://tsmp.us/projects/west-tennessee-projects/crooked-creek-project/.

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Resources

Stream Restoration Guidance

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Funding

"Home." *Tennessee Stream Mitigation Program* online. Last modified 2018, https://tsmp.us/.

"Grants, Loans, Trust Funds." Mississippi Department of Environemntal Quality online. Last accessed March 20, 2019. https://www.mdeq.ms.gov/about-mdeq/grants-loans-and-trust-funds-available-through-mdeq/.

1.2 Flood Barriers

Construct Barriers to Protect Against Flooding

Key Benefits

1 **Prevents damage to several properties with one intervention**

2 **Little or no change is required to existing structures**

3 **May create recreational and event space near the waterfront**

Limitations

1 **Does not reduce the need to comply with NFIP flood insurance requirements**

2 **May negatively impact hydrology, resulting in more frequent or higher flooding throughout the watershed**

3 **Requires regular maintenance and certification**

Overview

When it not possible to move people and assets outside of the floodplain or to reduce flood levels, hard infrastructure may be the best way to mitigate flood damage. Levees, berms, flood walls, and floodgates are all permanent structures that block stormwater up to a specific "design storm" water level. These structures work best in areas that experience low-level, low-velocity flooding such as flooding from a slow moving river or reservoir.

Levees and berms are both types of embankments or mounds of compacted earth. Levees are large, engineered structures that meet specific criteria to ensure structural stability. Berms generally refer to smaller, non-engineered structures. Both require large sites for their wide bases and ample earthen fill.

(Right) Example of a levee-integrated park alongside an historic neighborhood in Wilkes-Barre, PA.

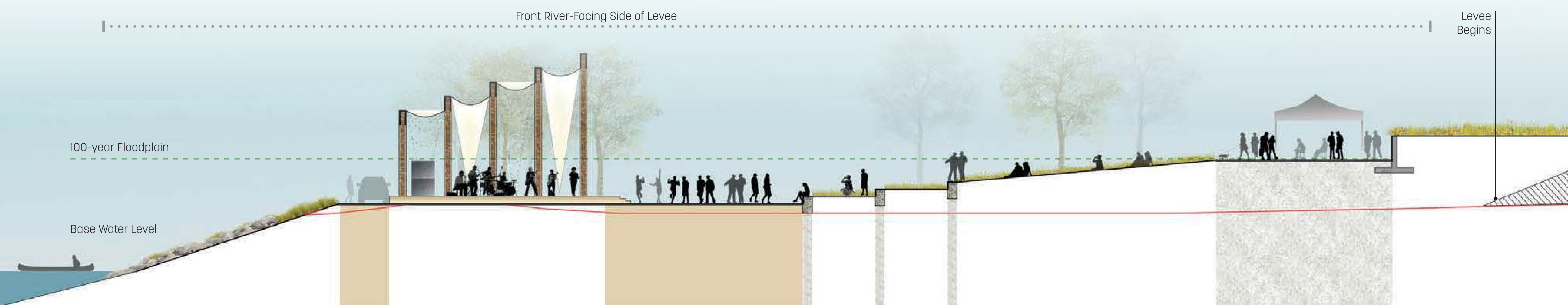
Flood walls provide similar flood protection to levees and berms but have the advantage of a smaller footprint and more structural stability. Since they are made with stone and concrete, flood walls can often be incorporated into the architectural design of a site. The main disadvantage to flood walls is that they tend to cost more than embankments.

Cost for these structures are generally expensive, though costs vary with several factors. For embankments, the size and location of fill material is a primary concern. For all projects, the complexity of the drainage system and design, additional architectural details, and length are all factors that can raise the cost.

Hard infrastructure is fallible: it can only protect up to its design height. After water crests over the top or the infrastructure fails, those areas that should be protected will flood quickly. A well known example of this is the destructive flooding that resulted from levees failing during and after Hurricane Katrina. Before considering hard infrastructure, explore opportunities to reduce local flooding through stormwater management throughout the watershed. Also, study the feasibility of moving people and assets out of the 100 and 500-year floodplain. In most cases, these preventative measures will be more effective and less expensive in the long run.

(Above) Yoga class at Tom Hanafan Rivers Edge Park Council Bluffs, IA where a levee doubles as a recreation asset.

Levees and berms can double as recreation spaces near the river



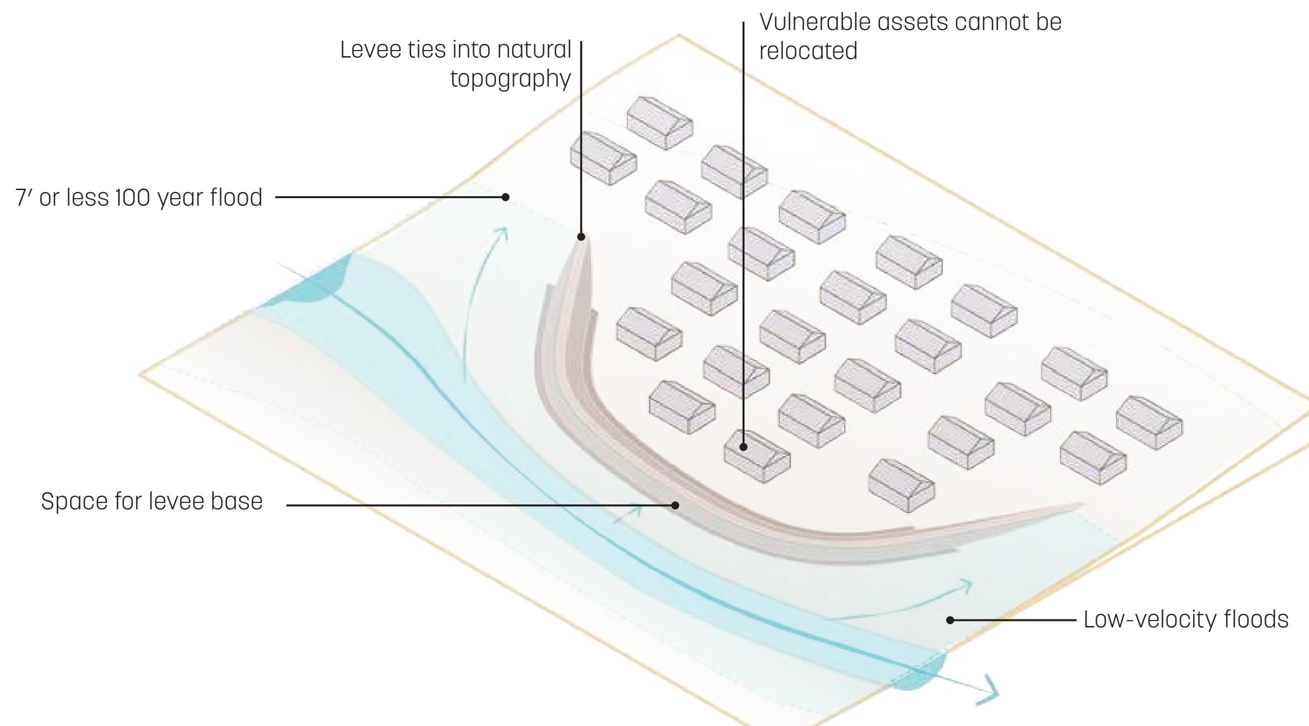
1.2.1 Levees

Levees are typically used to protect large areas, such as fields and vulnerable neighborhoods. They work best in areas where the design flood level is less than seven feet and floodwater has a velocity of less than eight feet per second. Higher floodwaters and velocities increase the chances that the levee will fail by erosion or pressure. Ideally, levees have at least one foot freeboard, which is the space between the highest design flood level and the crest of the levee. Levees are typically constructed where they can tie into the natural topography because this reduces the length, and thus the cost, of the levee.

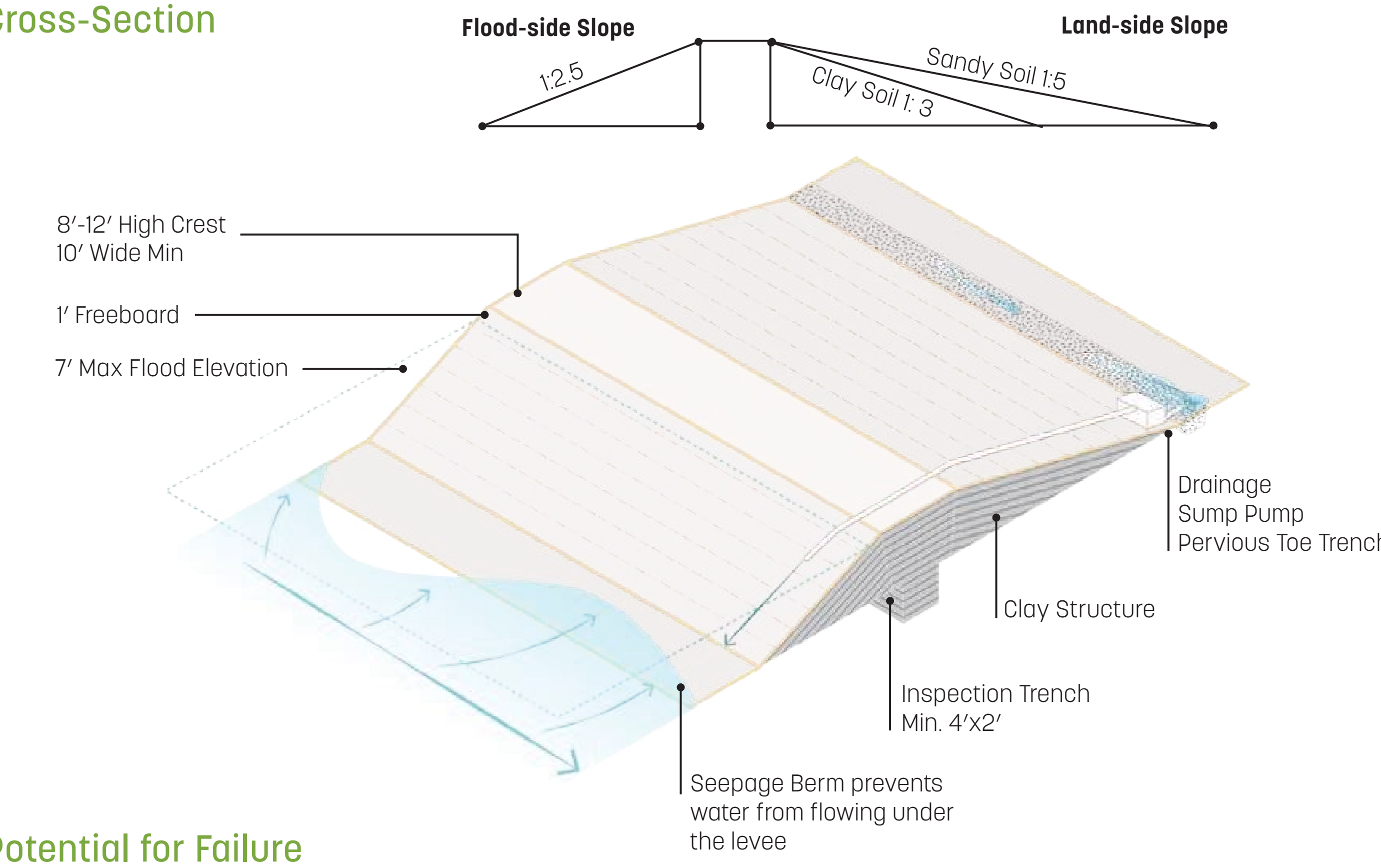
A typical levee structure has two sloping sides and a flat top. The flood-side should have a slope of 1:2.5 and a reinforced surface to prevent erosion. The slope of the land-side varies based on the soil type, from 1:3 for clay soils to 1:5 for sandy soils. The bulk of a levee should be made of layers, or lifts, of clay that are individually compacted in place. In order to be certified, levees need to be designed by a licensed engineer and constructed to federal regulations.

(Above) Theatre seating on a berm

Typical Site

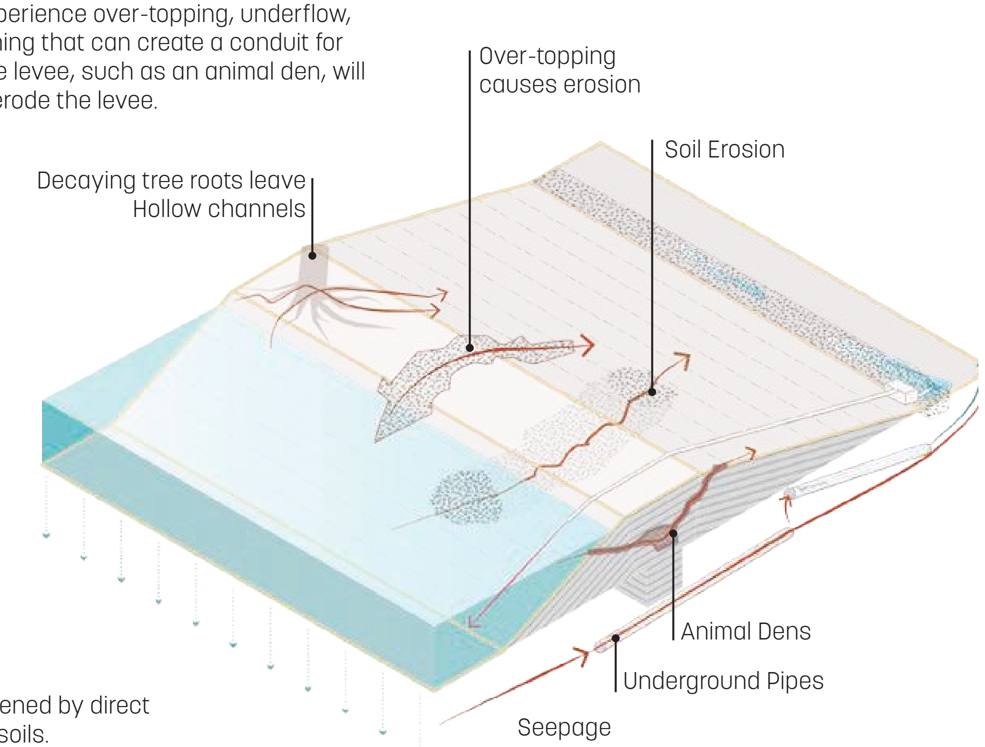


Cross-Section



Potential for Failure

Levees may fail if they experience over-topping, underflow, seeping, or erosion. Anything that can create a conduit for water to move through the levee, such as an animal den, will allow water through and erode the levee.



Levees may also be weakened by direct hits and lifting or shifting soils.

1.2.2 Flood Walls

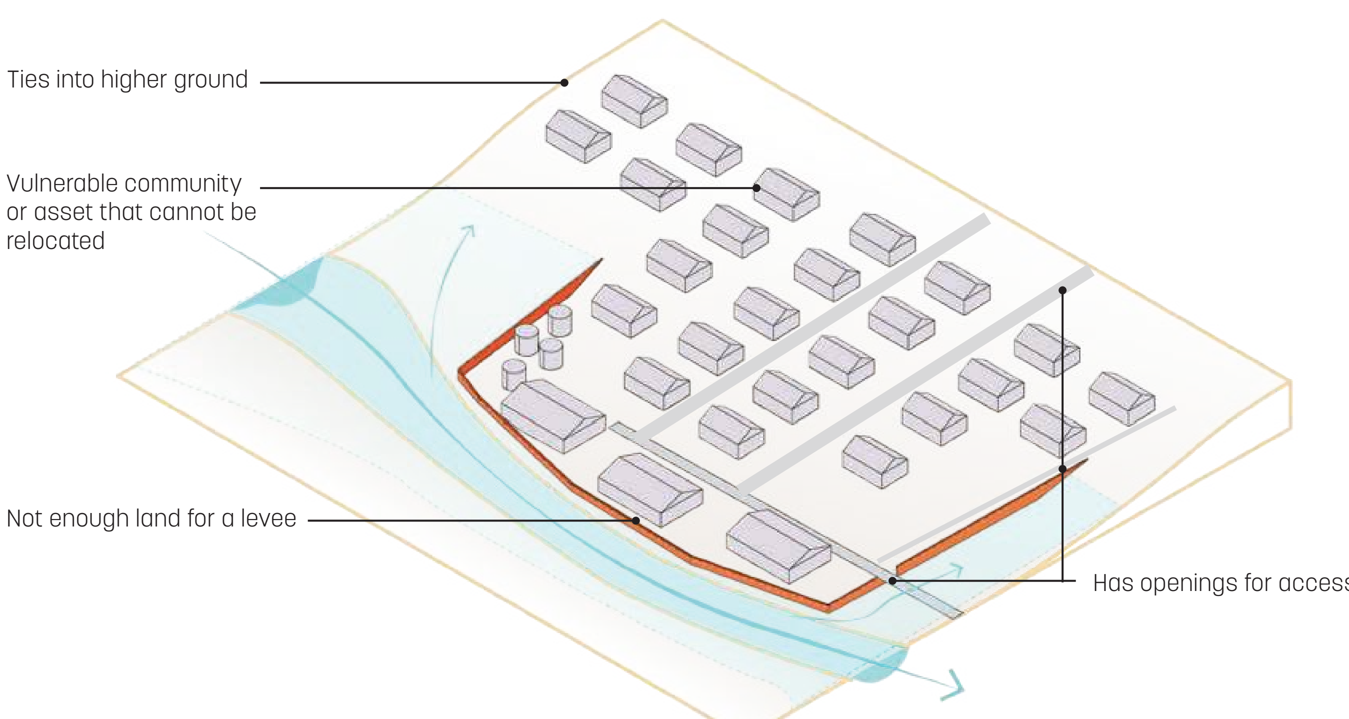
Flood walls provide protection similar to a levee but have several additional benefits. Typically made of concrete, masonry, and/or steel, flood walls are more stable than most embankment systems. Flood walls usually range from one to twenty feet high, substantially taller than their earthen counterparts. Walls can also be incorporated into the architecture of a site or appear as landscape elements and fences.

Flood walls are generally used in cases where the need to conserve space overrides the additional cost of building a wall. Flood walls typically protect a specific structure or fill a gap in a larger boundary system. Most include openings for passage when the area is not experiencing flooding. These openings must be closed before flood events to provide protection.

Flood walls fall into four structural types: gravity, cantilever, buttress, and counter-fort. Cantilever walls have the slimmest above ground profile, as their footing is below ground under the heavy floodwaters. Gravity walls have the bulkiest profile, since they rely on a land-side berm to resist floodwater pressure.

(Above) Floodwall and flood gate along the Mississippi River

Typical Site

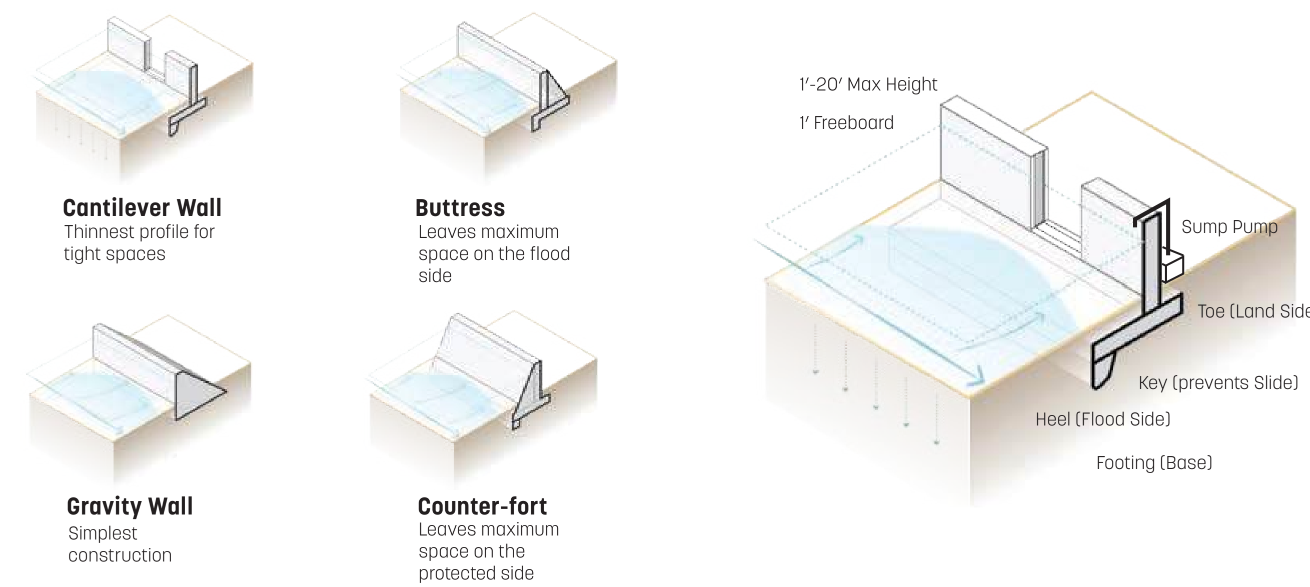


Cross-Section

Flood walls have four basic structures. It is a best practice to use the mass of floodwater to help hold the wall in place. For example, with a cantilever style wall, the base extends on the flood side, so that floodwater will flow on top of it. Walls should be higher than the design flood by at least one foot. This extra height is called "freeboard."

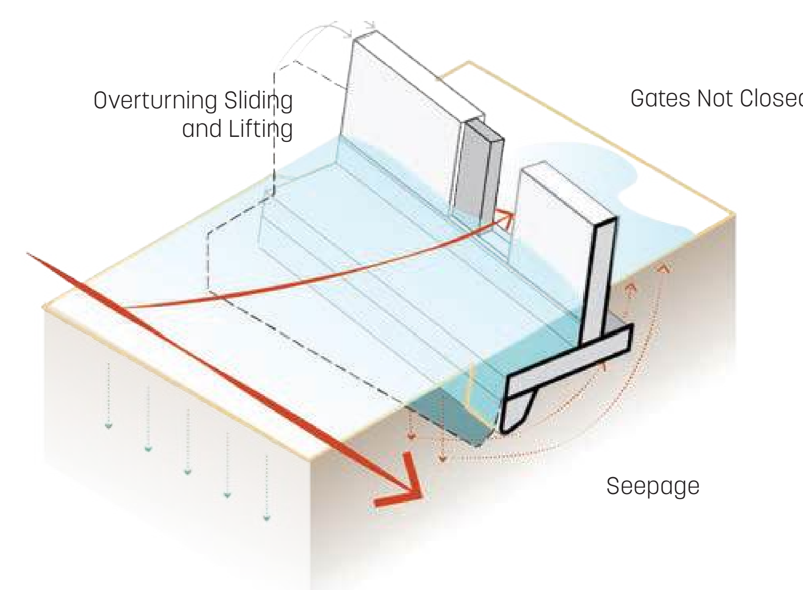
Flood walls should have a sump pump to remove water that collects on the toe (land side) of the wall.

Flood walls should not exceed 20 feet in height.



Potential for Failure

Flood walls typically fail due to an unstable base, broken walls, or gates not being closed in time to prevent flooding.



1.2.3 Flood Gates

Flood gates are part of a larger water control system, such as a reservoir, flood wall, lock, or levee. Gates can serve many different purposes, depending on where and how they are deployed. Gates on a reservoir or lock system are often used to control the water level behind the gate, releasing water when the upstream pressure exceeds the system's capacity. Alternatively, they can be used to improve downstream health by moderating water flow both in drought and flood. Gates on a levee or flood wall seal openings for roads, making the protective barrier complete.

Depending on the flood gate's use and situation, it may be moved by raising, lowering, pivoting on a hinge, or sliding in and out of a wall casing. Flood gates can be designed for manual or powered control.

Some new commercial designs are considered "passive flood wall opening systems" that are activated by floodwater and require no human intervention. Passive systems use the weight of flood water to trip a mechanical gate closure.

(Top Right) Closing a flood gate.

(Middle Right) A gate on a river system

(Below) Gate on levee

1.2.4 Retractable Flood Barriers

Another option for flood barriers is to build the infrastructure for a temporary wall. In these cases, the base for the barriers is built into the ground. The actual wall is attached only when flooding is imminent.

These systems are useful in places where it is important to keep the site open, such as public hospitals, roadways, and boardwalks. The barriers are only put up in extreme events. However, these systems require a significant amount of labor and equipment to deploy. If there is not enough time or labor available before the flood, the system will not work.

(Top Right) Retractable flood wall sectioning off a canal for repair work. Source: Aquafence

(Below) Retractable flood wall surrounding a Massport garage. Source: Aquafence

Implementation

Barriers such as levees and flood walls are generally implemented on two scales. Large-scale barriers protect a district or neighborhood, including public infrastructure, utilities, and publicly- and privately-owned assets. Site-scale barriers typically protect one building-size asset, public or private.

Barriers constructed within the Special Flood Hazard Area (SFHA) require a Floodplain Development Permit.[1] Barriers such as levees require significant land area and are likely to impede on the SFHA. In some cases, even the smaller footprint of a flood wall will impede on the SFHA and would similarly require a Floodplain Development Permit. The permit application will need to demonstrate that the barrier does not increase the flood level in the adjacent area.

City-scale

City-scale barrier projects can be implemented by a local or state government, or in partnership with the U.S. Army Corps of Engineers (USACE). As with all projects completed by the USACE, a specific process and funding commitment is required before the project can proceed.

If a local, regional, or state government implements a city scale barrier without an additional partner, several funding options exist.

FEMA Flood Mitigation Assistance Program[2]

For projects in the planning stages, FEMA provides Advance Assistance, capped at $100,000. For Community Flood Mitigation Projects, FEMA provides assistance capped at $10,000,000. Under current program rules, only one application is accepted from each state during each application cycle; FEMA will select which project is considered from a pool of sub-applicants. Selection priorities favor projects that have private partnership cost sharing, building code effectiveness grading schedule, are in communities with CRS participation, communities that are part of a cooperating technical partners program participation, and communities that have adopted International Building Codes. FEMA requires a 25% local match, unless the project would protect severe repetitive loss properties.

Projects eligible for FEMA Community Flood Mitigation Project grants include:

- Infrastructure protective measures
- Floodwater storage
- Utility protective measures
- Stormwater management
- Wetland restoration/creation
- Aquifer storage and recovery
- Local flood control to protect critical facilities (see 5.1 Critical Facilities for more information) 5.1
- Floodplain and stream restoration
- Water and sanitary sewer system protective measures

Special Districts

Local Infrastructure Financing Tool (LIFT) is a tax-increment financing (TIF) program. A special district with clearly defined borders may be established in order to capture tax revenue generated by private business activity to provide financing for public infrastructure improvements. Public infrastructure improvements may include flood mitigation infrastructure projects that protect the defined area. Many jurisdictions in Washington State, such as Mount Vernon, have taken advantage of LIFT financing for flood mitigation infrastructure.[2]

Flood Control Special Districts

A Flood Control Special District is a special tax district that is clearly defined to include at-risk parcels. This is more likely done through the advocacy of local at-risk residents. A tax is levied collectively on residents of these parcels to support flood protection investments. Through this process, larger communities in at-risk areas may also benefit from the organization of at-risk residents and the experience of local government in implementing infrastructure projects, relieving the cost burden from the entire community for such a project. This works particularly well when the assets at risk have higher personal benefit than community benefit and thus may not meet the standards required by a benefit-cost analysis. Communities on Long Island in New York have done this at the request of at-risk residents.

Local Scale

Local scale barrier projects may be implemented by a local, regional, or state government, a private entity/landowner, or a partnership between a government and a private entity/landowner.

For projects that protect community resources or assets, FEMA provides Flood Hazard Mitigation grants. A local government must sponsor an applicant or property owner and submit the applications to the State. The State then submits the formal application to FEMA. This grant is only available to communities that participate in the National Flood Insurance Program. Applications are approved based on the applicant's ranking of the project and the cost-effectiveness of the project. Applications are not guaranteed for funding. Conventional financing options may also be available for property owners.

Process

1 Planning	Define objectives: asset identification and level of protection required or desired Collect data (topography, soil composition, geological information), field survey, boring tests, geophysical surveys, existing document review Identify sites for permanent barrier installation Secure funding for implementation
2 Design & Permitting	Form teams: civil engineers, planners, landscape architects Select a suitable barrier Apply for federal, state, and local permits
3 Construction	Hire contractors to complete the work Manage contractors to ensure construction matches design drawings
4 Maintenance	Regular inspections and routine maintenance of permanent barriers to ensure continuing accreditation for the National Flood Insurance Program Regular inspections of temporary barriers, including after flood events to ensure all components are in working order and deployment teams are adequately trained.

1 Planning

Installing infrastructure at this scale is a substantial investment in time, money, and planning resources. It is important to be selective and strategic with such projects. When considering constructing an embankment or flood wall, extensive investigation into the site geomorphology, ecology, and hydrology is necessary. At a minimum, the site must meet the following criteria:

- Does not adversely affect watershed hydrology
- Does not adversely affect the local ecosystem
- Soils are able to support the structure
- There are no underground utilities
- Location can withstand inundation for the duration of the design storm
- Adheres to local zoning ordinances
- Can comply federal guidelines (such as 44 CFR 65.10 and 44 CFR 60.3)[3]
- Does not impede access to locally significant river uses or sites, such as fishing and recreation
- Adds a high degree of protection to valuable assets
- Levee/wall can connect to existing topography
- Funds and oversight are available for certification and maintenance
- There is local access to suitable fill soil

The first step in the process of erecting a flood barrier is project planning, beginning with the definition of project objectives, site selection and identification of assets to protect, and determining the desired level of protection.

Once the site has been selected, additional data will need to be collected related to topography, soil conditions and composition, and any known geological information. A field survey will need to be conducted to document the area geology and features. Subsurface explorations are also necessary, including borings and geophysical surveys. This may inform the planning team of the type and scale of barrier needed. During this stage, potential partners and funding sources should be identified.

2 Design and Permitting

For city scale barriers, a project team must be identified, and would include engineers to design the barrier and potentially architects or landscape architects to help integrate the barrier into the surrounding context and provide amenities during non-flood events.

For permanent barriers such as levees and most flood walls, construction permits will be required. These can vary across jurisdictions, but will typically include an §404 permit from the U.S. Army Corps of Engineers, as well as a permit issued by the state Division of Water Resources.

For temporary barriers, such as removable flood walls or filled containers, the appropriate product must be selected for the site condition. FM Approvals, a division of FM Global, has published FM Standard 2510, Approval Standard for Flood Abatement Equipment which recognizes temporary barriers that meet a specified approval system. In addition to product selection, this stage of the project would also include the identification of labor to erect the temporary barriers and storage locations for the temporary barriers and, if necessary, fill materials.

3 Construction

For permanent barriers, the next stage in the project process is construction. Typically the USACE constructs levees in the United States. If the Army Corps is not a project partner, the project owner may seek an experienced construction manager to oversee the construction process.

For temporary barriers, construction begins with product procurement and continues with a practice deployment of the barrier, including set-up, take-down, and storage.

4 Maintenance

Due to the dynamic nature of water, flood barriers must be periodically inspected and maintained to ensure they continue to perform as designed and desired. For levees built by the Army Corps, that organization conducts the inspections and determines federal assistance for necessary repairs. These inspections support accreditation used by the National Flood Insurance Program to reduce premiums for properties protected by the levee. For levees not built by the Army Corps, inspections and maintenance are necessary to protect against erosion, rust, animal damage, and wear and tear. The Army Corps provides an inspection checklist that is appropriate for other parties to use.

Both permanent and temporary flood walls must also be inspected periodically and maintained to ensure that they are in good working order. This is especially important following a flood event. For temporary barriers, the product manual will provide guidance on the required maintenance.

Typical Cost Factors for Barrier Systems

Barriers such as levees and flood walls typically cost millions or even billions of dollars depending on the scale and complexity. The least expensive systems are usually manufactured building-scale devices for temporary use. Cost factors typically depend on the scale and complexity of systems and components involved. Larger systems are often integrated into larger projects in conjunction with waterproofing systems, stream revitalization, and other water retention and diversion strategies. Funding may also vary based on the involvement of federal, state, and other agencies. Other important cost factors depend on the importance of certification, location, impact of insurance needs, costs of relocation/buyouts, and property acquisition. Scale and other implementation considerations in terms of cost distribution and implementor (such as the Army Corps or private/individual implementation as part of larger strategy) are also important to keep in mind.

Existing Flood Barriers

This map shows existing flood barriers and other flood control infrastructure at the regional scale. It also shows the density of buildings vulnerable to river flooding. Building vulnerability was determined by calculating the density of buildings within the 500 year floodplain and removing those that have not been historically impacted by river floods. Many of those removed from this map, and thus those considered less vulnerable, are categorized as such because they benefit from one or more flood control structures. The areas remaining—those visualized here—can be considered higher priority for allocating future resources to enhance regional flood barrier infrastructure and extending protection to additional properties.

Example Barriers

Image Source: Google Earth

A *Levee Road Levee*

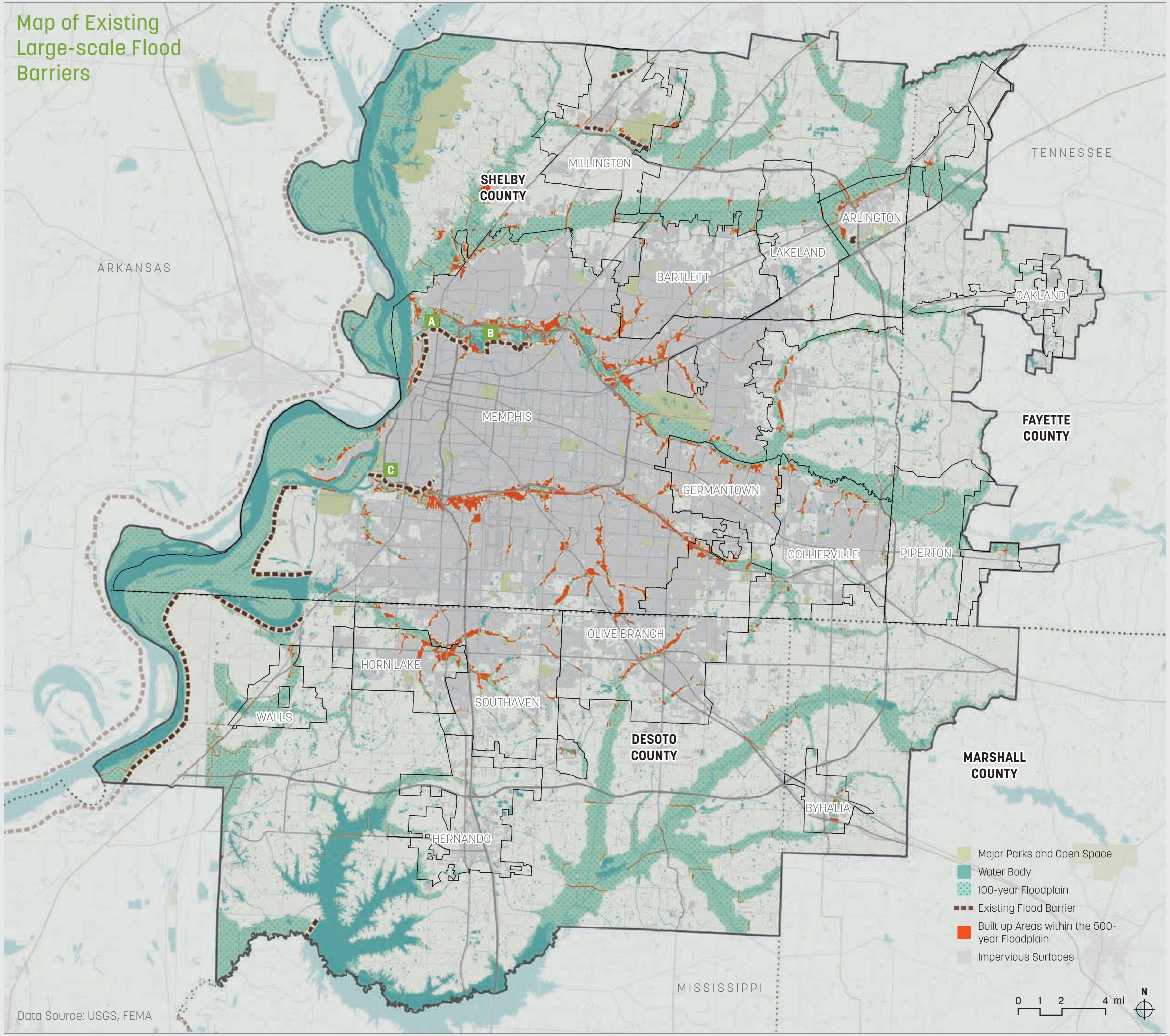
1. Wolf River
2. Levee
3. Rehabilitation Center

B *Levee in Hollywood*

1. Wolf River
2. Material Storage/Brownfield
3. Levee
4. Neighborhood

C *Karley Johnston Ave Levee*

1. Nonconnah Creek
2. Levee
3. Logistics Center



Case Studies

Tom Hanafan Rivers Edge Park Council Bluffs, IA

Completed in 2013, the Council Bluffs Riverfront Park[3] is a 90-acre public park situated within the broad riparian floodplain of the Missouri River. It is a park integrated within a levee system that provides flood protection while allowing the site to be publicly accessible.

The design of the park focuses intensity of public use and development in a core area of the existing site which allows access to the river and also preserves key habitat and riparian floodplain. Strategies to increase the ecological function of the site include nearly 20 acres of reforestation, roadside bioswales, porous pavement, diverse native plantings, and parking lot rain gardens. The ecologically sensitive areas north and south of the bridge's landing are reinforced by reforestation and wetland enhancement strategies and accessed via a series of trails and environmental interpretation.

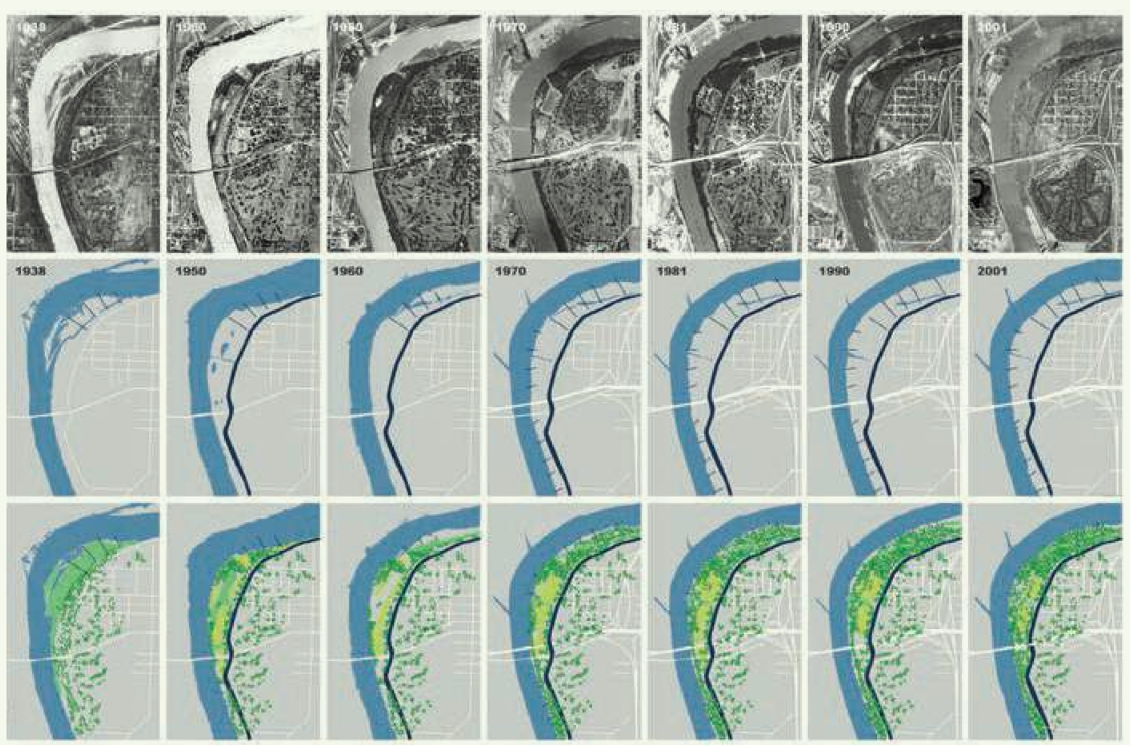
Key community amenities include public art, light installations, ice skating, and water features.

The project was designed and implemented with the U.S. Army Corps of Engineers and the Iowa Department of Natural Resources.[4]

Historic Aerial Photos

Site Structure and Levee

Vegetation



(Top Right) The park is designed to allow for occasional flooding while hosting a levee that is designed to protect against a 500 year flood event. Source: Sasaki

Undulating landscape creates distinct spaces with vegetation

Stepped landforms and open plazas establish temporary activation sites for the public

Stepped landforms alongside 'softer' areas for infiltration

(Bottom Left and Right) Photos of site and integration of seating and public-use elements into design of levee. Source: Sasaki

Flood Walls, Fargo, ND

Fargo underwent planning for flood mitigation infrastructure in anticipation of the Flood Insurance Rate Maps (FIRMs) of January 2015. The Provisionally Accredited Levee (PAL) in Fargo was required to be verified that it would be certifiable again with the new flood maps.[5] Through this certification, the flood insurance requirements would continue to be abated in this area. However, analysis of the levee revealed that it was too low and unstable to be certified. To retain its certification, the city had to improve much of its flood mitigation infrastructure.

The resulting flood wall projects are part of a larger storm water and flood mitigation strategy. From around 2015 to 2024, an estimated $309 million in construction projects have been planned for 2015-2024.[6] The flood walls along 2nd Street and 4th Street cost $16.6 million, and $17.4 million for the majority of the construction. The total cost is $1.3 billion for all of the associated work for the levee project.[7] The cost includes management services, utility relocation, property acquisition, riparian restoration, and demolition.

The flood walls were implemented as a cost-effective strategy to mitigate flooding from the Red River in areas where constructing levees is difficult due to the width of the land available. To deal with important road infrastructure, the wall incorporates areas where flood walls can be temporarily deployed in times of flooding.

(Below) Before Implementation at 4th Street.
Source: Houston Engineering

(Below) After Implementation at 4th Street.
Source: Houston Engineering

Construction Process

Excavation and prep-work for wall foundation

Installation of concrete form-work

Foundation infill and regrading

(Below) Section Along 2nd Street

(Below) Map of Implementation Area around 2nd Street

Endnotes

1 44 CFR § 65.10: "Mapping of areas protected by levee systems," reference: https://www.law.cornell.edu/cfr/text/44/65.10; 44 CFR § 60.3: "Flood plain management criteria for flood-prone areas," reference: https://www.law.cornell.edu/cfr/text/44/60.3.

2 "Local infrastructure Financing Tool (LIFT)." *City of Mount Vernon Washington* online. https://www.mountvernonwa.gov/509/Local-Infrastructure-Financing-Tool-LIFT

3 "Special Flood Hazard Area," *Federal Emergency Management Agency*, Website, last updated September 14, 2018, https://www.fema.gov/special-flood-hazard-area."Flood Mitigation Assistance Grant Program," *Federal Emergency Management Agency*, Website, last updated December 3, 2018, https://www.fema.gov/flood-mitigation-assistance-grant-program.

4 "Connect Past + Present + Future +: Downtown Omaha Bike Tour," *ASLA Central States* online, last updated 2014, http://www.aslacentralstates.org/2014-tours/2014-downtown-omaha-bike-tour/.

5 "Fargo Metropolitan Area Diversion Project: About the Project," Diversion Board of Authority, last accessed March 29, 2019, https://fmdiversion.com/about-the-project/.

6 *Fargo In-Town Flood Projects Status Report*, Presentation to Water Topics Committee, Flood Diversion Authority, June 15, 2016, available at https://www.legis.nd.gov/files/committees/64-2014%20appendices/17_5122_03000appendixr.PDF

7 Associated Press, "10-year, $1.3 billion solution for Fargo Floods?," *NBC News online*, March 22, 2010, http://www.nbcnews.com/id/35989498/ns/weather/t/-year-billion-solution-fargo-floods/#.XJ2fkJhKhaQ..

Resources

Floodplain Management and Economics

Hammond, Mark. *USACE Inland Navigation Economics, Cost-Benefit Analysis 101*. Presentation to the Inland Waterways Users Board Meeting 77, (2015).

Tennessee Floodplain Management 2018 Quick Guide. Tennessee Department of Environment & Conservation (2018).

Other Case Studies

"Community News." *Town of Southampton New York* online. Last updated March 5, 2018. http://www.southamptontownny.gov/CivicAlerts.aspx?AID=434

2
Watersheds

2.1 Large Scale Water Detention

Store Water Upstream to Mitigate Flooding Downstream

Key Benefits

1	**Increases water storage capacity and reduces destructive flooding**
2	**Reduces flash flooding and slows river flow**
3	**Provides year-round social and ecological benefits**
4	**May store water for use during droughts**

Limitations

1	**Often requires partnerships with private land owners**
2	**Privately owned sites may be reverted back to non-flood mitigation uses after contracts expire**

Overview

This recommendation proposes to use a network of land upstream throughout the Mid-South's watersheds like a sponge to store water and reduce the amount of runoff that drains into the region's creeks and streams, thus reducing river flooding for downstream communities. Other names for this strategy include "Water Farming" and "Dispersed Water Management." An example project site could be a 20-acre vacant agricultural parcel. Ditches are dug around the site and riser boards are installed to block runoff, causing rainwater to flow back onto the property where it is retained until it evaporates, drains into the ground, or can be safely released. This strategy uses the land's natural contours to create shallow retention/detention ponds and is considered a type of "green infrastructure."

The technology required for this strategy is minimal—it functions based on topography, ditches, and adjustable gates. Because of this, dispersed water detention is relatively inexpensive compared to conventional solutions, such as expanding the size of municipal stormwater pipes.

(Right) Example water detention area in Milwaukee

(Above) Illustration of a water retention site.

On the basis of water retained per dollar invested, water farming is typically several times more cost effective than conventional flood control methods. In practice, this strategy is best viewed as a compliment to conventional strategies, not as a replacement. It can provide a cost-effective boost and a sustainable enhancement to the regional stormwater drainage system.

There are several factors that make dispersed water management a good strategy for the Mid-South. These include:

- The frequency and severity of river flooding: this is a region-wide problem and could be significantly mitigated with a network of dispersed water retention sites.
- Widespread water quality challenges: many of the Mid-South's waterways have poor water quality. This strategy addresses this issue by filtering run-off before it enters the region's creeks and streams.
- The need for ecological conservation and restoration: high-value ecological areas are rapidly being consumed by development. Putting them into service as water retention areas is a good way to protect them and enhance the functioning of otherwise degraded landscapes.
- Availability of suitable sites: the Mid-South has an abundance of well-suited, inexpensive upstream land throughout its watersheds

The depth of water retained on each site is usually a few inches up to a few feet. Since the water depths are shallow, increasing acreage is the best way to scale up the impact of this strategy. Successful case studies typically involve large regional networks that include dozens of sites that collectively form a large-scale water retention system.

Benefits of Large-Scale Water Detention

The benefits of water farming are numerous, including:

- Flood reduction
- Improved water quality
- Groundwater recharge
- Recreational amenities
- Habitat restoration

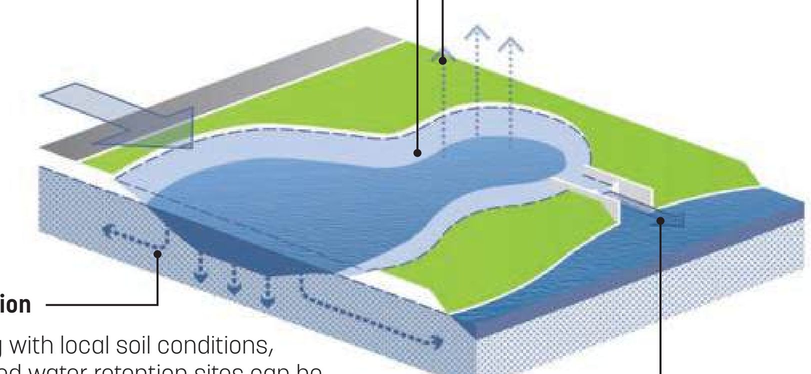
See the accompanying diagrams for more information about how each of these benefits is achieved.

Beyond the direct hydrological benefits that this strategy provides, water farming sites can be used simultaneously to achieve other valuable co-benefits. One example of this is renewable energy generation: project sites can be designed to include wind turbines, solar arrays, or other sources of renewable energy. Another example is wetland banking: there is a global market for wetland conservation via credits that could be unlocked through the creation of a network of dispersed water retention sites, since these sites essentially function as wetlands from an ecological perspective.[1]

(Above) Example of retention mechanism.
Source: Sasaki

Water Quantity

Helping to moderate peak flow events, Water farms can be designed to maintain pre-development runoff levels and help to reduce downstream flood risk and water management cost. Stored water can be managed in a number of ways, depending on client and regulatory needs.



Water Quality and Erosion Prevention

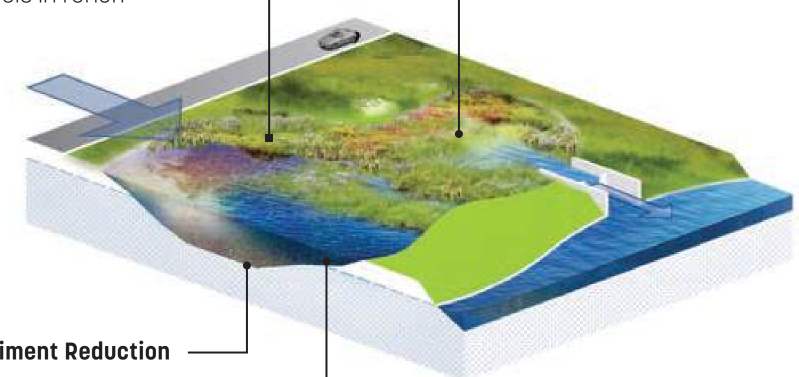
Stabilizing soil resources and ensuring clean water for future use, water farms utilize best management practices to filter overland flow, reduce total suspended solids, and provide efficient, low-cost removal of nutrients. As an additional benefit, integrated wetland systems and vegetative shading can help to cool and oxygenate water, improving habitat quality for wildlife.

Buffering

Vegetated buffers and swales help to effectively reduce suspended sediment and nutrient levels in runoff

Nutrient / Pollutant Reduction

Wetland vegetation metabolizes excess nutrients and can degrade and stabilize many common water pollutants



Sediment Reduction

Extended storage of water effectively settles out suspended solids, improving overall water clarity

Water Temperature Reduction

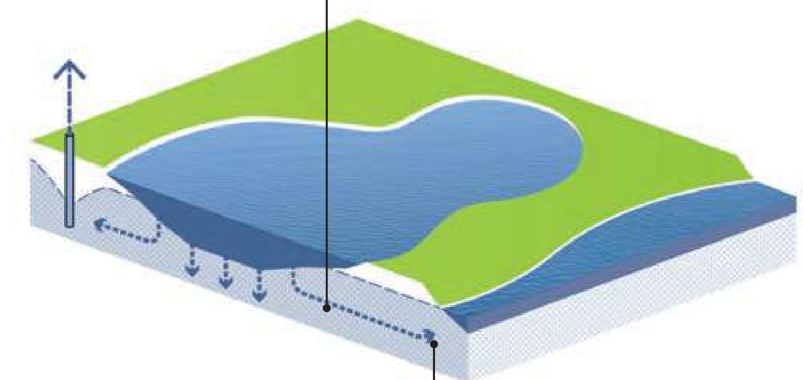
Heated runoff from impervious surfaces is cooled by passing through wetland vegetation and deeper water depths, improving oxygenation of the water

Groundwater Recharge

When coupled with the appropriate soil and geological conditions, water farms can provide a low-tech low-cost alternative to recharging and maintaining local aquifers and stream base flows.

Replenish Local Aquifers

Designed around local soil conditions and surficial geology, dispersed water retention sites can be used to maintain local aquifers



Maintain Base Flow

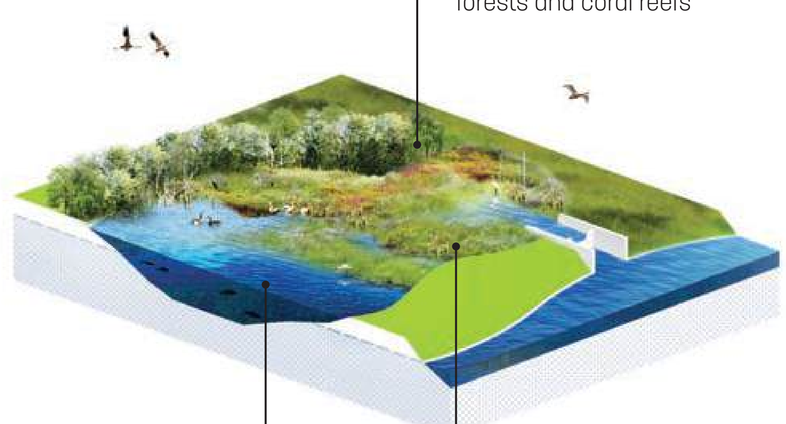
Allowing excess runoff to infiltrate into the groundwater helps to maintain consistent baseflow in local streams

Wildlife Habitat

Building upon improved water quality conditions, water farms can provide a framework for a productive and resilient ecosystem, supporting patches of high biodiversity. These patches of high primary (vegetative) productivity become a critical nutrient and carbon sink, providing some of the highest sequestration rates of carbon of any ecosystem.

Highly Productive Ecosystem

Wetlands are some of the most highly productive ecosystems in the world, often comparable to rain forests and coral reefs



High Biodiversity

Due to the high net primary productivity at the their foundation, wetland systems support an immense variety of microbes, plants, insects, and other wildlife

Nutrient and Carbon Sink

Freshwater wetlands are significant to global carbon and nutrient cycles, storing up to 200 tons of carbon/acre

Recreation and Education

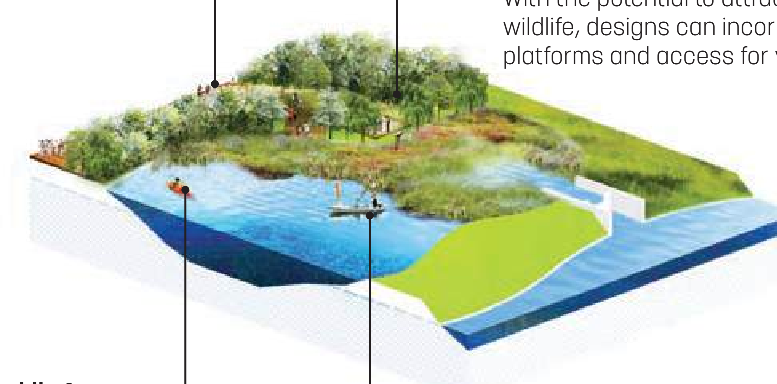
While water farms can be highly variable in size and location, there may be recreation and education opportunities providing
a place for interaction with the landscape.

Interpretive Opportunities

Dispersed water retention sites offer an ideal opportunity to educate visitors about the benefits of "green infrastructure"

Birdwatching / Wildlife Viewing

With the potential to attract wildlife, designs can incorporate platforms and access for viewing



Paddle Sports

If water quality (and scale of facilities) supports contact, open water areas could be used for paddling and other uses

Fishing

While dependent on water quality, dispersed water retention ponds could be stocked and offer a local spot for anglers

Performance Comparison

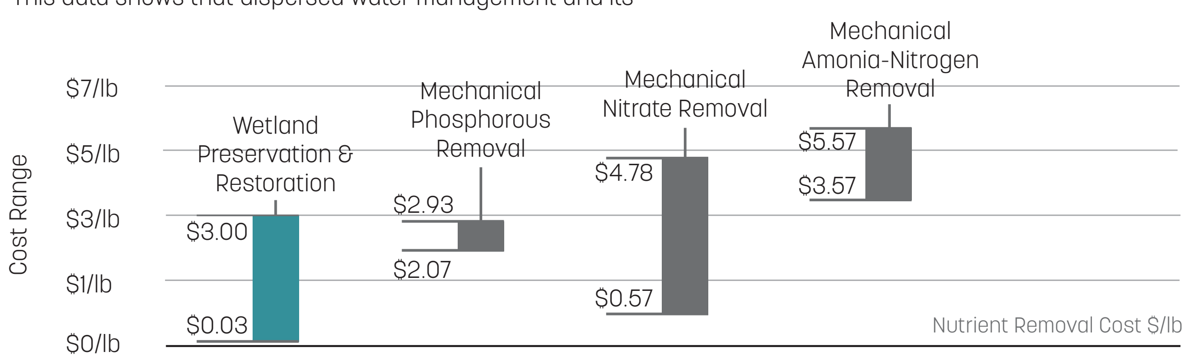
In general, dispersed water management performs very well compared with conventional alternatives. Performance in this case is measured by the cost-per-unit-of-service to control water quantity and quality. In the charts below, the bars represent different water management approaches and technologies. The vertical distance of the bars shows the range of costs-per-unit-of-service derived from empirical precedents.

For the sake of providing a broad overview, this cost comparison considers multiple green infrastructure variations that all generally fall under the heading of dispersed water management. These are represented by the green bars. Conventional options are represented as gray bars. The key comparison is between the averages and ranges of the green bars versus the gray bars. Specific performance metrics from select case studies appear later in this chapter.

Water Quality

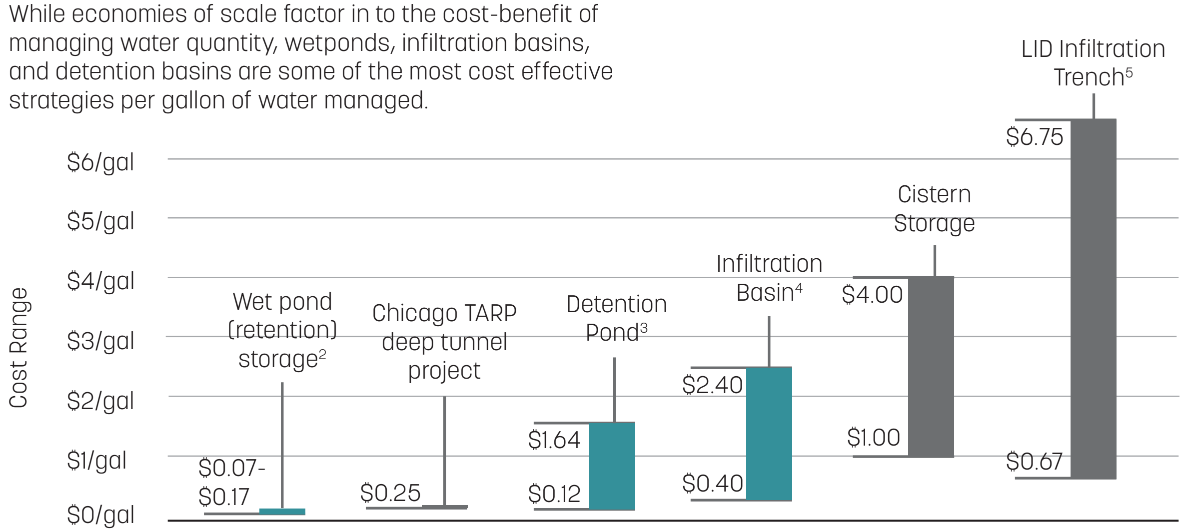
Dispersed water management functions ecologically like a wetland system. Wetlands are well known to provide a variety of valuable ecosystem services, including water quality improvement by absorbing and filtering excessive nutrients

This data shows that dispersed water management and its associated green infrastructure variations are, at a minimum, cost competitive with conventional technology, and in many instances, are significantly less expensive and provide a much higher value on a per-unit-of-service basis compared with gray infrastructure alternatives.



Water Quantity

While economies of scale factor in to the cost-benefit of managing water quantity, wetponds, infiltration basins, and detention basins are some of the most cost effective strategies per gallon of water managed.



Site Suitability Criteria

Vacant or agricultural land is important because the water retention sites will be intentionally flooded, which would be unacceptable on developed land. It is also essential that the sites either be publicly owned, or, if they are privately owned, that they be low cost. High-value private land will present a prohibitively high cost barrier. Vacant rural land and grazing areas are often good matches from a land use and cost perspective.

Multiple soil types work with this strategy, but make sure to pick the appropriate type based on the program's specific goals. If ground water recharge is a key goal, then the sites should have soils with good drainage capacity; if more of a wetland condition is desired, select for hydric soils.

A flat site is important to maximize the amount of horizontal space that will naturally collect water. Sites with steep slopes require expensive regrading.

Pre-existing drainage structures are beneficial in two ways: (1) they indicate sites that naturally collect water and would thus make good water retention areas and (2) in some instances, they can be reused as the retention mechanism itself, thus saving money to build new ditches and riser boards.

Adjacency to rivers and streams is valuable because it positions the site for maximum impact on water quantity and quality right before it enters the waterway—it is the last stop for run-off and the last "line of defense".

Finally, since these sites are protected and put into service as quasi-wetlands, prioritizing areas with high ecological value achieves the added benefit of protecting an area of environmental concern while also providing hydrological benefits to the region.

There are several potential sites across the Mid-South that could be used for dispersed water retention. When looking for a suitable site, consider the following:

Essential Criteria

- Vacant or agricultural land use
- Public land or low cost private land
- Minimum size of 10 acres per site
- Function-appropriate soil type

Preferred Criteria

- Minimal slope
- Preexisting drainage structures
- Adjacency to a river or stream
- High ecological value
- Large land area: the larger the better. Some precedent sites are over 1,000 acres.

Proposed Water Detention Sites

Using the criteria described above, several sites were identified as being suitable for large-scale water detention. These sites are depicted on the map to the right. For Shelby and DeSoto Counties, the proposed sites are parcel-based, whereas for Marshall and Fayette Counties, due to data limitations, the sites are based on contiguous areas with similar or complimentary land cover types that would support this strategy.

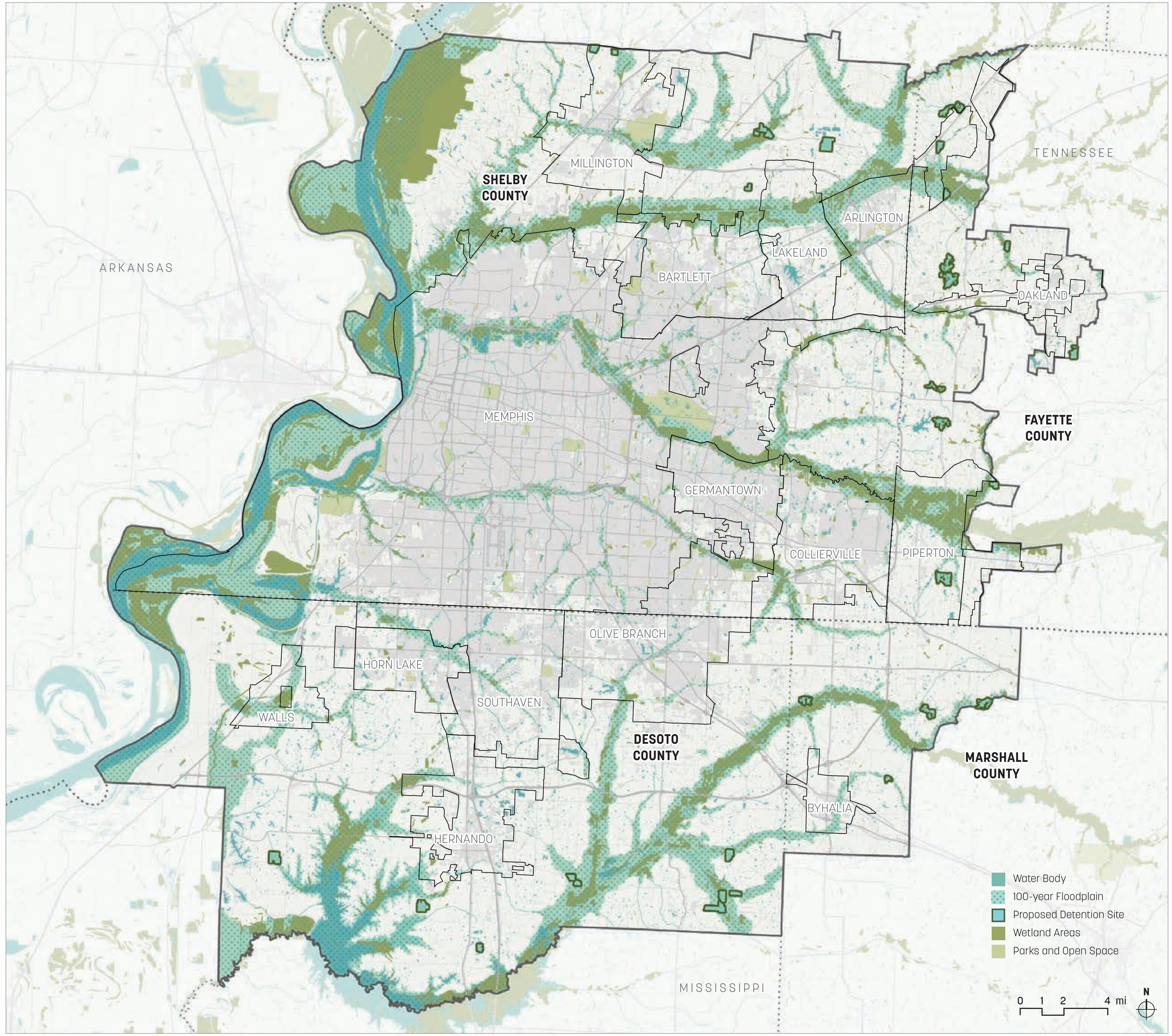
These sites are almost entirely rural—most are in unincorporated county land. All are at least 10 acres in size, and many are much larger than that. They are also almost always comprised of active or fallow agricultural land or undeveloped open space. Where land use data was not available, the following land cover types were selected: emergent herbaceous wetland, grassland, pasture/hay, and shrub/scrub. To further narrow down potential sites, the following conditions were considered: sites that are flat or gently sloping, sites situated shortly upstream from surface water to act like a sponge catching water draining into the region's waterways, and sites removed from current or likely future development.

This list of potential sites provides an objective starting point, based on regional geographic data, for implementing a dispersed water management program in the Mid-South. More acreage is proposed than what would feasibly be put into service, since some of these sites may be more suitable than others based on factors like land ownership, willingness of the land owner to participate in a program, site contaminants, easements, and zoning, to name a few. Additional site-by-site due diligence would be required to make a final selection and begin implementation.

There are 32 sites total adding up to nearly 2,400 acres. A minimal network size target would be 1,500 acres. The following is a further breakdown of these sites by County:

Acres of Storage by County

County	Acres	Sites
Fayette	944	13
Desoto	761	9
Shelby	416	6
Marshall	273	4



Implementation

Dispersed water retention programs have been historically initiated by diverse groups of stakeholders across multiple sectors that come together over a shared interest in using green infrastructure for regional watershed management. Once these programs are fully established, they usually reside within the domain of one or more governmental entities that have responsibility for water infrastructure. In the Mid-South, a program like this could be undertaken by the engineering departments of one or more jurisdictions, for example. For programs with an explicit conservation focus, conservation non-profits often act as lead partners and a key source of funding.

One of the primary issues to address is sourcing the land for the retention sites. This is most commonly achieved through some combination of the following four options:

1. Use public land
2. Use land owned by a non-profit willing to participate at low or no cost, such as a conservation land trust or a public research university
3. Purchase private land
4. Pay private land owners to use their land rather than acquiring it

Options 1 and 2 are typically lower cost, but options 3 and 4 may also be required to access key sites or increase the overall network extent. In some instances, paying private landowners is viewed as a program feature rather than a cost. For example, paying rural landowners to retain water could be viewed as an economic development strategy that provide them with additional income and offsets the pressures of sprawl development (see the FRESP and NE-PES case study for additional information on this program consideration on 167). When private land is involved, the question of permanence comes into play. If the sites need to be permanent flood mitigation assets in a regional hydrological system, such as in the Greenseams case study (165), acquisition or an easement is necessary. On the other hand, if the program is intended to pay private landowners as service providers, either because this arrangement better suits the buyers (government) and/or sellers (landowners), then option 4 may be preferable, as in the FRESP/NE-PES case study.

With a fee simple land purchase (option 3), there is typically a long-term conservation interest that overlaps with the water retention goals which makes the acquisition financially compelling. The amount, sources, and timing of program funding will also directly affect which of these options is most feasible.

Option 4—paying private landowners for environmental services—is the most complex from a transactional perspective. It is based on a contract that outlines site usage, payments, and the length of commitment. The price for service must be higher than what the landowner could otherwise achieve using the land for some other purpose, while it must be lower than what the buyer would pay to produce the same service by some other means.

Other Considerations

In any arrangement where the level of service needs to be quantified, the amount of water retained and/or pollutants reduced is calculated based on a site model assuming average annual precipitation, rather than being measured empirically. This is for multiple reasons:

- The buyer needs to be able to budget predictably. If the price were connected to real time fluctuations in performance, it would be impossible to know how much to set aside for the program. During a dry year, the buyer would pay very little; during a wet year, the opposite would be true. The buyer—City, County, or Regional government—needs to anticipate with consistency how much it will spend on these programs.
- The sellers needs the assurance that they will receive a consistent and predictable cash flow in order to decide whether to participate in the program. If a farmer, for example, participates expecting a certain level of payment and declines to plant or graze their land in order to put it into service, it may hurt them financially if precipitation—and thus service—ended up being less than predicted.
- Real time measurement is logistically burdensome and expensive. A scaled-up system will have many large properties spread out across a wide region. Monitoring, compiling, and reviewing data in real time would be cost prohibitive.

Contract length is another key variable in the payment-for-service model. Some private landowners will only make their land available on a time-limited basis, rather than an outright sale or permanent easement. A mutually favorable contract length is typically about 10 – 15 years, with an option to renew that must be agreed upon by both parties. This also means that the buyer needs to plan for the eventual possibility that the land would revert to a non-water retaining use after the contract ends.

In the payment-for-service model, it is often useful—though not essential—to have a neutral 3rd party, such as an environmental non-profit, to identify potential landowners for participation and broker the negotiations regarding price and terms between the buyer (the government) and the seller (the landowner).

Key Programs

The EPA offers several grant and loan programs that could be used to launch and support a dispersed water management program. These include:

- EPA's 319 Grant Program for States and Territories www.epa.gov/nps/319-grant-program-states-and-territories
- EPA's Water Pollution Control (Section 106) Grants www.epa.gov/water-pollution-control-section-106-grants
- EPA's Clean Water State Revolving Fund www.epa.gov/cwsrf

Note that all of these funding sources are targeted at water quality improvement, so an eligible program would need to emphasize water quality as a primary program goal.

Case Studies

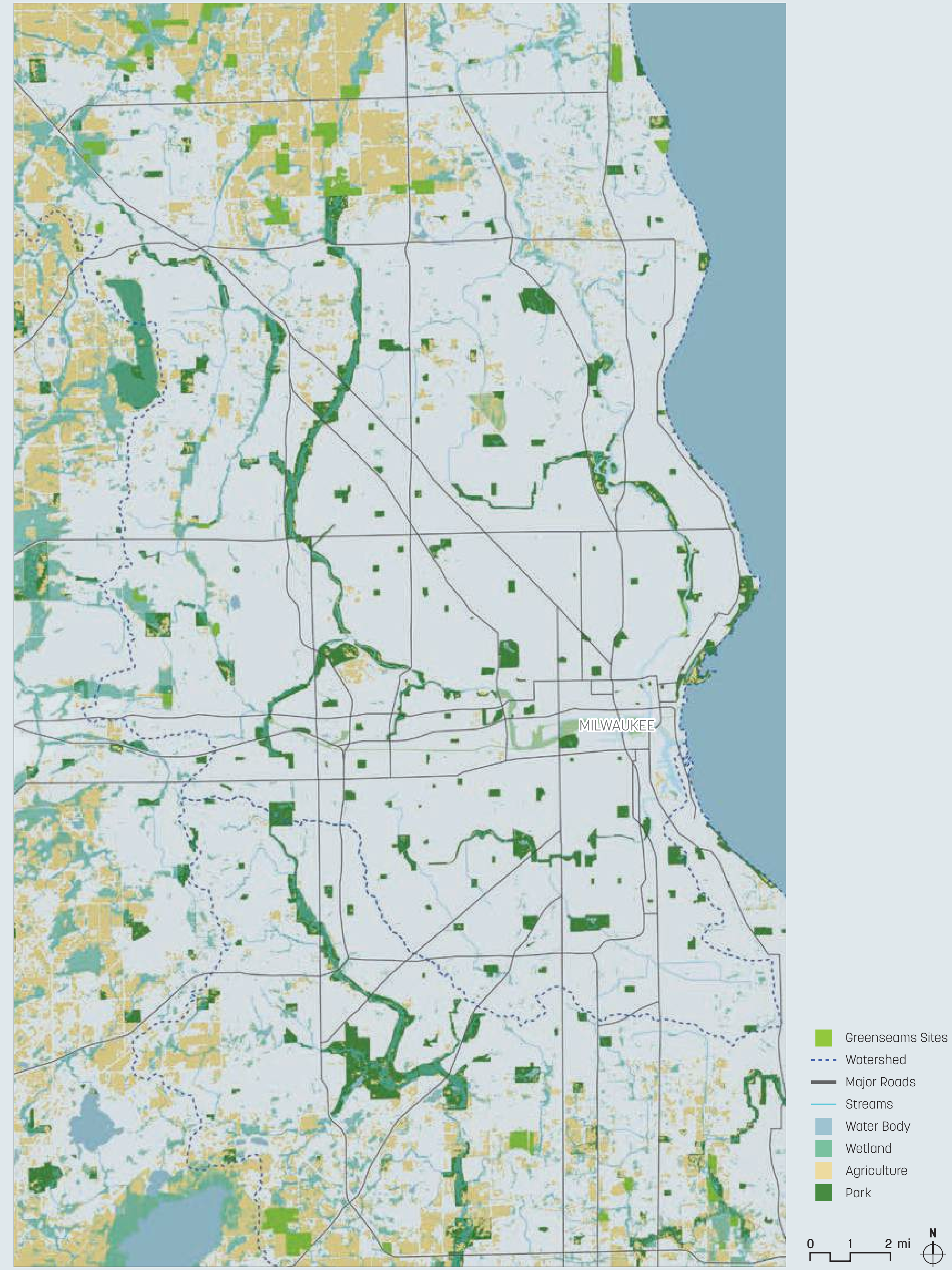
Greenseams, Milwaukee, WI

Greenseams is a flood management and conservation program, active since 2001, that was initiated by the **Conservation Fund** and the **Milwaukee Metropolitan Sewerage District**, the latter being a regional entity responsible for water reclamation and flood management services across greater Milwaukee.[6] The program has assembled a network of **3,700 acres** of property that store and drain water using natural landscape characteristics with minimal site alterations. These properties collectively provide a variety of benefits to the region, including flood mitigation, habitat restoration, erosion reduction, education, and recreation.

The program was prompted by severe flooding that occurred across the region in the late 90s, along with an emerging consensus that a mix of green and gray infrastructure would be the best approach for achieving the region's watershed management and ecological goals. The land for the program comes from both private and public sources. Funding is comprised of dollars traditionally allocated to the storm and wastewater systems, as well as dollars from the environmental conservation community.

From a purely performance-based perspective, Greenseams has been a huge success. The network of sites retains over **1.5 billion gallons of water** at an average cost of $0.31 per gallon, which is over **10x less expensive** than conventional systems on a dollar-per-gallon basis. The program is even more successful when considering the other non-flood-related benefits that are listed above but harder to quantify succinctly.

(Right) Photograph of greenseams site. Source: Greenseams

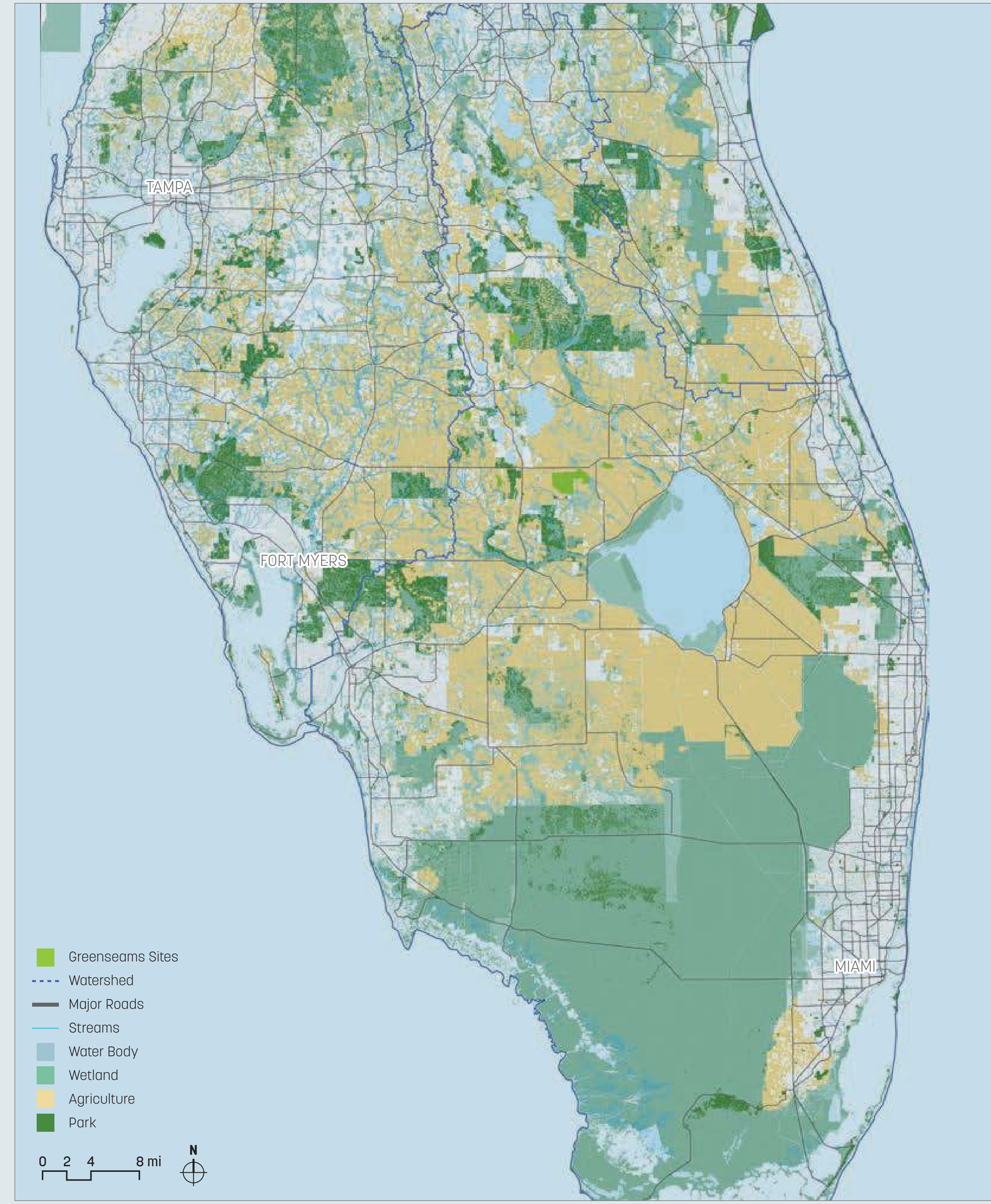


FRESP and NE-PES, Central and South Florida

FRESP—the Florida Ranchlands Environmental Services Project[7]—and NE-PES—the Northern Everglades Payment for Environmental Services Program[8]—are related initiatives with the same general geography and objectives. FRESP was a successful pilot project launched on 8 participating ranches in 2005 by the **World Wildlife Fund, the ranching community, academic researchers, and a consortium of State and Federal partners** to test the feasibility of using ranch land to provide dispersed water management benefits to Central and South Florida, including the greater Everglades ecosystem. FRESP's success resulted in NE-PES, which is a scaled-up program implemented by the **South Florida Water Management District** (SFWMD), a public-sector regional water management entity. Any rancher within the Northern Everglades with suitable land is eligible to participate in the program. Like Greenseams, these programs provide multiple benefits to multiple stakeholders, including flood mitigation, water quality improvements, habitat restoration, and de facto land conservation through the additional revenue streams generated for the ranchers.

The land for these programs is almost entirely private and is serviced by the SFWMD through a contract analogous to a lease. The payment rates are established by a reverse auction system wherein qualified landowners submit quotes to the SFWMD at which they would be willing to put their land into service. The most competitive sites are selected based on cost and site characteristics, and the on-site retention is achieved by making low-tech site modifications such as ditches and riser boards. The cost to use the land, construct the water retention mechanism, and administer the program is covered by SFWMD's annual budget. The services that are purchased include both water retention and/or water quality improvements via phosphorous or nitrogen removal.

FRESP's success is evident from its evolution into NE-PES, which itself is admired as a scaled-up, payment for environmental services program. In terms of water retention performance, the program sites are estimated to retain over **4 billion gallons** of water. This rate of service is approximately **5–10x** less expensive than conventional systems in terms of dollars-per-gallon. These figures only address the water retention and flood mitigation benefits and do not include the program's other significant benefits in terms of water quality, conservation, and economic development.



Endnotes

1 Conservation Compliance and Wetland Mitigation Banking, Website, https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/farmbill/?cid=nrcseprd362686.

2 NY Rising Rye Project Cost Estimate Documentation

3 NY Rising Rye Project Cost Estimate Documentation

4 Costs and Benefits of Storm Water BMPs

5 Costs and Benefits of Storm Water BMPs

6 Milwaukee Metropolitan Sewerage District (MMSD) Greenseams, Website, https://www.mmsd.com/what-we-do/flood-management/greenseams.

7 Northern Everglades- Payment for Environmental Services (NE-PES) Program, Website, http://www.fresp.org/ne_pes.php.

8 Florida Ranchlands Environmental Services Project (FRESP), Website, http://www.fresp.org/.

Resources

Flood Information

FEMA Flood Maps (FEMA, 2019), https://msc.fema.gov/portal/home

USGS Flood Information (USGS, 2019), http://water.usgs.gov/floods/resources/

Map My Risk Flood Tool (FloodTools, 2019), http://www.floodtools.com/Map.aspx

Water Quality

EPA National Summary of Impaired Waters (EPA, 2019), https://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T

USGS Water Quality Data for the Nation (USGS, 2019), http://waterdata.usgs.gov/nwis/qw

2.2 Watershed Conservation

Protect Critical Watershed Assets

Key Benefits

1	**Reduces flooding with natural detention and infiltration methods**
2	**Cleanses the nutrient and pollutant load from stormwater runoff**
3	**Protects and replenishes the Memphis Sand aquifer**

Limitations

1	**Protected land is not available for certain uses, including development**

Overview

For many, the first things that come to mind when they hear "critical assets" are built structures, such as roads, bridges, and power lines. This section is about another equally critical but uniquely natural asset: the watershed. The components of a watershed control the quality and quantity of life-giving water available to a region. Watershed health affects how much water is available, whether or not it is potable, and the frequency and intensity of floods and droughts.

Watersheds are drainage basins formed by topography where all the precipitation that falls within it drains to the same river. When functioning well, watersheds reduce flooding, increase infiltration, and improve water quality. In urban areas around the country, development in the watershed has reduced its ability to slow, filter, store, and infiltrate water. Impervious roads and buildings whisk rainfall downstream, picking up spilled oil, chemicals, fertilizers, and pesticides along the way. The result is more frequent and severe flooding along with degraded water quality.

Like roads and bridges, we need to maintain and protect watersheds if they are to remain in working order. This starts with caring for key components of the watershed: wetlands, aquifers, and headwaters.

(Right) Wetland in Bartholomew Bayou, Arkansas. Photo by Keith Yahl

Watersheds in the Mid-South Region

Several different rivers run through the Mid-South, with headwaters and tributaries contributing to each. The natural topographic ridges and valleys determine the boundaries between watersheds.

1 Headwaters

In the Mid-South, Headwaters tend to be wooded land in rural areas.

2 Wetlands

Wetlands occur alongside the mid and lower reaches of rivers. They are often located inside river bends or flood plains.

3 Aquifer Recharge Area

The Memphis Sand aquifer supplies high quality drinking water to the Mid-South. A large aquifer recharge area runs along the eastern portion of the region.

Watershed/Subbasin Unit
Wetland Areas
Tributary/Headwater
Waterbody
Aquifer Recharge Area
Impervious Surface/ Development Intensity
Major Parks, Open Space, and Tree Cover

2.2.1 Wetland Protection and Restoration

Wetlands are vital to watershed health. For the Mid-South region, the most important function of a wetland is in reducing flooding. Wetlands are inherently able to store large volumes of water in their wide, shallow basins. Beyond storage, wetlands improve water quality through natural biological, physical, and chemical processes. Wetland vegetation stabilizes soil, reducing erosion along the banks of streams and ponds. What's more, wetlands can be valuable public assets for recreation, education, and boating.

The best way to distinguish a wetland from an area that is experiencing temporary flooding is through the soil and vegetation. Wetlands are defined by their anaerobic water-logged "hydric" soils and their water-loving "hydrophytic" vegetation.

Unfortunately, development during the 18th, 19th, and 20th centuries destroyed the majority of the wetlands in the United States. Recent decades have seen some improvement– wetlands are now protected by Federal and State regulations. In order to alter an existing wetland, a developer would need to obtain an Aquatic Resource Alteration Permit (ARAP). These protections are an improvement, but they are still limited.

Preserving and enhancing wetlands is a critical part of resiliency in the Mid-South. A first step towards this goal is mapping all existing wetlands and identifying candidate sites for conservation. Outside of the conservation area, development and use should be limited through various zoning and regulation methods.

Expanding existing wetlands or restoring historic ones is a follow-up step in increasing flood capacity and water quality. The cost and efficacy of such programs varies dramatically based on the situation. Creating new wetlands on sites that did not have them pre-development is usually not successful.

What is a Wetland?[1]

- Permanently or seasonally flooded
- Near rivers, lakes, and low-lying areas
- Depending on location and characteristics, may be called marshes, mires, ponds, fens, swamps, bogs, lakes, or floodplains

Issues

1. Filled wetland to increase land for development
2. Pollutant runoff from development and industry
3. Fertilizer runoff from lawns and agriculture causes algae blooms
4. Dredging for boats and reservoirs reduces wetland health

Conservation

Many of the wetlands in the Mid-South are in rural areas that have not been developed. Where possible, this land should be officially conserved. For all critical watershed assets, a best practice is to create buffers from development.

Where land will be developed, special zoning, easements, and transfer of development rights are some of the ways to regulate development that could pollute, dry up, or flood the wetland.

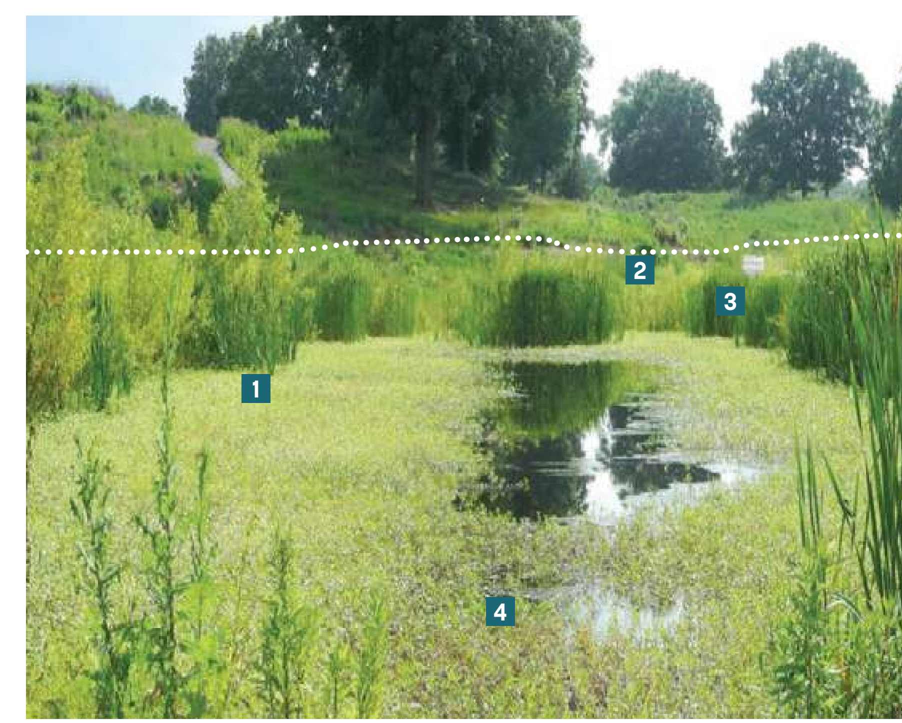
Using zoning is an effective way to create buffers around sensitive watershed assets like wetlands. Typical buffers in the US range from 100' to 500' away from the asset.

Process

1 Identify Land Asset to Protect	Identify land that it is important to preserve Work with landowners to gain control of the land. This may be through purchasing private land, easements, public-private partnerships, conservation groups, etc.
2 Zone	Define what kind of development will and will not disturb the wetland Delineate approved land use and development on official zoning maps
3 Manage Future Uses	Create a process for oversight of future land use and development. For conservation, this may be a public-private partnership organization, a department of the government, or a conservancy, etc. Require special permits to develop within the protective zones around the wetland

Wetlands at Work

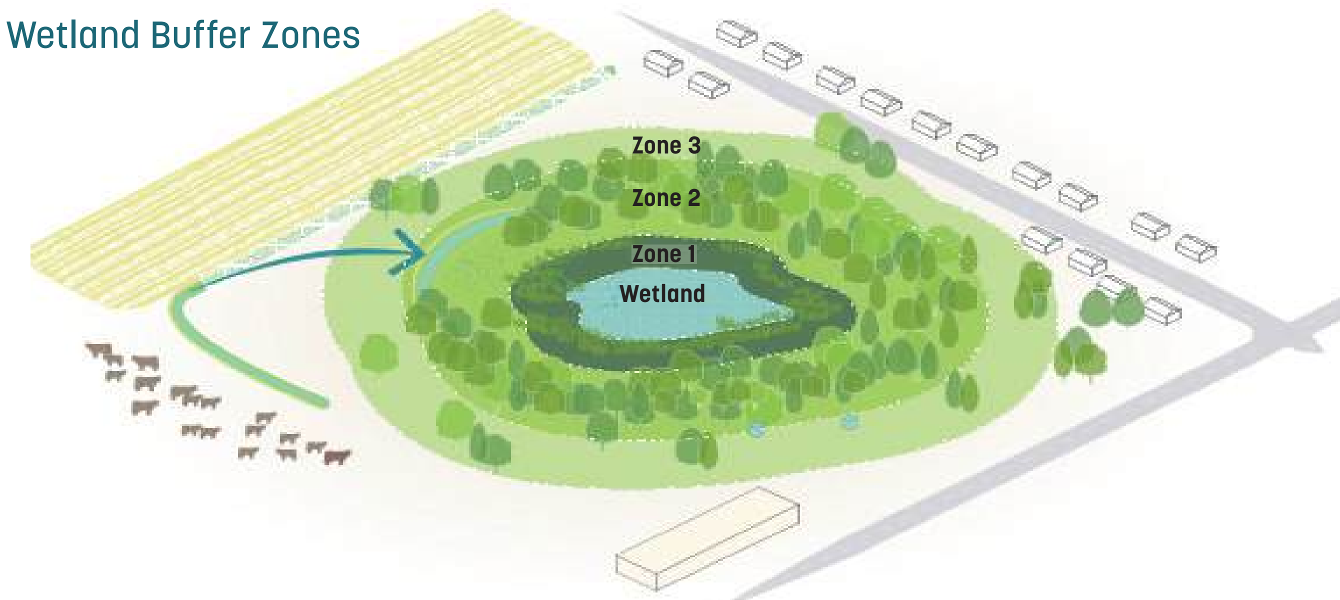
1. Microbes digest pollutants and fertilizer
2. Certain wetland plants absorb pollutants and convert them into harmless grasses and byproducts
3. Certain wetland plants accumulate pollutants in plant tissue, which can be removed
4. Filtration: plant roots and wetland soil filter shallow water



Protective Zoning

Permitted uses within each zone vary based on distance from the asset. For example, a soccer field can be located 50 ft from a wetland, but a parking lot must be 100 ft and a house 150 ft.

Wetland Buffer Zones



Zone Land Uses

Zone 1

Undisturbed Zone

Minimum 50 ft

Development limited to road crossings at least 1,000 ft apart and pedestrian trails.

Zone 2

Transition Managed Forest Zone

Minimum 100 ft

Stormwater management, such as swales and detention ponds permitted

Hiking and biking permitted

Zone 3

Outer Runoff Control Zone

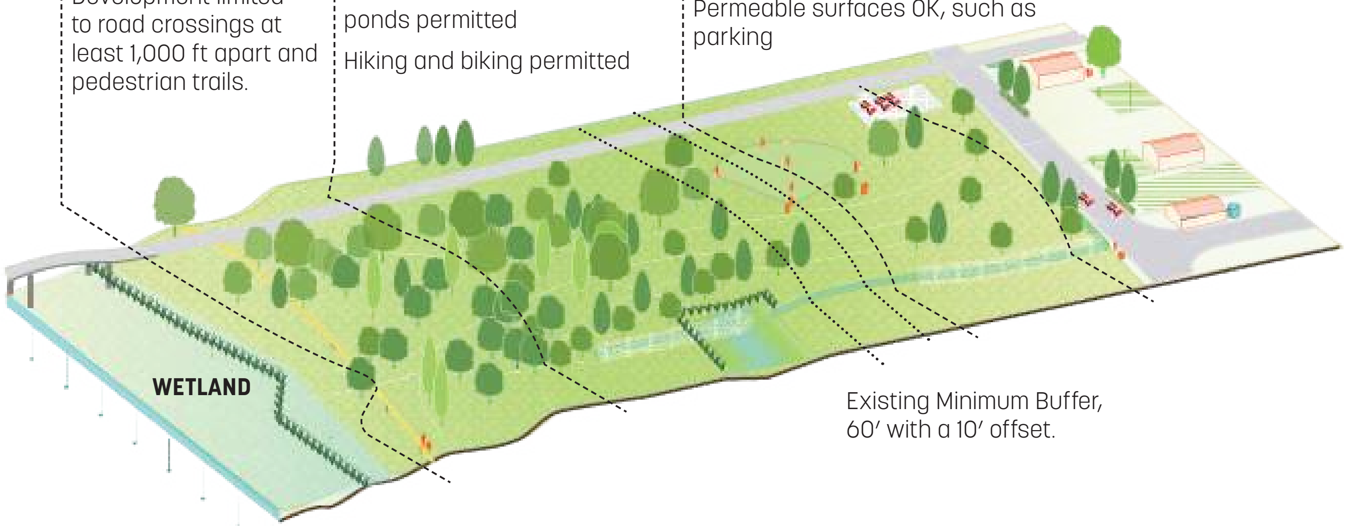
Minimum 50 ft

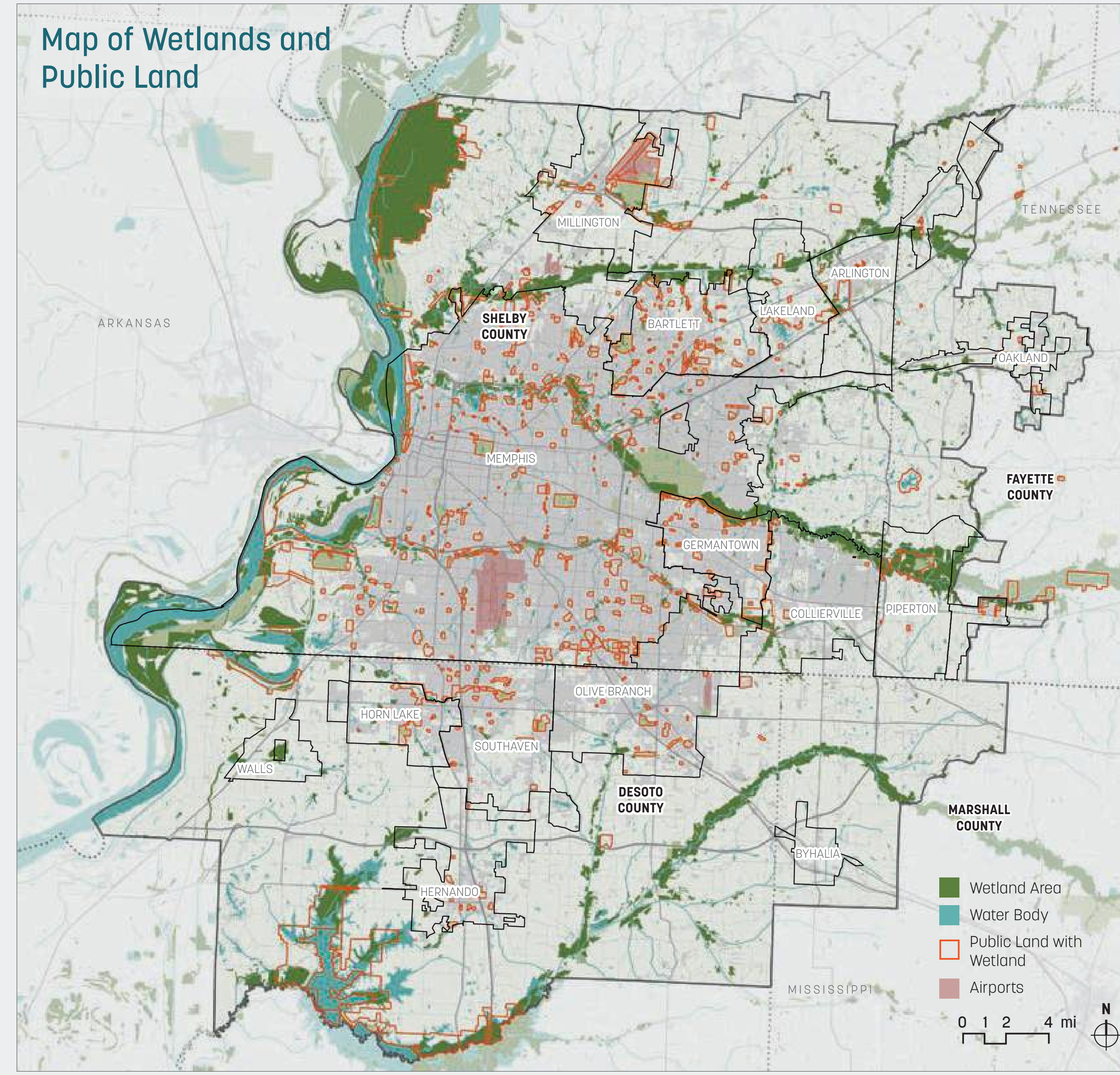
No septic, compost, or trash areas

No buildings or structures

Impervious areas limited to roads and paths

Permeable surfaces OK, such as parking





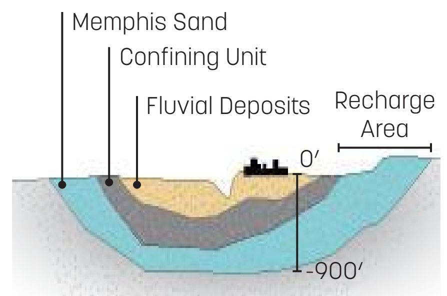
Data Source: USGS, NHD, DeSoto County, Shelby County, HIFLD

2.2.2 Aquifer Conservation and Recharge

The Memphis Sand aquifer provides some of the best drinking water in the country. The water in this aquifer seeped in over thousands of years and is protected and pressurized by a thick, impermeable layer called a confining unit. Where the confining unit is cracked or missing, surface water can get into the Memphis Sand more quickly. To retain the quality and supply of water, it is critical to protect the recharge area from harmful development.

Protecting the recharge area requires the same conservation, planning, and zoning techniques as with wetlands. Refer to Section 2.2.1 Wetlands for a discussion of appropriate uses for buffer zones.

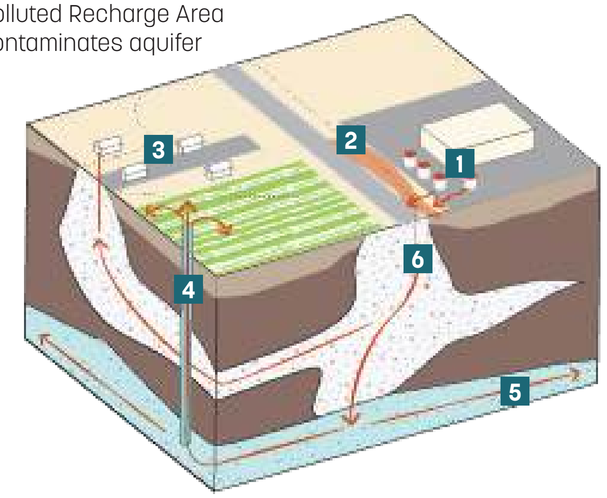
Aquifer Section



Issues

1. Pollutants seep into the recharge area from roads, erosion, chemical use, and industry
2. High runoff limits the amount of water available for infiltration
3. Development limits the area available for infiltration
4. Wells tap directly into the Upper Clairborne Confining Unit, allowing polluted surface water to seep into the aquifer
5. Pollutants in the Memphis Sand aquifer easily spread underground, affecting the whole region
6. Recharge takes much longer than extraction

Polluted Recharge Area contaminates aquifer



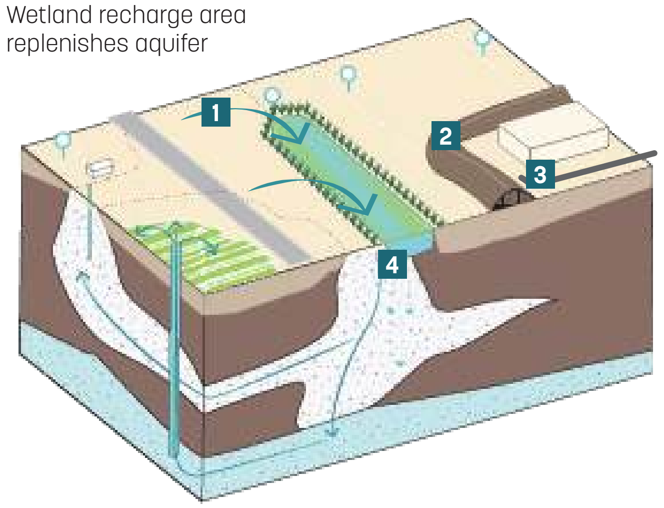
Managed Recharge

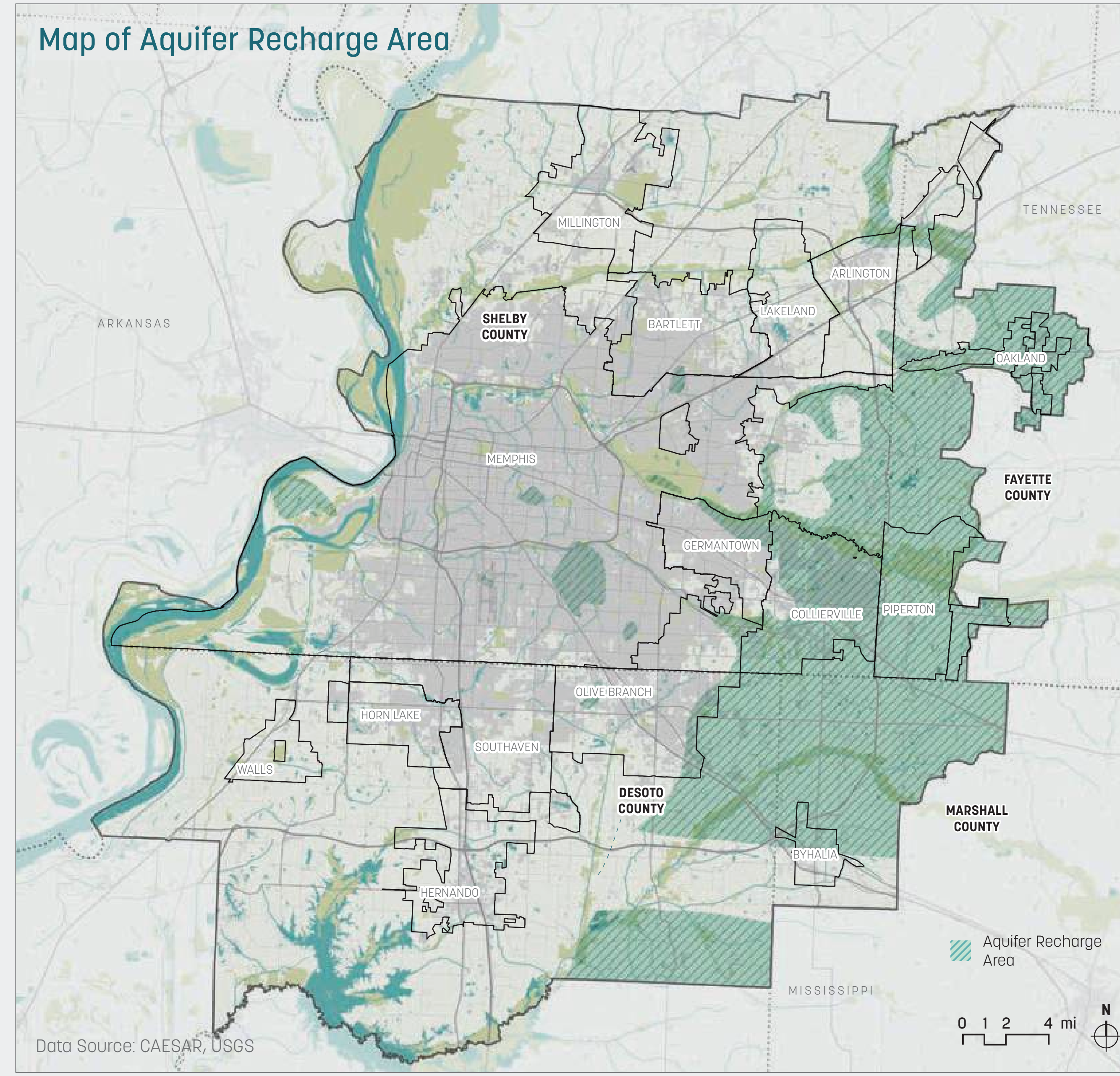
In addition to protecting water quality in the aquifer recharge area, it is also possible to increase rates of recharge. Clean surface water can be diverted to retention basins within the aquifer recharge area. These projects should involve engineers and geologists who can take extreme care not to contaminate or disrupt the aquifer.

Creating human-made wetland recharge basins provides the space and bioremediation to support healthy recharge.

1. Divert clean stormwater
2. Mitigate risk of contamination
3. Signage designating recharge area
4. Recharge basin

Wetland recharge area replenishes aquifer





Regulation Recommendations

The state of Tennessee is currently working on legislation to create a committee to oversee aquifer health and develop regulation guidelines. For any oversight of the aquifer to be successful, there must be more study to map the aquifer recharge area with greater precision. The existing maps encompass an area that is too large to regulate feasibly; finer grain mapping would identify more manageable priority areas.

In addition to regulations for the priority areas, best practices across the region include:

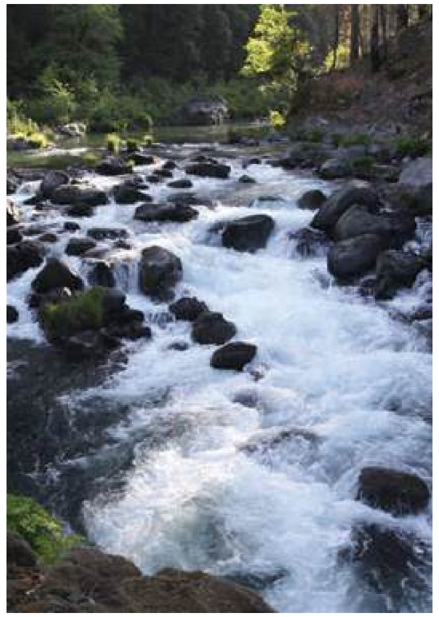
1. Requiring users to seek out greywater alternatives before pumping aquifer water;
2. Increasing monitoring of existing wells to ensure early detection of aquifer quantity and quality issues;
3. Adopting a regional plan to close wells that are no longer used or have been abandoned.

2.2.3 Headwaters & Tributaries

Headwater refers to the source of a river, the place where a spring bubbles up out of the ground, or snow melts off of mountains and glaciers. This source, and all the land surrounding and along it, is a precious area in all watersheds. Changes to the headwaters ripple down the river system, for better or worse.

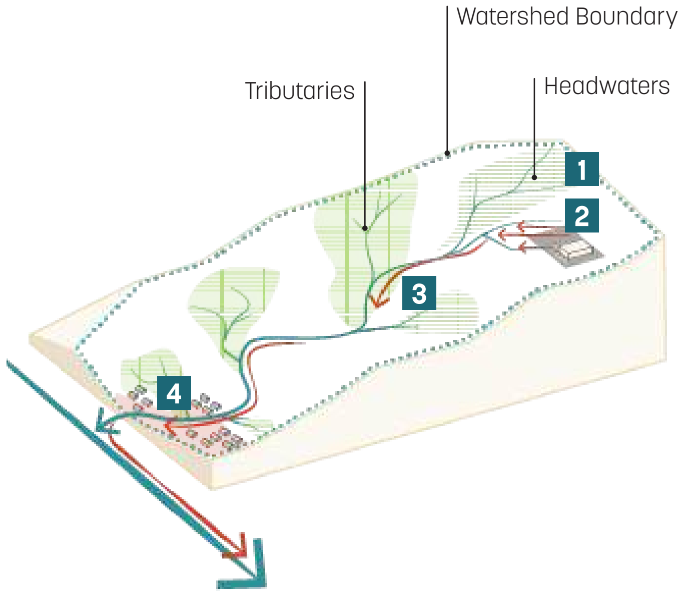
In the Mid-South, the undeveloped forests and fields of the upper watershed are helping to maintain watershed health. Forests are the most effective land use type for reducing runoff. Trees evaporate and transpire large amounts of water, and leaf litter on the ground slows runoff, giving it time to infiltrate into the soil. Meadows and pastures are also valuable for watersheds. Agriculture land can be effective as well, but not if the land has been compacted, channelized, or over-fertilized.

The health of headwaters and tributaries are threatened by deforestation, development, damming, and diversion of water for crops, homes, and industry. High nutrient or pollutant runoff causes major damage as well. Fertilizer and animal waste from large farms is of particular concern in the Mid-South.



Issues

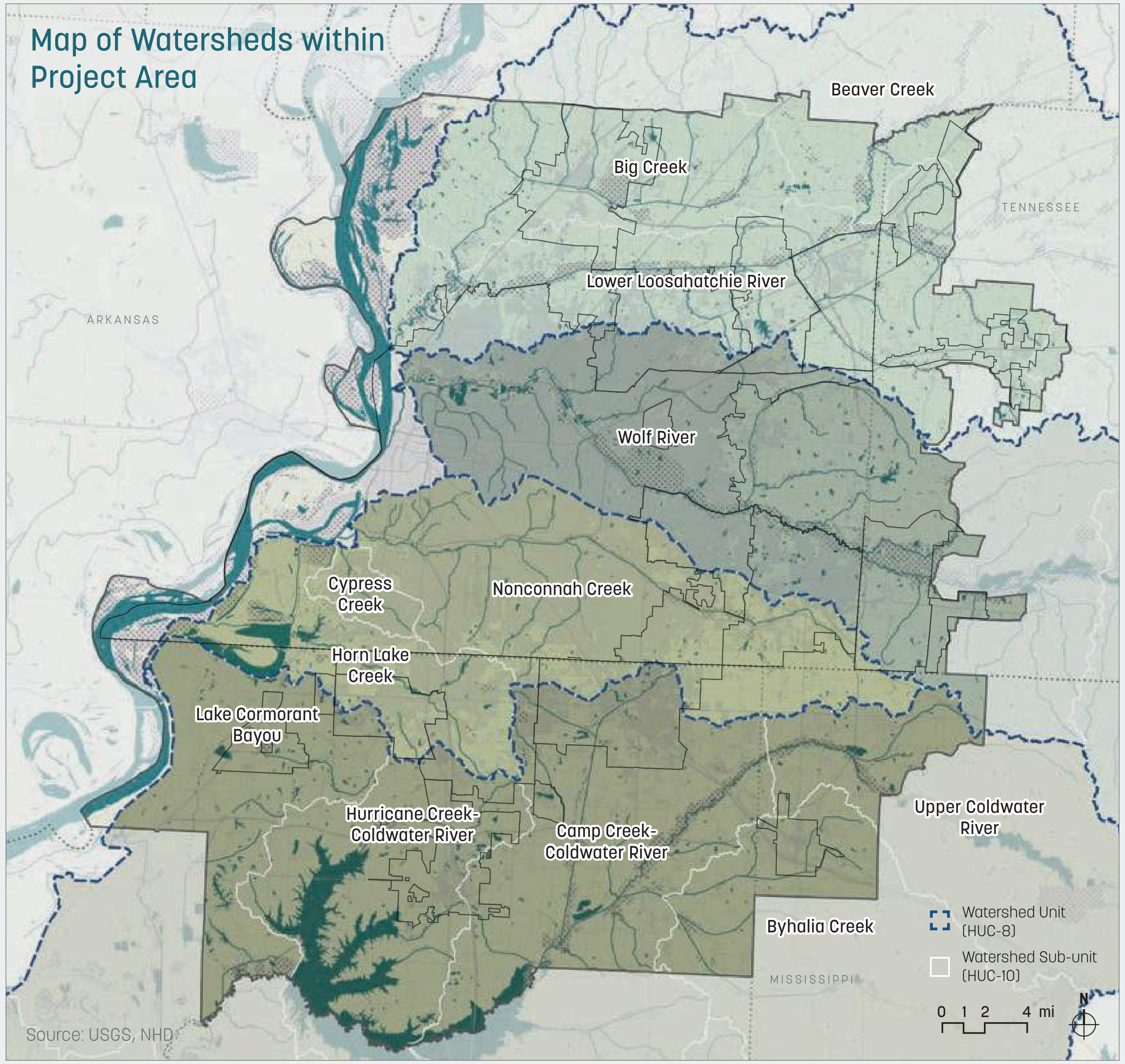
1. Loss of mature forests increases runoff
2. Impermeable surfaces increase runoff
3. Pollution from development and industry washes into rivers
4. Flooding downstream results from increased runoff



Cooperative Zoning and Conservation

The quality and quantity of river water is directly correlated with headwater health. If one town up-stream develops too much hardscape, every town below it will have additional flooding.

Mid-South headwaters and tributaries are largely in rural areas and in unincorporated county land. Counties in the region are encouraged to come together to delineate and zone areas for headwater conservation (and wetland and aquifer conservation).



Implementation

Effectively protecting watershed assets relies heavily on regulating development and conserving land. Zoning and development regulations are tools that governments can use to manage systemic impacts by limiting the effects of new development. By contrast, conservation essentially prohibits new development. Neither of these methods are exclusive. A robust strategy could be devised through a combination of both.

Land Conservation

Public Land Conservation

Public land conservation includes federal, state and local stewardship of land for the purposes of protection of key natural resources.

Land conservation is a means to protect open space for future generations while preserving the natural aspects and functions of the systems within these lands. It helps to prevent habitat and species loss and can accommodate recreational uses ranging from gardens to parks and trails for communities to enjoy.

While there is a significant amount of protected land under state and federal stewardship, there are several types of land conservation outside of state and federal ownership, these include:

- working land programs,
- land retirement programs,
- land trusts,
- private reserves, and
- conservation easements.

For information on key organizations involved in land conservation, see "Resources" on page 193.

Private Land: Conservation Easements

Private land conservation includes non-governmental stewardship methods such as: working land programs, land retirement programs, land trusts, private reserves, and conservation easements.

Easements occur when property owners release certain rights such as the ability to develop, subdivide plots, or change the land use while retaining other rights, such as the right to farm, the right to sell the property, transfer the land to heirs or others through a will, among others stipulated in an agreement of transfer. An easement can be held by a government, non-profit entity, or land trust, such as the Land Trust for Tennessee.

Land under the jurisdiction of easements usually remains under private ownership but can also stipulate requirements of the landowner to protect land and water resources such as by erecting fencing. This does not mean that the land is automatically opened to public use but usually preserves the landowners right to restrict or give public access. Easements are flexible and established on the basis of particular property's conditions, as opposed to zoning and development regulations that are broader and systemic.

Private Benefits of Conservation Easements

Income Tax Reduction: A landowner can agree to give up its rights to develop a piece of land, thereby reducing its appraised value. Landowners can receive a federal income tax reduction under the Internal Revenue Code (IRC) section 170(h) related to the difference between the value of the land pre-easement and the value of the property after the easement is established.

Reduced Property Taxes: A conservation easement may reduce or stabilize property taxes, depending on current zoning, land use, and assessed value.

Reduced Estate Taxes: Through the gift of an easement under IRC 2031(c), a landowner may qualify for an estate tax exclusion based on a portion of the value of the underlying land that is conveyed for a conservation easement. This transfer can reduce the value of the land from which estate taxes are calculated. This benefit can mitigate potential issues for heirs in having to sell or develop the property to pay estate taxes. It may also allow the property to remain in the family or retain its existing use.

For a piece of land to be eligible for a conservation easement, the landowner must:

- comply with state law requirements for land easements,
- be transferred to a suitable organization able to hold the easement,
- be transferred "exclusively for conservation purposes" and in perpetuity, and
- obtain a qualified independent appraisal for the purposes of relinquishing development rights.

Summary of Watershed Protection Methods

Type	Actors Involved*	Related Programs & Description
Public Land Conservation		
Federal	National Park Service, US Fish and Wildlife Service, US Forest Service, Bureau of Land Management	Includes the Land and Water Conservation Fund (LWCF) that supports the protection of federal public lands and provides matching funding to states for the acquisition of land for conservation efforts.
State	TDEC or MDEQ	The State Lands Acquisition Fund (SLAF) facilitates the structuring of land purchases involving multiple funding sources, non-profit agencies, and state agencies.
Local	County, City and Town Governments, and Non-profits such as Wolf River Conservancy	An example of a public entity involved in public acquisition of land for conservation is the Shelby County Conservation Board.
Private Land Conservation		
Working Land Programs	US Department of Agriculture, County, City and Town Governments	Provides funding for agriculture lands with wetland and conservation easements.
Land Retirement Programs	US Department of Agriculture, County, City and Town Governments	Retires land from agricultural production to support conservation efforts.
Land Trusts	Nature Conservancy, Land Trust for Tennessee, County, City and Town Governments	Land trusts for conservation hold land and provide stewardship services or assist private landowners in establishing conservation easements.
Private Reserves	US Department of Agriculture, County, City and Town Governments	The Forest Legacy Program of the LWCF provides funding through state partners to protect critical privately-held lands.
Conservation Easements	US Department of Agriculture, The Conservancy, County, City and Town Governments	Establishes easements on private land for critical watershed assets. Emergency Watershed Protection Program (EWP), Farm and Ranch Lands Protection Program (FRPP), Grasslands Reserve Program (GRP), Wetlands Reserve Program (WRP), Wetland Reserve Enhancement Program (WREP), etc.
Zoning and Development Regulations		
Floor Area Ratio (FAR)	County, City and Town Governments	Zoning mechanism that regulates total floor area of built structure as proportion of total site area.
Setbacks	County, City and Town Governments	Zoning mechanism that establishes required distances for development or use limitations from streams or wetlands.
Lot and Open Space Coverage	County, City and Town Governments	Zoning mechanism that limits total amount of built area and open space on a site.
Use	County, City and Town Governments	Zoning mechanism that regulates the types of uses permitted to reduce the harmful effects of intense use types on environmentally critical areas.
Conservation Subdivisions and Cluster Development	County, City and Town Governments	Zoning mechanism that can regulate subdivision of land to require higher density of clustered development while preserving larger open spaces.
Promotion of Higher-density Development in Less-critical Areas	County, City and Town Governments	Zoning mechanism that can promote high-density development in areas of less-critical environmental concern.
Sustainability Requirements	County, City and Town Governments, LEED, National Green Building Council	Zoning and building code mechanism that sets performance requirements for buildings. The LEED certification program and the National Green Building Council are leading the establishment of building performance requirements nationwide.

*This list provides only a small sample of the actors involved in conservation efforts

Public Benefits of Conservation Easements

There are several public benefits of conservation easements. Conservation easements protect watershed assets and aquifers that provide ecological and functional benefits to communities. They retain landscapes under traditional uses and can help to retain small family farms on the land and provide buffers between developed land and parks and other scenic assets. They may also help to generate local revenues through the limitation of uses to farming, ranching, forestry, and other public spaces that often outweigh the costs of public services in comparison to developed land.[7]

Other Methods of Conservation Easement Designation

Other than private property owners voluntarily conveying land for conservation easements, the Nature Conservancy has led another method called 'conservation buying' that may be applied to specific areas. Conservation buying is a process where an entity (usually a conservancy) buys land in critical conservation areas, such as land that buffers assets such as the aquifer recharge area or wetlands, and places conservation easements on the land. The Conservancy then sells the property to interested buyers. The buyers are willing to forgo the rights that are restricted by the conservation easement such as subdividing or development while the entity retains the easement rights in a trust. This method requires substantial marketing of these properties to prospective buyers who share in the values of preservation, but can be a cost-effective way to establish conservation areas.

Funding Resources

- Conservation Stewardship Program (CSP)
- Environmental Quality Incentives Program (EQIP)
- Watershed and Flood Prevention Operations Program
- The Conservation Fund
- National Conservation Innovation Grants (CIG)
- State Conservation Innovation Grants (CIG)
- Emergency Watershed Protection Program (EWPP)
- Wetland Program Development Grants (WPDGs)
- Agricultural Resources Conservation Fund (ARCF)
- Tennessee Department of Environment and Conservation (State Revolving Fund)
- Tennessee Wildlife Resources Agency Land Acquisition Program
- Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP)
- USDA Conservation Reserve Program
- USDA Conservation Reserve Enhancement Program
- USDA Emergency Conservation Program
- USDA Farmable Wetlands Program
- USDA Agricultural Conservation Easement Program (ACEP)
- US Fish and Wildlife Service's North American Wetlands Conservation Act Grant Program
- National Fish and Wildlife Foundation's Five Star and Urban Waters Restoration Grant Program
- Corporate Wetlands Restoration Partnership
- McKnight Foundation
- Walton Family Foundation's Lower Mississippi River Grant Program

Technical Assistance

- Conservation Technical Assistance (CTA)
- Conservation of Private Grazing Land (CPGL)
- Farm Wildlife Habitat Program
- Tennessee Partners Project
- Mississippi Department of Environmental Quality (MDEQ)
- Mississippi Water Environment Association
- Soil and Water Conservation Society (Mississippi State University Student Chapter)
- Mississippi Water Resources Research Institute (Mississippi State University Student Chapter)

Zoning and Development Regulations

Existing Permitting Regulations

One method that currently regulates the development of watershed assets is permitting regulations. In Tennessee, the Aquatic Resource Alteration Permit (ARAP) or Section 401 Certification is required to make alterations to the functions of a wetland. This permit may also include compensatory mitigation requirements after a review that scores the potential impact of an alteration request. It also includes a social and economic impact analysis requirement as part of the permit application.

Considerations of Locations for Development Regulations

There are several considerations of locations for development regulations. In areas with a high water table, critical hydrological concerns, or restoration needs, development regulations should be increased to prevent further impacts. Other regulatory considerations should include: soil permeability, topography, geology, wetland and aquifer locations, and hydrological systems analysis.

Elements of Regulatory Tools and Zoning Overlays

There are many dimensions to development regulations embedded within zoning overlays.

Floor Area Ratio (FAR)

FAR limitations regulate the amount of built area within a parcel as a proportion of the total site area. This is a simple method of regulating development density that is already a feature of many zoning codes and can be regulated under the same jurisdiction.

Setbacks

Like FAR limitations, setbacks are also typical zoning tools that apply to site conditions such as regulating a setback from a road or neighboring parcels. A common method of using setbacks to help with limiting the effects of ecological damage may be to establish wetland or riparian buffer setbacks. These range in size from 25 to 300 feet depending on existing densities. Shelby county regulates development along streams with a buffer of 60 feet (Memphis and Shelby County Unified Development Code, Section 6.4)[2] while also regulating the uses within the buffer to sanitation easements and improvements to erosion control. Buildings are required a further setback from a stream buffer of 10 feet.

Lot and Open Space Coverage

Another common zoning tool is to regulate lot and open space coverage. For instance, a larger percentage of a parcel can be required to be open space, while hardscape and buildings are restricted to a smaller area.

Land Use Regulations

While FAR, setbacks and lot coverage limit building on a site-scale, land use zones direct land use on a neighborhood scale (or larger). As shown in 2.2.1, municipalities can limit use within a zone to those that will have minimal negative impact.

Conservation Subdivisions and Cluster Development

This is one tool that has been employed that allows for higher-density parcel subdivisions than would otherwise be possible under normal zoning conditions. These can be applied through special provisions in the zoning code such as regulating the development of large parcels to preserve contiguous open space (such as by promoting more density through clustering and minimizing distances between structures) or through the establishment of special districts.

Promotion of Higher-density Development in Strategic Locations

Thoughtful land use zoning will not only restrict development in ecologically sensitive areas, but also promote development in specific areas where it can have the most positive impact.

Increasing FAR near core urban areas limits the need to extend infrastructure, which also saves municipalities money in capital, operation, and maintenance costs.

(Above) Meeman-Shelby Forest State Park is an example of a critical watershed asset protected by the State of Tennessee.

Other Regulations

Other forms of regulation can include requirements on sustainable development goals such as those specified in the LEED program. However, although requirements that are in-line with LEED are a significant step forward, different techniques might be applicable given circumstance and the context. Regulations on building energy consumption, energy recycling, material standards, and related criteria may also be considered within a larger regulatory framework for the protection of watershed resources.

Variances

Developers who wish to build on parcels that are different from standard parcels can request a variance.

Such parcels may be an odd shape or have unique surface features. Municipalities should evaluate variance requests to ensure there will be no negative effect on watershed assets. Review of variances should be governed by a well documented cost-benefit analysis with clear goals and requirements in mind to establish a fair process as well as public health and safety.

Administration and Review

To avoid unnecessary complexity in the development process, new regulations should be folded into existing structures/procedures.

Benefits of Development Regulations

There are several key benefits of development regulations. Centralized enforcement and management of regulations may typically go through a permitting process that is already in place. Development regulations also enable a more systematic coverage over all areas of concern and can enhance other strategies for ecological preservation

Aquifer Management

In 2017, a bill authorizing the establishment of the Memphis Sand Aquifer Regional Management Board was considered in the Tennessee State Legislature. As of June 2019 the bill is still filed for introduction to both representative bodies of the legislature.

This bill would authorize the creation of a nine-member board "for the purpose of managing, conserving, preserving, and protecting the Memphis Sand aquifer, and increasing the recharge of such aquifer while preventing waste or pollution in the aquifer."[3] Creating a regional aquifer management board would be a significant step towards having the resources and support needed to protect the watershed.

Value of Memphis Sand Aquifer Regional Management Board

The board would provide additional oversight into the extraction of water from the Memphis Sand aquifer which can support efforts to regulate and secure permits. The board meetings and records will be open to public inspection and will be a useful tool to increase accountability in the management of aquifer resources.

Conservation Priority Areas

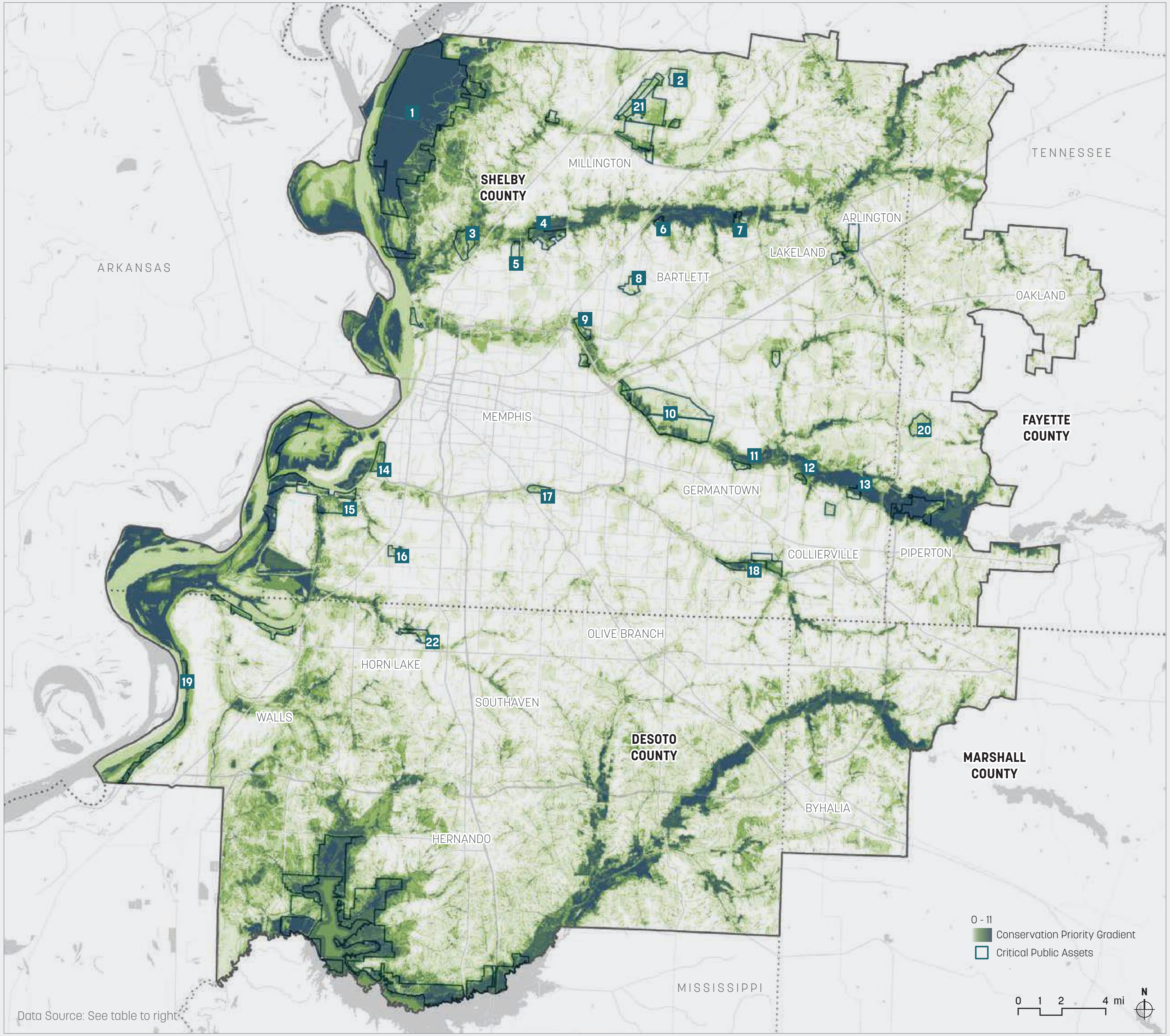
This map compiles areas that are important to conserve for watershed health. Major parcels of public land are outlined with a dark blue border. The majority of public parcels are located in Shelby County as there are not many publicly-owned parcels with high priority levels in DeSoto County. Concern areas are shaded based on a 0-11 scored scale indicating priority level. The table below indicates the layers used, and how they have been scored to create this map. The resulting gradient overlay is shown on the map to the right with colors from light green (low score) to dark blue (high score).

Layer Table

Layer	Source	Score
TNC Resilience	The Nature Conservancy	0-4
Priority Landscapes	EPA	0-2
30 m Stream Buffer	National Hydrologic Dataset	0-2
Wetlands	National Land Cover Database	0-2
100-year Floodplain	FEMA	0-1
Water Bodies	NLCD & NHD	0-1
300 m Protected Lands Buffer	Wolf River Conservancy	0-1

Critical Public Assets (Sample)

1. Meeman-Shelby Forest State Park
2. Edmund Orgill Park
3. Firestone Park
4. Oakley Park
5. Links at Davy Crockett
6. Rivercrest Natural Area
7. Blue Lagoon
8. Nesbit Park
9. John F. Kennedy Park
10. Shelby Farms
11. Cameron Brown Park
12. Robbins-Halle Nature Preserve
13. W.C. Johnson Park
14. Martin Luther King Riverside Park
15. T.O. Fuller State Park
16. Walter Chandler Park (Mississippi Park)
17. Nash Buckingham park
18. Nonconnah Trail Head
19. Hernando DeSoto Park
20. State Fish and Game Refuge
21. Millington-Memphis Airport
22. Horn Lake Creek Area



Case Study

Edwards Aquifer Protection Program, San Antonio, TX

In 1995, the City of San Antonio took action to protect its major source of water, the Edwards Aquifer. The San Antonio City Council passed a county ordinance that strengthened the development codes for land in and around the aquifer recharge zone. The ordinance also dedicated assistance to studying the aquifer.

Passing Aquifer Protection Ordinance No. 81491 did not happen overnight. It took eight years for the city to move from the first report on aquifer health to the first legislative action. The first major study on the aquifer was undertaken in 1987, and it resulted in a report that evaluated the ways to protect it from threats like increased development. Planning and research continued through 1994, when a new report was published outlining the 33 most crucial actions, or mandates, needed for success.[4] Since then, Ordinance 81491 has guided development to protect the aquifer.

The 33 Mandates addressed in the Ordinance encompass many different aspects of land management, organized into a unified development code, stormwater code, and water code.

Highlights of the Code[5]

- Establishes three zones for protection: the recharge zone itself, the area above that contributes to the recharge zone, and the transition area
- Outlines the uses allowed in each zone, excluding most industrial and manufacturing processes
- Addresses common sources of water pollution, such as underground storage tanks, septic systems, and runoff
- Establishes density limits and green space requirements for plats in the recharge overlay district
- Designates buffers on floodplains and the recharge area
- Requires testing of pollution abatement measures
- Establishes oversight for pollution prevention
- Recommends a watershed management plan
- Addresses well closure and abandonment

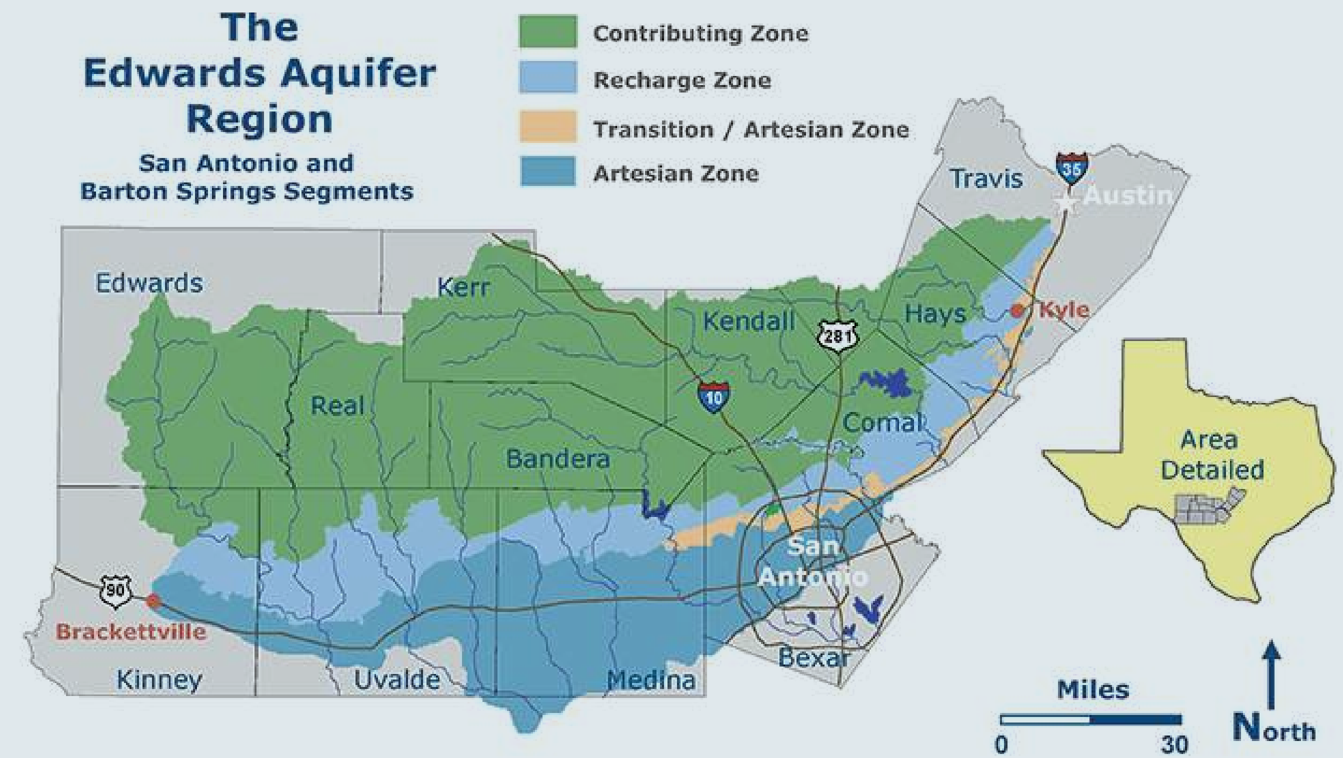
On an individual level, for people in Bexar County the Ordinance has meant that they need to seek an Aquifer Protection Plan (AqPP) permit before developing in a protected area. On a municipal level, the San Antonio City Council has been able to support several research projects studying water quality and pollution mitigation.

(Left) Monitoring wells, such as the J-17, are highly visible.

(Right Page, Top) Map of the Edwards Aquifer in the San Antonio region. Source: Edwardsaquifer.net

(Right Page, Bottom Left) Water flowing into the aquifer through the open caves at the ground surface.

(Right Page, Bottom Right) Signs alert visitors when they are entering the sensitive recharge area.



Endnotes

1 “What is a wetland?,” National Ocean Service online, last accessed March 13,2012, https://oceanservice.noaa.gov/facts/wetland.html

2 Memphis and Shelby County Unified Development Code, (Shelby County Board of Commissioners and Memphis City Council, 2010).

3 *Tennessee House Bill 816: An ACT to amend Tennessee Code Annotated, Title 4, Chapter 29 and Title 69, relative to aquifers*, 110th General Assembly of the Tennessee Legislature, introduced on February 8, 2017.

4 “Aquifer Protection and Evaluation,” *San Antonio Water System* online, Last accessed January 30, 2019, https://saws.org/environment/resourceprotcomp/aquifer_protection.

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2.3 Low-Impact Development

Encourage Development that Supports Healthy Watersheds

Key Benefits

1	**Reduces flash flooding and downstream flooding**
2	**Improves groundwater levels through infiltration**
3	**Improves quality of surface water and environment**
4	**Engages local community in flood mitigation**

Limitations

1	**Relies on interest and actions of individual property owners**
2	**Dispersed nature of LIDs makes them more labor intensive to promote and manage than larger single-site projects**

Overview

Development can cause or exacerbate a variety of hydrological issues, including flash flooding, river flooding, and water pollution. Low-Impact Development (LID) techniques are targeted interventions that mitigate these adverse impacts. Typical LIDs are small, site-scale features that generate the following benefits: a reduction in the volume of water that drains from a site, an improvement in water quality, and an increase in infiltration rates.

In the Mid-South, institutions like school and government buildings have already been early adopters of LIDs. Municipalities can encourage additional institutions, businesses, and individuals to install LIDs through education and incentives. Educational pilot projects, demonstrations, mailers, and give-aways support voluntary implementation programs. Financial incentives, such as reductions on water and sewer bills, encourage additional LID adoption. Along the way, municipalities can help by offering logistical supports such as small grants, subsidized supplies and labor, and expert consultants.

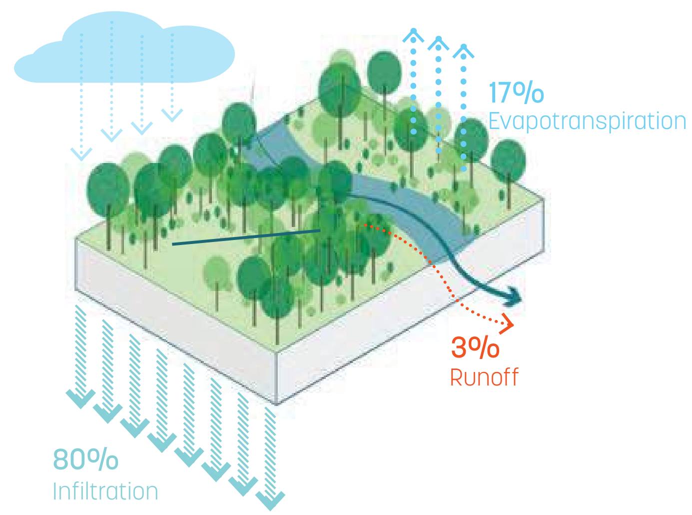
(Right) Demonstration rain garden in Rochester, MN.

Development and Hydrology

Areas in the Mid-South that have not been developed, such as meadows and forests, have very low run-off rates. This changes dramatically as sites are developed using conventional techniques.

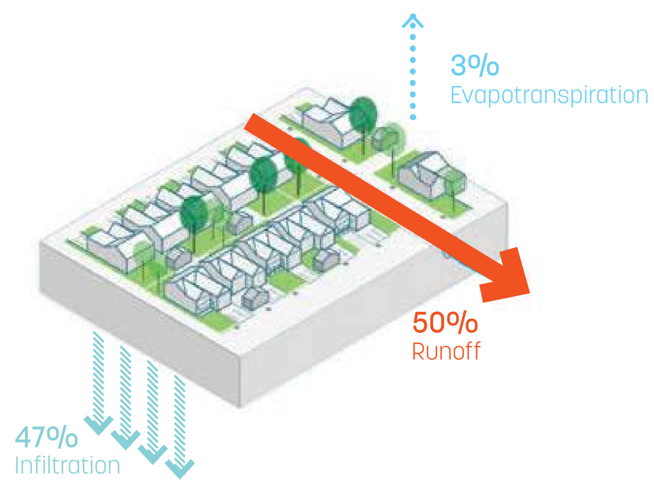
Pre-development (Forest)

In a pre-development condition, such as a forest, nearly 1/5th of the rain that falls lands on leaves and evaporates. Of the remaining 4/5ths, almost all of it is slowly absorbed in the rough textured leaf litter, with only a small fraction (3%) running off into surface water bodies.



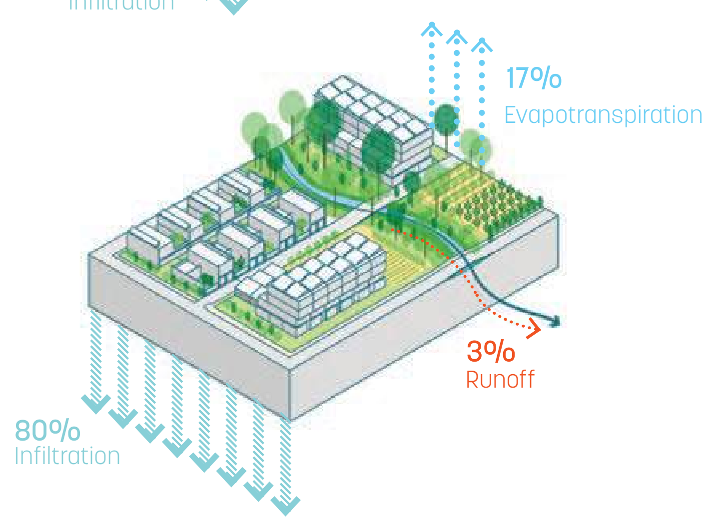
Conventional Development

Impermeable surfaces, channelized streams, and reduced vegetation make runoff peak sooner and with higher volumes, overloading the system and causing flooding.



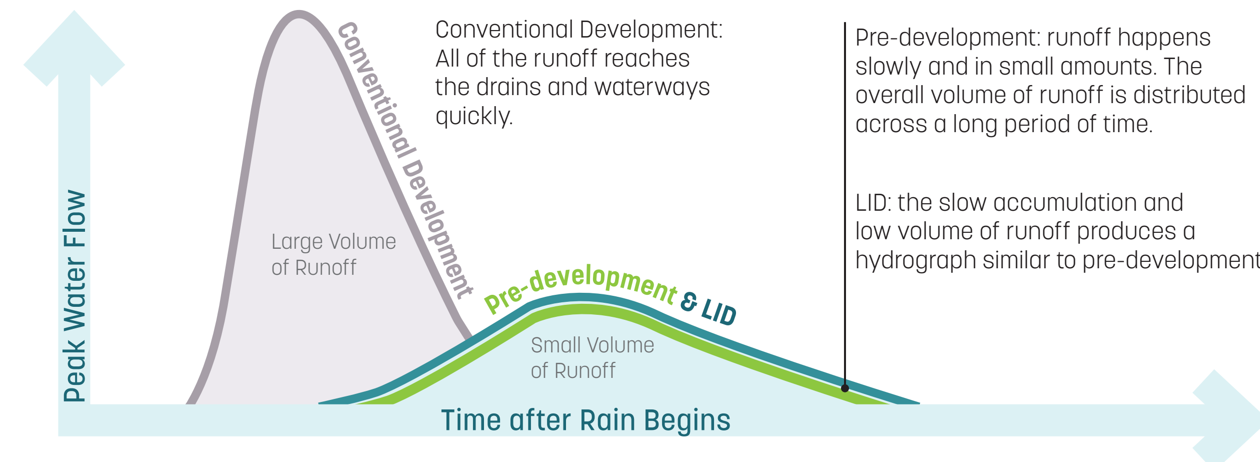
Low-Impact Development

Using LID techniques, even heavily developed areas can recreate pre-development hydrological conditions.



Comparative Hydrograph

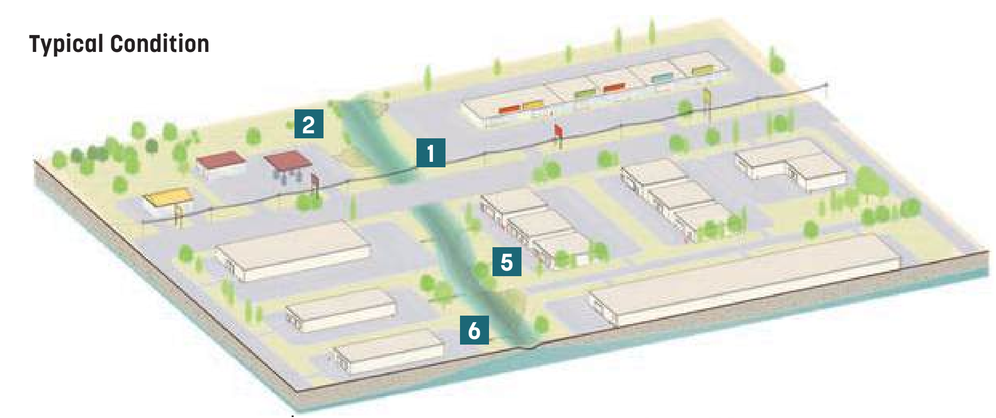
The goal of LID techniques is to imitate the way a natural system handles stormwater, which is shown using hydrographs. Hydrographs show the volume of water reaching a drain or river over the course of a rain event. For the Mid-South, this means trying to achieve the same low and wide hydrograph profile as an undeveloped landscape, such as a forest.



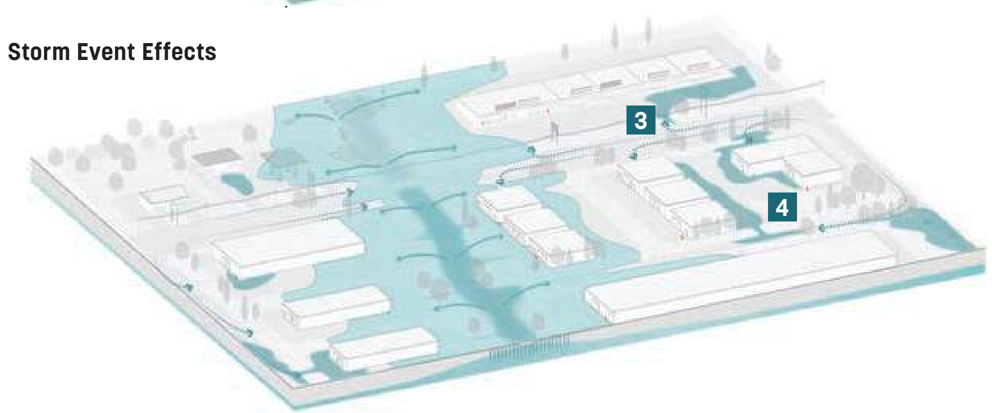
Common Site-Scale Hydrologic Issues

1. Increased impervious area increases runoff quantity and velocity
2. Loss of vegetative cover increases runoff quantity and velocity
3. High run-off rates and volumes cause flash flooding
4. High run-off rates and volumes overload sewer systems, causing overflows
5. High run-off rates and volumes cause erosion and increase debris and sediments in water
6. Increased pollutant and sediment concentrations overload water bodies, causing eutrophication and dead zones

Typical Condition



Storm Event Effects



2.3.1 LID Techniques

There are many different low impact development techniques that work together to create a system of local stormwater management. An effective LID system accomplishes these four steps:

1. Pre-treatment screening to remove trash
2. Filtration to remove solids (mechanically) and pollutants (chemically and biologically)
3. Infiltration to reduce runoff and improve quality
4. Storage and reuse of run-off for greywater uses such as irrigation

This list of LID techniques summarizes those highlighted by the Tennessee Permanent Stormwater Management guide. The diagram shows how they might be implemented across a site.

Linear/Ultra-Urban Bioretention

Small vegetated areas that collect runoff through local inlets and drains. May be depressed areas in sidewalks and plazas.

Green Roof

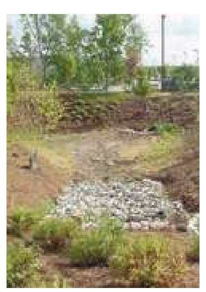
A bed of soil and vegetation on a roof that absorbs and slows rainfall, reducing run-off.

Residential Rain Gardens

Small-scale basins designed to capture a target amount of water from the site. The water is treated through chemical and biophysical processes by vegetation and engineered media.

Manufactured Treatment Device

Manufactured systems that meet the Stormwater Management Standards to treat stormwater on-site.



Dry Detention

Basins within the landscape that fill with run-off during rain events. Designed to hold water for up to 24 hours after the rain event and release it slowly to reduce flooding.

Rainwater Harvesting

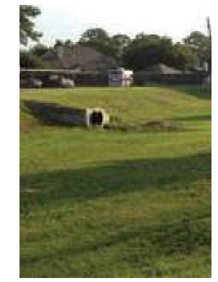
Using barrels and tanks to store rainwater for future use in irrigation or other greywater applications.

Extended Detention

Dry basins that are designed to hold water for up to 72 hours after a rain event. Designed to remove pollution and settle sediments.

Selective Downspout Disconnection

Remove connections between downspouts and sewer drains and divert rainwater to lawns or gardens.



Infiltration Areas

Large, flat vegetated areas that retain and infiltrate stormwater within a few days after a rain event.

Stormwater Treatment Wetland

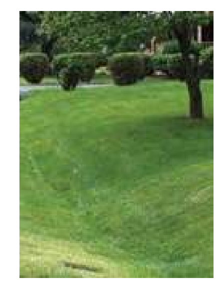
A wetland designed to capture, treat, and infiltrate stormwater.

Filter Strip

Used to slow and filter run-off before it can enter a waterway.

Permeable Pavement

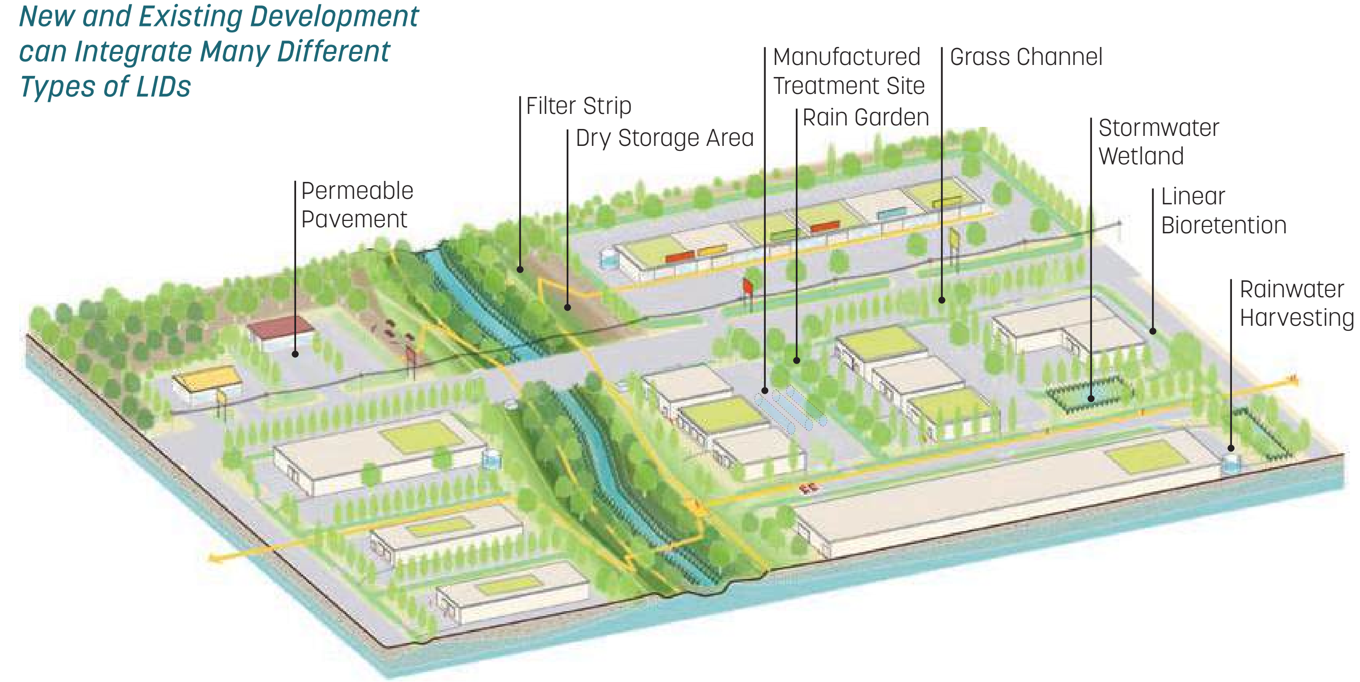
Porous paving (such as porous concrete or gravel) or unit pavers set with permeable joints and on a permeable setting bed that allow water to infiltrate through to the subsoil, rather than run-off.



Grass Channel

A gently sloping, shallow linear channel used to convey and treat stormwater.

New and Existing Development can Integrate Many Different Types of LIDs



Implementation

Low Impact Development is widely known as a best practice in stormwater management. There are many resources for LID funding, education, and implementation. The two major resources are the Environmental Protection Agency and the Army Corps of Engineers. Specific publications are listed under resources at the end of this chapter.

Since LIDs are often implemented at the site scale, it is necessary to encourage large numbers of individual property owners to participate in this strategy to maximize reductions in flooding and improvements in water quality.

Funding

LIDs are typically funded by grants, through development requirements for new building projects, stormwater fees, and capital projects.

Grant Funding

The U.S. EPA is a major source for grant funding through Urban Waters Small Grants.[1]FEMA has three applicable grant programs: **Hazard Mitigation Grant Program, Pre-Disaster Mitigation, and Flood Mitigation Assistance.**[2] Development requirements can be incorporated into zoning or on a project-by-project basis. Finally, state and local budgets or bonds typically fund capital projects.

The Army Corps of Engineers may help fund, design, and/or construct projects.

Development Requirements

LID specifications may be written into local zoning codes. This is likely the most straightforward way to ensure the inclusion of LID techniques in new projects. Zoning ordinances may require on-site LIDs or allow developers to implement LIDs elsewhere in the neighborhood.

Stormwater Fee Credits

Many jurisdictions within the Mid-South Region charge property owners a stormwater fee using a rate schedule that is based on average impervious surface for specific property types. Stormwater fees charge residents for the runoff from their site (usually calculated by square feet of impervious surface). Offering stormwater credits to property owners who implement low impact development strategies will encourage more owners to do so, reducing the stormwater burden for the city. Credits could be awarded for installed rain barrels, roof gardens, rain gardens, detention basins, and use of permeable pavers which reduce the stormwater runoff.

(Below Left and Right) Students at the Harvey Scott School in Portland, OR build a rain school garden that a local non-profit helped design, plan, and maintain.[3]

Capital Projects

Flood mitigation and water treatment projects can be funded with money set aside for infrastructure improvement projects. Municipal bonds, ballot initiatives, grants, donations, and discretionary spending may all be used for capital projects.

Education

Education is the first step in implementing low impact development stormwater management best practices. Many residents are willing to help mitigate flooding and will implement LIDs when they learn about them. Several strategies exist to help raise awareness about the importance of stormwater management in relation to flash flooding, as well as options for individuals, organizations, and government agencies who seek to implement stormwater management strategies on their property.

Local partners, such as Mid-South Clean Water, can help with publicity and implementation of smaller sample projects.

Public Information Campaign

Increasing public awareness about LIDs starts with a public information campaign. Information about the cause of, and potential solutions to, localized flooding could be outlined in a clear and easily-understood manner. The intent is to give individuals clear direction about how to take action if they so choose. This could include newspaper articles, television and radio advertisements, e-mail campaigns, public presentations, and educational events for children and adults at schools, libraries, or community centers.

Pilot Projects

Civic buildings such as city hall, public schools, public libraries, and community centers are ideal locations for pilot projects like rain gardens, rain barrel water collection, and green roofs. See 7.2 Outreach for focus on the public outreach components of projects. Still, common techniques can have aesthetic appeal as well as stormwater functions. When implemented in visible places within the community, they can entice property owners to consider implementing them at home. Other strategies, such as detention basins, stormwater treatment wetlands, and grass channels can be implemented in visible areas on public land that feels less precious, such as adjacent to transportation infrastructure or surrounding parking areas. Complemented by informational signage, these projects can help educate passers-by about the relationship between the stormwater management project and flood mitigation, as well as providing actual stormwater management benefits.

7.2

Public Workshops

Certain stormwater management strategies are relatively easy for individuals to create and implement with a little guidance. Public workshops for community members can provide instruction and tools to create rain barrels or information on rain garden design. These events help educate the community about the need for these strategies in a fun and engaging way. The workshops can also be part of a public information campaign, held outdoors in a visible public space and open to people passing by.

Incentives

Some property owners may need encouragement or incentives to implement low impact development techniques. Mitigating the out-of-pocket costs for property owners may be a win-win for owners and the region's Departments of Public Works.

Stormwater Tax Credits

Storm water taxes not only help fund LID construction, they incentivize it. Property owners can be motivated to reduce their tax burden.

Subsidized Materials

Stormwater is a direct cost to a Department of Public Works. Property improvements that reduce the overall quantity of stormwater reduce a jurisdiction's stormwater management costs. Providing property owners with subsidized materials for low impact development techniques such as rain barrels or rain garden kits can be a cost effective strategy for managing stormwater. Local jurisdictions can offer this subsidy at little or no cost to themselves by partnering with manufacturers or distributors of stormwater management materials to buy in bulk and sell to constituents.

Siting LIDs

LIDs are ideal for neighborhoods where there is a lot of runoff from impermeable surfaces such as buildings, streets, and parking lots. This map shows concentrations of impermeable surfaces. LIDs can also improve the quality of water. Focusing installation of LIDs in areas where there is both high impermeable surface rates and poor water quality can have a big impact on watershed health.

Process

1 Education	Public information campaign Pilot projects on prominently located public sites Public workshop to make rain barrels and design rain gardens
2 Incentives	Free consultation for property owners to learn about LID credits for their property Subsidized implementation materials such as rain barrels and rain garden kits Stormwater reduction credits that reduce water and / or sewer charges Other local tax credits

(Above) Two women in Farmington, Minnesota build a rain barrel out of a donated Coca Cola syrup container with guidance from the Friends of the Mississippi River staff.

Case Study

Green City, Clean Waters, Philadelphia, PA

At the turn of the 21st century, the City of Philadelphia faced an inadequate and failing combined sewer system that was no longer in compliance with federal clean water regulation.[4] When faced with similar problems, other cities began the long, expensive process of separating sewer and wastewater systems to reduce the load on treatment plants. Looking for another way, the City found that for a similar amount of money, it could implement a green infrastructure system that would reduce runoff by 85% while improving quality of life for all residents.

The City decided to try green infrastructure and began to develop a plan, beginning with mapping sources of stormwater runoff and outflows. To ensure that city residents and organizations would help construct LIDs, it was essential to learn community priorities and gain local support. To ensure funds, the City had to coordinate investors and technical partners, such as the EPA and Rio Prefeitura. Along the way, the Philadelphia Water Department (PWD) collaborated with fourteen different City agencies and departments.

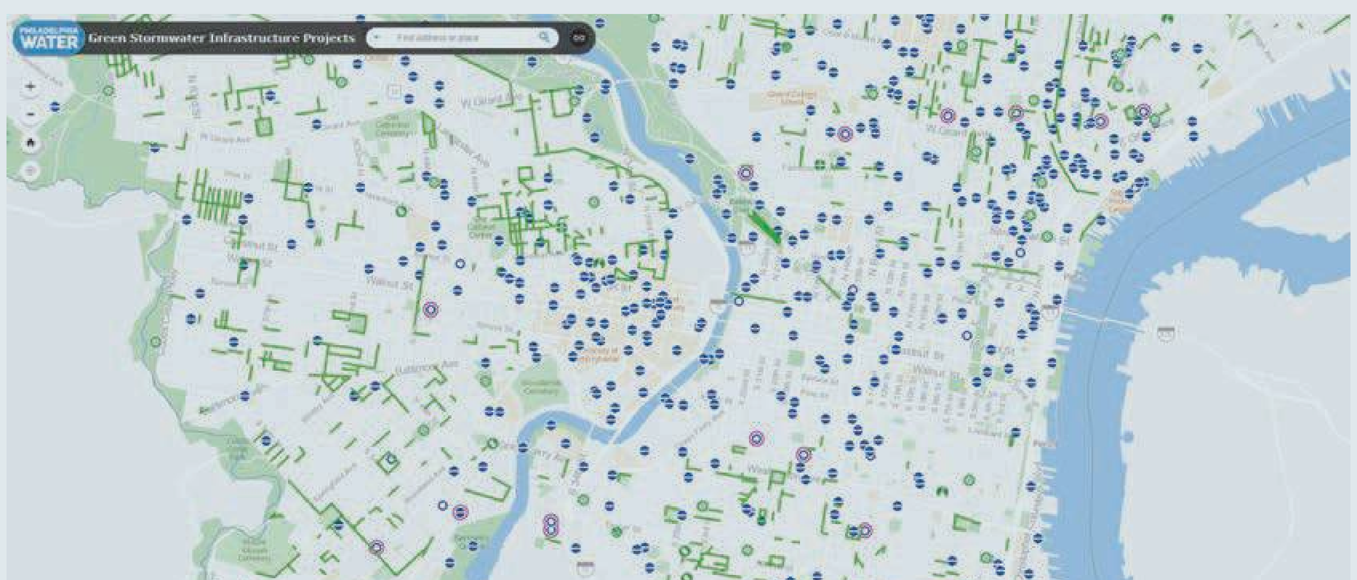
The resulting Green City/Clean Waters Program will run for 25 years under the guidance of the PWD, which has pledged to invest $1.2 billion over the 25 year life of the project ($2.4 billion in 2034 dollars).[5, 6]

The GCCW Vision

- Large-scale implementation of green stormwater infrastructure to manage runoff at the source on public land and reduce demands on sewer infrastructure
- Requirements and incentives for green stormwater infrastructure to manage runoff at the source on private lands and reduce demands on sewer infrastructure
- A large-scale street tree program to improve city appearance and manage stormwater at the source on City streets
- Increased access to and improved recreational opportunities along green stream corridors and waterfronts
- Preserved open space utilized to manage stormwater at the source
- Converted vacant and abandoned lands to open space and responsible development
- Restored streams with physical habitat enhancements that support aquatic communities
- Implement additional infrastructure-based controls when necessary to meet appropriate water quality standards.

From the Green Cities Clean Waters Program Summary, June 1, 2011

(Below) Public Map of GCCW Projects in Central Philadelphia. Source: phl-water.maps.arcgis.com



Implementation

At the five year mark, there are 441 new green stormwater infrastructure sites. Together, these projects are the equivalent of 837 "greened acres," and keep over 1.5 billion gallons out of the local rivers. The three types of projects are below.

(Re)Development Green Stormwater Infrastructure

New development and redevelopment projects, must comply with stricter City of Philadelphia Stormwater Regulations (updated in 2006 and 2015).

Example: Paseo Verde is a mixed use building with low and moderate income housing and offices.

Incentivized Stormwater Infrastructure Projects

Developed on non-residential private lots which can earn a stormwater billing credit. Major funding sources are the Stormwater Management Incentives Program and the Greened Acre Retrofit Program.

Example: The West Philadelphia Coalition for neighborhood schools replaced the asphalt at Lea Schoolyards with permeable paving and gardens. Funded by SMIP, PECO Green Region, Knight Foundation, Garden Court Community Association, Quirk Books, Spruce Hill Community Association, University City District, and over 100 individual donations.

Public Green Stormwater Infrastructure Projects

PWD (or partner) initiates, builds, and maintains these features. When the PWD has to build conventional infrastructure, they try to add a GSI feature at the surface.

Example: Bioswales and large tree pits are visible green stormwater infrastructure along a traditional street.

Endnotes

1 "Urban Waters", *U. S. EPA* online, https://www.epa.gov/urbanwaters.

2 *Fund Low Impact Development/Green Infrastructure Projects with FEMA Grants for Flood Mitigation*, Document Number Document Number, Document number EPA 901-F-09-005, (U.S. EPA September, 2015).

3 "Harvey Scott School Rain Garden Grant Support, Verde," Stamberger Outreach Consulting, https://stambergeroutreach.com/h arvey-scott-school-rain garden-grant-support-verde/.

4 "Enforcement," U.S. EPA online, last modified October 23, 2018, https://www.epa.gov/green-infrastructure/enforcement.

5 Office of Watersheds, *Amended Green City Clean Waters*, Philadelphia Water Department, June 2011. Available at http://www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf.

6 "Green City, Clean Waters," *Philadelphia Water Department* online, last modified 2018, http://www.phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan.

Resources

Low Impact Development Techniques

Community Stormwater Solutions BMPs Cost Catalog. Massachusetts Watershed Coalition, 2016-2017. Available at http://www.commonwaters.org/resources/resource-guides.

Incorporating Low Impact Development into Municipal Stormwater Programs. Document Number EPA 901-F-09-005. (U.S. EPA New England, April 2009).

"Green Infrastructure." *U.S. EPA* online. Last modified November 14, 2018. https://www.epa.gov/green-infrastructure

"Hydrology and Low Impact Development (CXS)." *U.S. Army Corps of Engineers* online. https://www.usace.army.mil/Missions/Sustainability/Hydrology-and-Low-Impact-Development/.

2.4 Open Space Strategies

Use Parks, Trails, and Other Open Space to Protect Against Flooding

Key Benefits

1. **Reduces risk of flooding and damage from flooding.**
2. **May add funding sources for construction and maintenance.**
3. **Reduces maintenance needs compared to conventional landscaping.**
4. **Reduces load on existing stormwater infrastructure.**

Limitations

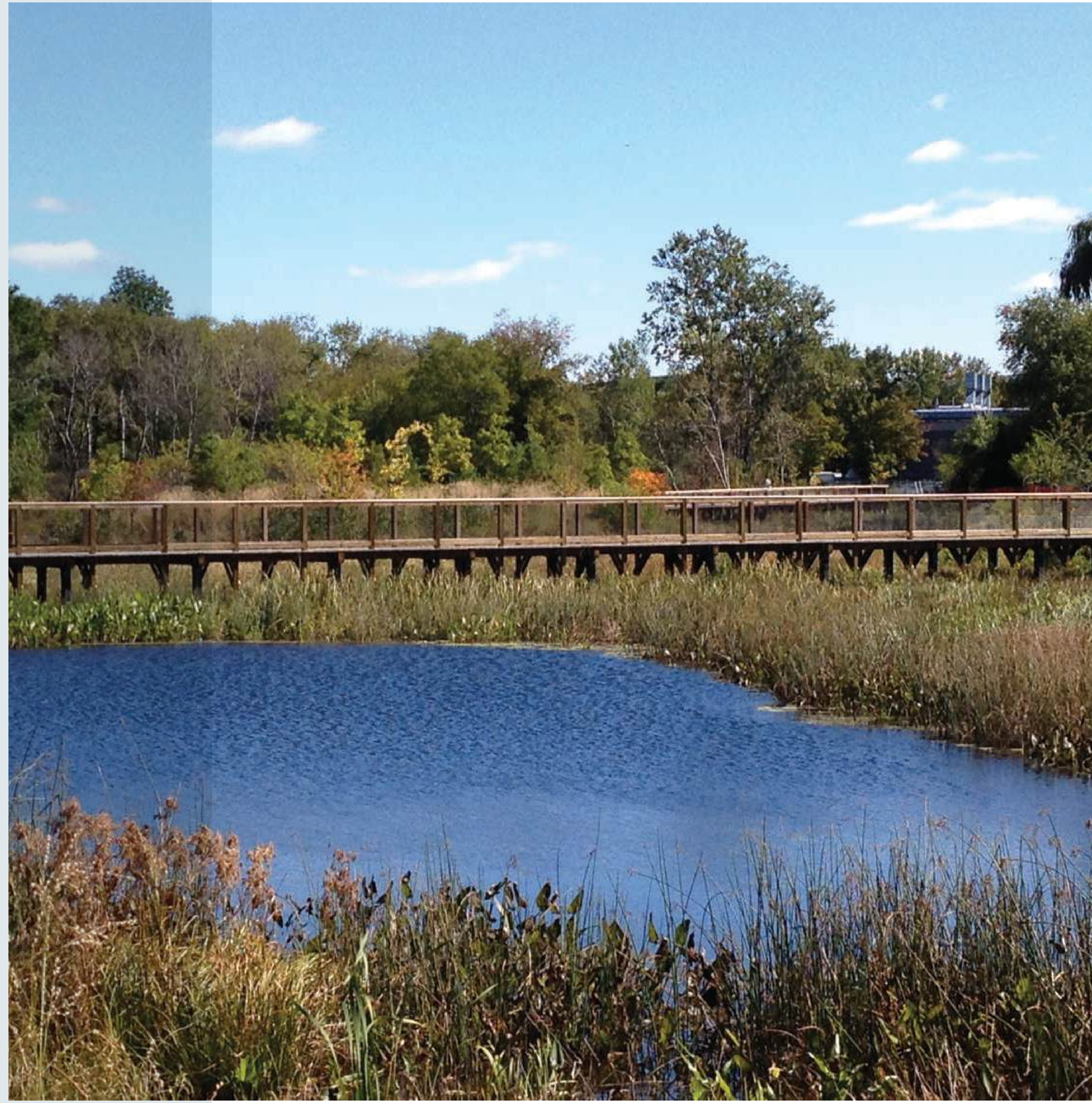
1. **May limit residential and commercial development.**
2. **May rearrange or eliminate existing park functions.**

Overview

Parks have an untapped capacity to reduce flooding. Whether parks are downtown or along a river, there are design strategies that will help collect, filter, detain, retain, and infiltrate floodwater. If well-planned and implemented, incorporating stormwater management into park design benefits community financial, environmental, and social health.

There are several factors that help pinpoint good candidates for park-based stormwater management. Ideal sites are already publicly owned with large low-lying fields for water storage or conversion to wetland. The most effective sites are those within or upstream of developed areas. In addition to floodable areas, park trails and landforms can be designed to act as berms, protecting downstream assets and buildings in the floodplain.

In the Mid-South, an estimated 9,700 acres of land are potential candidates for floodable parks.



(Right) The new Alewife Stormwater Wetland offers trails, views, and education opportunities in Cambridge, MA (Friends of Alewife)

Types, Benefits, and Considerations

Types of Flooding

Protecting homes, businesses, and infrastructure requires an understanding of the type and cause of flooding. The two main kinds of flooding threatening the Mid-South Region are flash flooding and river flooding. River flooding is caused when the volume of water draining into a riverbed exceeds the river's capacity and spills over onto the surrounding land. Flash flooding is caused when large volumes of water pass through an area that is normally dry, such as a dry creek bed or a city street. Flash flooding in the Mid-South is largely a result of increased runoff from developed areas, such as roads, parking lots, and buildings.

Since the causes of flooding vary, the solutions vary as well. As a result, cities and towns can incorporate flood mitigation in many different settings.

Primary Benefits of Open-Space Flood Mitigation

1 *Mitigate River Flooding*

Where: Upstream from development adjacent to a river

Minimum Size: 5 acres

Parks and trails can divert floodwater from a river into a floodplain or wetland. This strategy is most effective upstream from development because it reduces the volume of floodwater downstream.

2 *Protect from Flash Flooding*

Where: Urban area

Minimum Size: 1+ acres

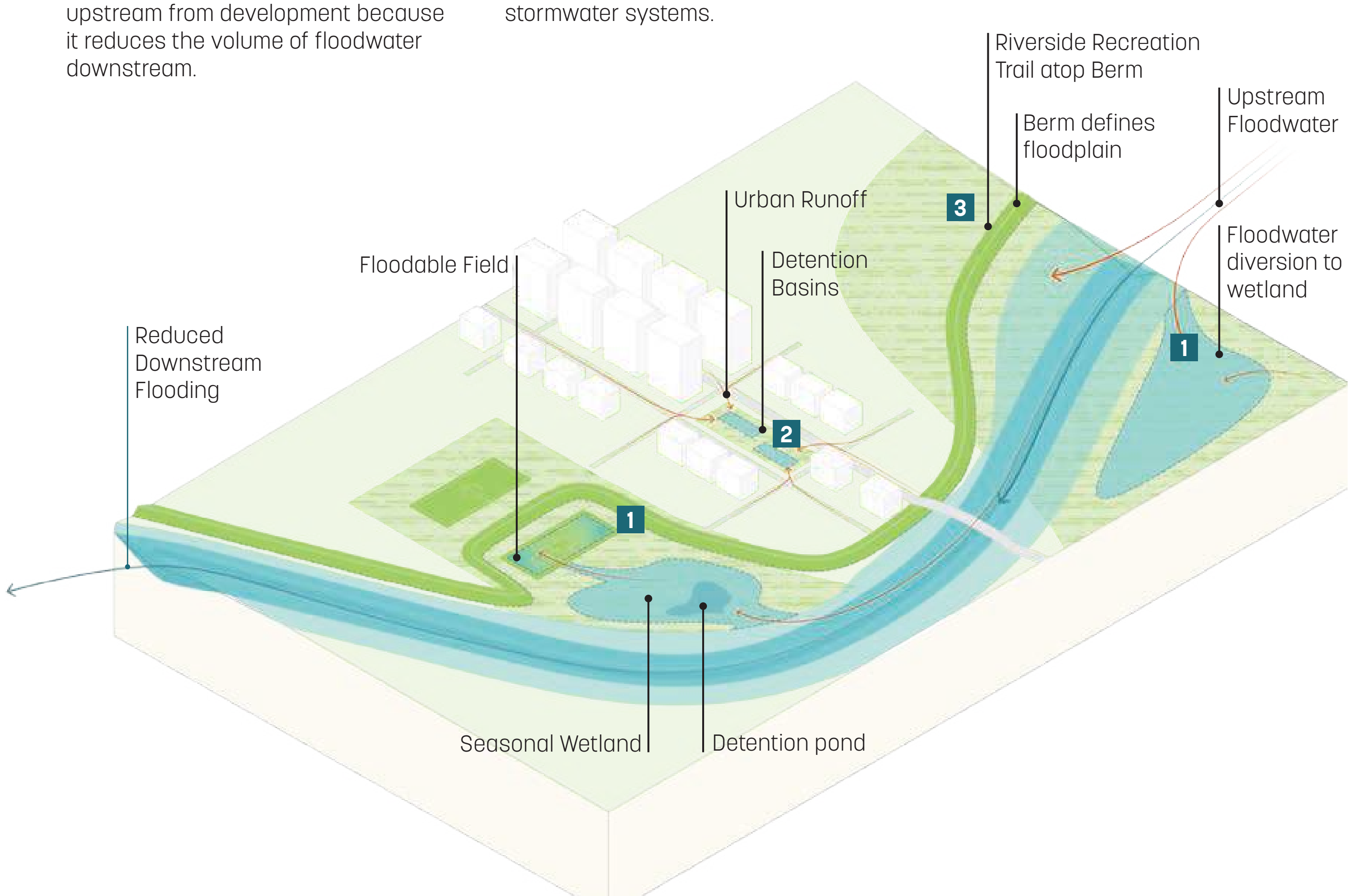
Small, urban parks can collect and store runoff from local roofs, streets, and parking lots as well as provide overflow storage for overloaded stormwater systems.

3 *Protect from River Flooding*

Where: Developed areas along a river

Minimum Size: Long enough to tie back into natural topography

Parks and trails along rivers may be designed to act as berms, protecting the communities behind them.



Secondary Benefits

Environmental Equity

Funding for stormwater projects may help municipalities fund parks in under-resourced areas. Parks may mitigate flood damage to vulnerable residents nearby.

Reduced Maintenance

Converting fields into wetlands or floodable areas can reduce the amount of time and resources usually spent on lawn care.

(Right) Alewife Stormwater Wetland a popular urban park in an area that used to be degraded and undesirable.

Additional Considerations

Anticipate Wildlife

With an increase in vegetation and water, parks may attract more diverse wildlife. Research and plant species that will attract desired animals, such as pollinator gardens.

Include Signs and Boundaries for Safety

Stormwater management parks may contain more varied topography, areas that flood quickly, or sensitive vegetation. Clearly define paths, add boardwalks over low lands, and create physical barriers between usable and non-usable space.

Prevent Stagnant Water

To prevent mosquitoes, other insects, and aquatic bacteria from developing, all stormwater management areas must be designed to drain within 72 hours of a storm event.

(Right) Clearly defined walking paths provide a safe route over the floodable wetland in Hassett Park, Gollings, France

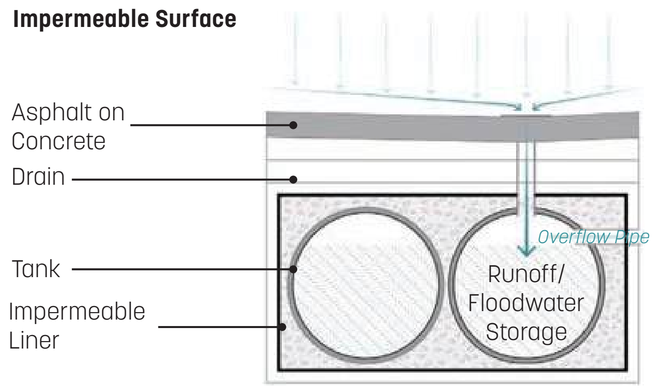
Methods

The most common park-based flood mitigation strategies fall into the categories listed below. Methods are flexible and the variations shown in this list can be adapted to most sites and budgets.

Underground Storage under an Impermeable Surface

Tanks beneath park structures like sports fields and plazas hold stormwater overflows. Stormwater is directed to the tanks through some combination of drains, channels, or permeable surfaces. Water is drained or pumped out for release or greywater purposes.

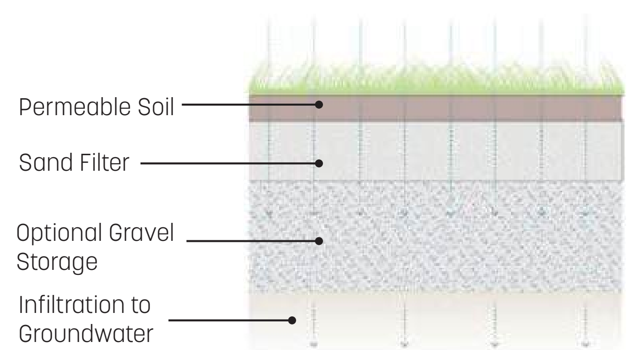
Impermeable Surface



Floodable Fields with Natural Infiltration

Class A and B soils provide quick absorption of water. A thick gravel layer underneath can provide storage.

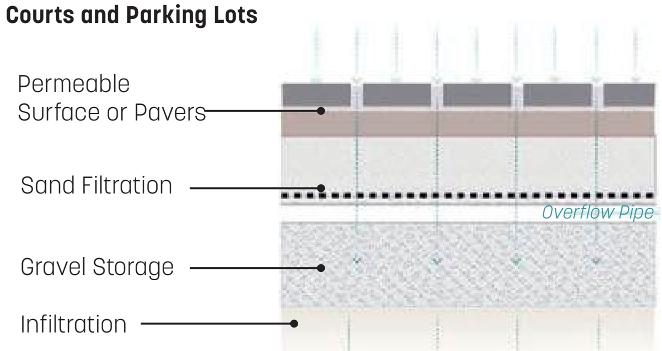
Sports or Naturalistic | Field



Permeable Pavement with Natural Infiltration

Permeable pavement provides quick absorption of water. A Thick gravel layer underneath provides storage.

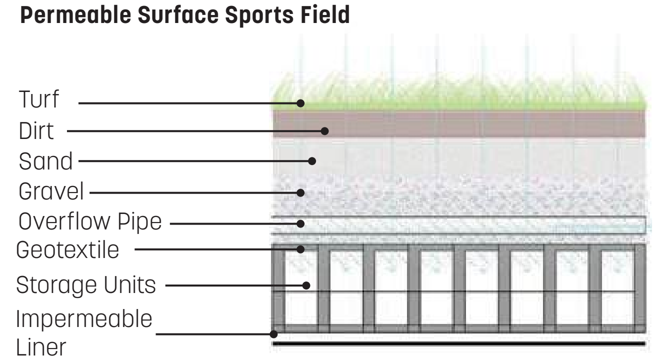
Courts and Parking Lots



Floodable Fields with Underground Storage

Water enters storage chambers through surface drains.

Permeable Surface Sports Field



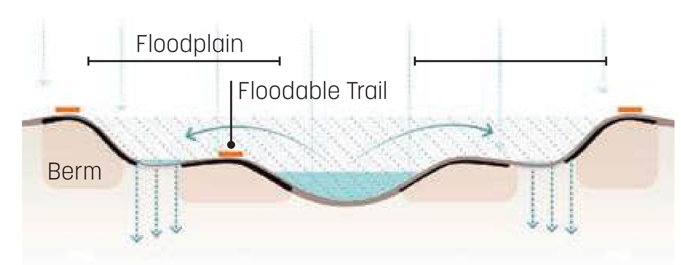
Berm

Determining where a park trail could become a berm requires analysis that is more detailed than the regional scale. Berms along the river's edge can serve many purposes but also may have negative effects on downstream flooding or the community's connection to the river. Ideally, the berm expands the floodplain and adds interest and views to the park. Factors to look for include whether:

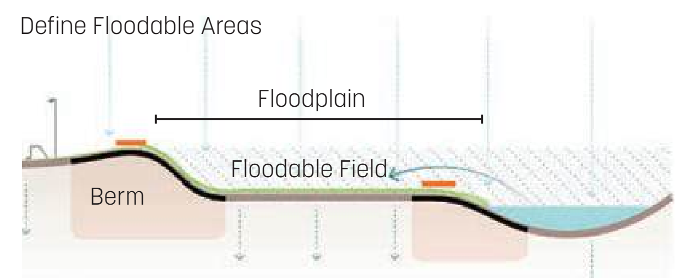
- the berm would mitigate flood damage in developed areas
- there is a local alternative place to store floodwater so that flooding does not increase downstream
- people can continue to access the river over the berm
- the berm could expand the floodplain beside the river

Functional Variation of Park-Trail Berms

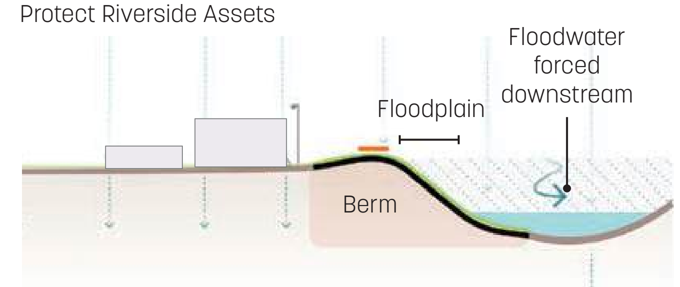
Expand River Storage Capacity



Define Floodable Areas

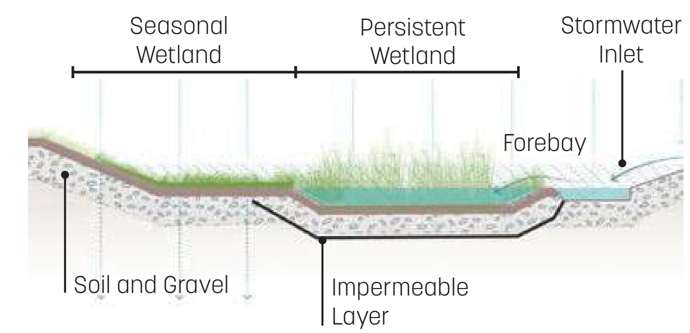


Protect Riverside Assets



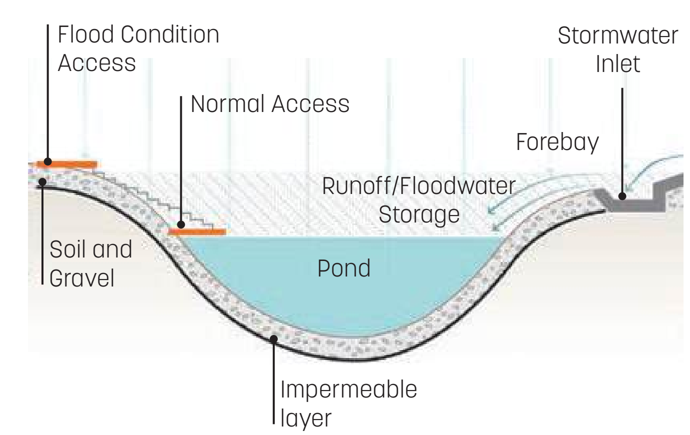
Seasonal Wetland

Low-mow area vegetated with water loving species. A gentle slope allows the flooded area to expand after storm events. An impermeable layer under the soil ensures some water retention.



Detention Pond

A small pond within a park that is designed to store a specific volume of stormwater. During non-flood conditions, the pond maintains a size suitable for fishing, wildlife, views, or other purposes.

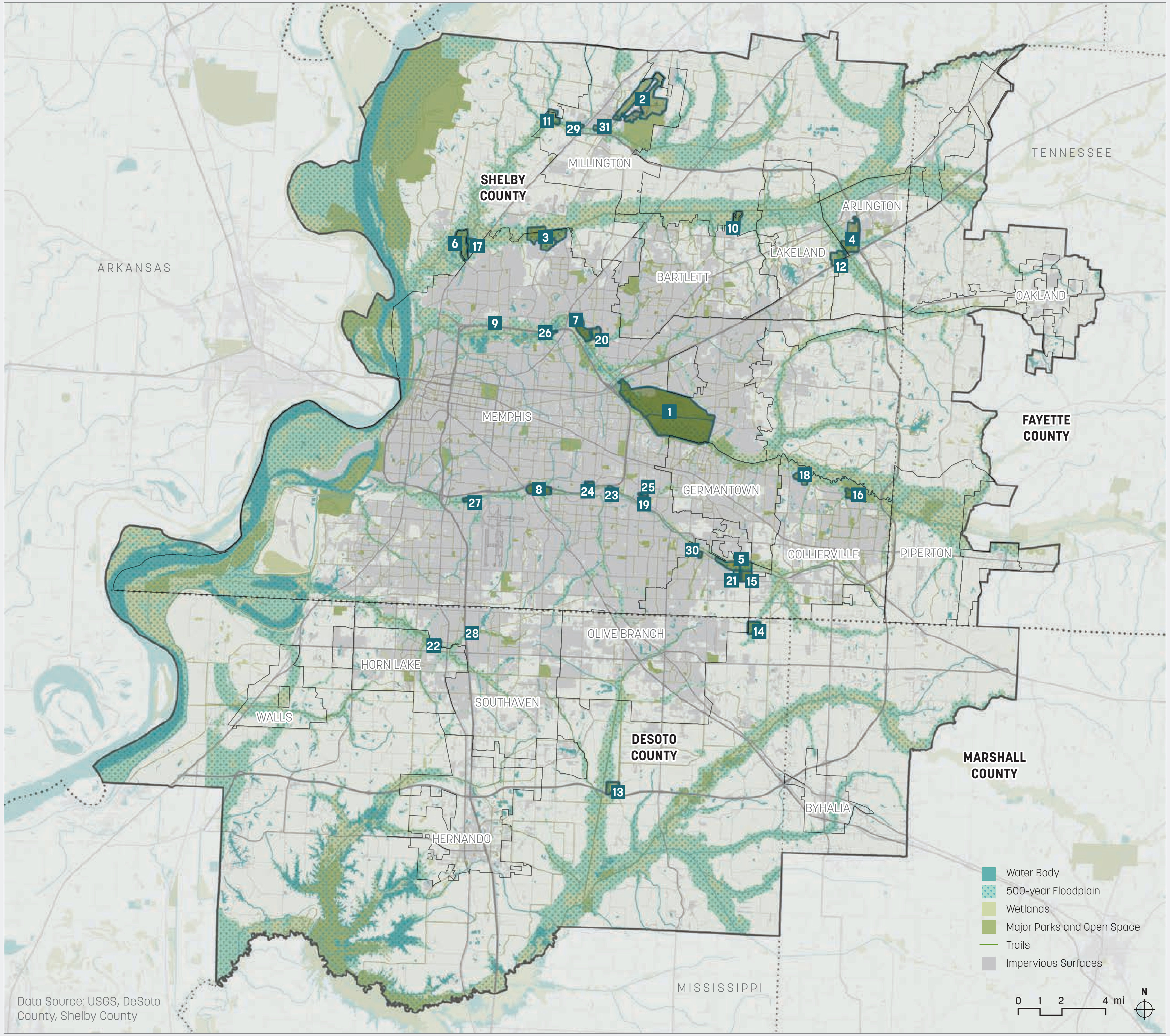


Flood Mitigation Priority Areas

Parks and public open spaces have been identified throughout the project area based on the following criteria: open space (at least five acres), areas within the floodplain, availability of sports fields, flatness, and location upstream from urban areas.

Key Parks and Open Spaces

	Name	Jurisdiction	Acres	Additional Criteria
1	Shelby Farms	Shelby County	4,323.74	Large area
2	Millington-Memphis Airport	Millington City	1,170.31	Large area
3	Oakley Park	Shelby County	694.56	
4	Hall Creek	State of Tennessee	507.82	Sports fields, existing water body
5	Nonconnah Trail Head	Shelby County	395.17	
6	Firestone Park	Shelby County	328.65	Existing water body
7	John F Kennedy Park	Memphis City	260.57	Sports Fields
8	Nash Buckingham Park	Memphis City	215.87	
9	Rodney Baber Park	Memphis City	76.65	Sports fields
10	Blue Lagoon Park	Bartlett City	161.89	Existing water body
11	Sewer Plant Site	Millington City	157.89	
12	Lakeland Vacant Land	Memphis City	149.62	
13	Lewisburg Schools	Desoto County	148.89	Sports fields
14	Center Hill Schools	Desoto County	146.92	Sports fields
15	Mike Rose Soccer Park	Shelby County	133.86	
16	W.C. Johnson Park	Collierville Town	112.71	
17	Police Academy Area	Memphis City	102.16	Sports fields
18	Robbins-Halle Nature Preserve	Collierville Town	99.14	Existing water body
19	May Park	Memphis City	64.97	Sports fields
20	Raleigh Substation	Memphis City	92.03	
21	Southwest Tennessee Community College	State of Tennessee	82.24	
22	Boosters Club Park	Southaven City	79.33	Sports fields
23	Arthur Halle Park	Memphis City	64.14	Sports fields
24	Willow Road Park	Memphis City	60.09	Sports fields
25	Ridgeway Middle School	Memphis City	29.32	Sports fields
26	Gragg Park	State of Tennessee	28.63	Existing water body
27	Nonconnah Creek	Memphis City	28.18	
28	Southaven Vacant	Southaven City	25.31	
29	USA Baseball Stadium	Millington City	24.04	Existing water body, sports fields
30	Lowrance Road Park	Shelby County	17.05	Sports fields
31	Biloxi Park	Millington City	10.76	Sports fields



Implementation

There are many considerations to make when deciding to incorporate green infrastructure stormwater management solutions in a park or trail project. Primary considerations include the local need for flood mitigation and the capacity of the site to provide significant flood mitigation. Secondary considerations include selection of appropriate techniques relative to other design or programmatic goals of the park or trail.

The Mid-South Regional Greenprint has completed planning for parks, greenways, bike trails, conservation lands, wildlife management areas and other features relevant to long-term planning needs of the Mid-South.[1]

Process

1 Identify Park/Trail for Renovation	Identify a park or trail in a flood-prone area or upstream of a flood-prone area, or a park that is already slated for improvements, and find project partners
2 Create a Park/Trail Plan	Determine design goals, stormwater management goals, and program goals
3 Design the Park/Trail	Landscape architects and stormwater engineers design park and/or trail amenities and stormwater management features
4 Build the Park/Trail	Identify funding opportunities and hire a contractor to build the park or trail
5 Maintain the Park/Trail	Identify a maintenance schedule based on recommended timeframes and assign maintenance responsibilities

1 Identify Park/Trail for Renovation

Ideally, an existing park or trail in a flood-prone neighborhood is identified by a local government agency as an opportunity site for a flood mitigation project and that agency becomes the project owner. This will help ensure that stormwater management strategies are major drivers of park or trail renovation plans.

During this stage, it is beneficial to identify project partners. Potential partners include the local parks and recreation department, stormwater utilities, conservation organizations, philanthropic foundations, or even area property owners. These partners can be advocates for the project, help with project funding, and participate in park or trail maintenance for years to come.

2 Create a Park/Trail Plan

Once a park or trail has been identified for renovation, a plan should be developed for the project. The plan should include the design goals, stormwater management goals, and program goals for the park. The stormwater management goals should align with storage capacity needs based on a specific level of storm. The planning process can include a park needs assessment that evaluates other parks, trails, and open spaces in the area to determine if the community is under-served by any specific amenities. This can help identify specific stormwater management strategies to implement in a specific park or trail segment.

An important part of the planning process is stakeholder engagement. Members of the local community should be welcomed into the planning process.

3 Design the Park/Trail

Because the primary purpose of the park or trail is to provide aesthetic and recreational amenities to users, the design of the park or trail should be granted to landscape architects with support from planners, stormwater engineers, and public works operators or others who will be involved in park maintenance.

During the design process, different green infrastructure opportunities should be tested based on site-specific data such as soil type, topography, and the relative permeability/impermeability of the context. These opportunities should be evaluated against their potential to mitigate local flooding for the level of event identified in Stage 2.

Once a final design is selected, a corresponding maintenance plan should be identified, including the necessary maintenance activities, schedule, and people responsible to ensure that the stormwater management strategies can function at their peak potential.

4 Build the Park/Trail

During Stages 3 and 4, the project owner should begin identifying funding sources for the construction and maintenance of the park or trail. Often, parks are funded using local budgets, but sometimes private foundations or non-profit groups with mission alignment will contribute to the cost. In many cases, the stormwater management strategies embedded in the design provide relief to local stormwater utilities, and that entity may share some of the construction costs as well. In some cases, a local developer will contribute funding because it needs to compensate for stormwater requirements at another project site.

5 Maintain the Park/Trail

The maintenance plan identified in Stage 3 needs to be implemented to ensure optimal functionality of both the park or trail recreational amenities and the stormwater management functions. Maintenance of parks and trails is often the responsibility of local departments of public works. Due to the incorporated stormwater management components, the local stormwater utility may also shoulder some of the financial or personnel maintenance burden.

Friends of the park groups, local conservancies, local businesses, or local property owners may also choose to sponsor park or trail "clean up" days. These can be very effective for certain kinds of maintenance, including removing invasive plants from wetlands and weeding detention basins. Other maintenance activities, such as vacuuming debris from porous pavement areas, can be outsourced to private companies for a relatively low annual cost. This may be a particularly appealing option for smaller jurisdictions whose public works departments are at capacity with current workload.

Typical Costs for Green Infrastructure[2 3]

Strategy	Capital Cost/Acre	Annual Maintenance Cost/Acre
Seasonal wetland	$21,000 - $30,000 per acre ($1.00 - $2.00 per cubic feet of storage)	$1,000 - $1,200
Floodable field	-cost of field, plus any additional drains and berms-	-depends on frequency of flooding-
Detention basin	$16,500 - $31,000 per acre ($0.80 - $1.60 per cubic feet of storage)	$500 - $2,500 (depending on plant selection)
Underground storage	$11,000 per acre ($5 - $9 per cubic feet of storage)	$500
Levee/berm/floodwall	$60 - $170 per linear foot, based on height	
Porous pavement	asphalt costs in line with non-porous options plus $1.30 per cubic feet of storage	$500 - $1,000

Case Studies

West Riverfront Park and Amphitheater, Nashville, TN

Following a 1,000 year flood in 2010 that caused $2 billion in private property damage in downtown Nashville, the city reimagined a waterfront open space as a destination park with integrated stormwater management strategies. The park design strategy was "park first," prioritizing recreational amenities and aesthetics and working stormwater infrastructure into the preferred design. The result is a park that connects two existing downtown greenways with a generous series of lawns, pathways, an amphitheater, a dog park, and gardens.

Within the park design, 2,000 square feet of bioretention areas including detention basins, green roofs, and seasonal wetlands provide stormwater storage and treatment. The great lawn covers a 375,000 gallon cistern used for stormwater storage and rainwater harvesting. A floodwall designed to protect against a 500-year storm event is part of an integrated seating strategy and dog park enclosure. The promenade along the river extends beyond the park as part of an existing trail network, and is part of the floodwall strategy. Finally, 12,500 square feet of permeable pavers provide surface parking that contributes to stormwater management rather than runoff. The total cost of the park improvements was $52,000,000.[4,5]

(Left) Flooding of the Cumberland River near downtown Nashville, Tennesse.

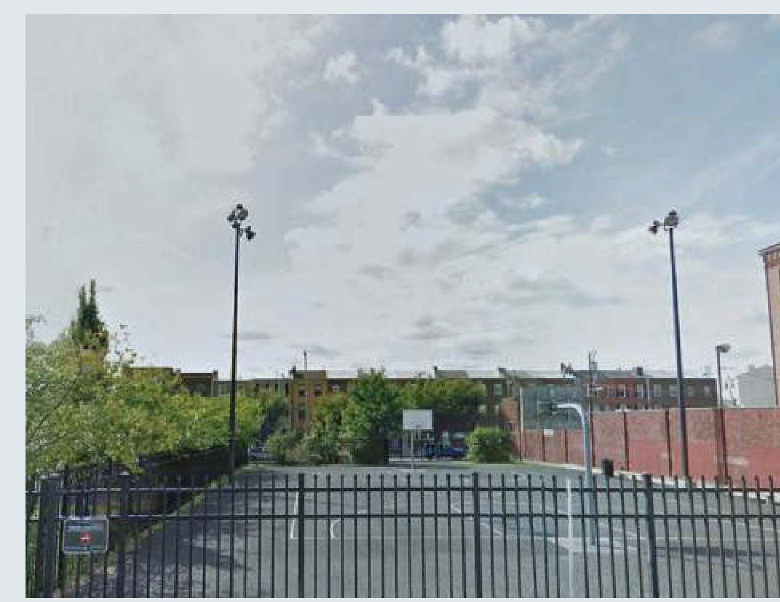
(Above and Right) Nashville Riverfront Park opened in 2015. The "park first" design strategy incorporates significant flood mitigation strategies.

Herron Park, Philadelphia, PA

The Herron Park renovation was a collaborative effort between the Philadelphia Water Department, Department of Recreation, and the City's Capital Program Office. The park renovation included a redesigned playground, rain gardens, bioswales, and a basketball court surfaced with porous asphalt. Underground storage is provided by a subsurface infiltration system that manages stormwater from the site and collects runoff from the surrounding neighborhood. The new park converted 95% of the former park's impervious area into permeable surfaces. Herron Park now captures water from the 1.12 acre park site as well as 1.17 acres of adjacent impervious land. The park contributes to the City of Philadelphia's 25-year plan *Green City, Clean Waters* which aims to capture the first one inch of stormwater runoff. Total park reconstruction costs were $1.1 million.[6]

(Left) Playground features like rock outcroppings, surfaces suitable for children's bikes, picnic tables, and a spraypad provide neighborhood park amenities.

(Above) Native plants and impermeable paving create a comfortable and resilient respite in South Philadelphia.



(Right) Porous paving surfaces were used at Herron Park's basketball court to collect stormwater in a subsurface structure.

Endnotes

1 Mid-South Greenprint, *Mid-South Regional Greenprint and Sustainability Plan 2015/2040*, 2015, https://midsouthgreenprint.org/greenprint-20152040/

2 "Community Stormwater Solutions BMPs Cost Catalog," *Massachusetts Watershed Coalition* online, http://www.commonwaters.org/.

3 Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management.

4 "Fact Sheet: West Riverfront Park and Amphitheater," *Metro Government of Nashville and Davidson County, Tennessee* online, https://www.nashville.gov/News-Media/News-Article/ID/3397/Fact-Sheet-West-Riverfront-Park-and-Amphitheater.aspx.

5 Bill Lewis, "Bringing an Open-Air Venue and park to a former Landfill in the Music City," *Urban Land Magazine* online, https://urbanland.uli.org/development-business/bringing-open-air-venue-park-former-landfill-music-city/

6 "Green Infrastructure and Stormwater Management Case Study: Herron Playground," Case Number 468, *American Society of Landscape Architects* online, https://www.asla.org/uploadedFiles/CMS/Advocacy/Federal_Government_Affairs/Stormwater_Case_Studies/Stormwater%20Case%20468%20Herron%20Playground,%20Philadelphia,%20PA.pdf.

Resources

Parks and Green Infrastructure

Green Infrastructure in Parks: A Guide to Collaboration, Funding, and Community Engagement Resources. Document Number EPA 841-R-16-112. (U.S. Environmental Protection Agency, 2017). https://www.epa.gov/sites/production/files/2017-05/documents/gi_parksplaybook_2017-05-01_508.pdf.

City Parks, Clean Water: Making Great Places Using Green Infrastructure. (Trust For Public Lands, 2016).

Funding

Naturally Resilient Communities online. http://nrcsolutions.org/nashville-tennessee/.

3

Buildings

3.1 Floodproofing Buildings

Retrofit Critical Buildings for Flood Protection

Key Benefits

1	Can be implemented by individual entities on single buildings
2	Requires less organizational effort of larger systems
3	Can be combined with many other flood mitigation techniques

Limitations

1	Many floodproofing techniques are only site-specific and temporary
2	Protection techniques can be costly and depends on overall building quality

Overview

While there may be major infrastructural needs to mitigate flooding on a systemic level, it is often much more feasible to implement building-scale flood protection measures. Approximately 1.6% of buildings in Shelby and DeSoto Counties have a 1% annual risk of flooding. Buildings such as police stations, fire stations, community centers and hospitals (critical facilities) have the most need for floodproofing. In the event of a disaster, these facilities provide an important first line of response and play a major role in saving lives. Floodproofing measures can help to keep these critical public services functional during and after a major disaster.

While this section focuses on floodproofing for critical buildings, individual home and business owners can implement many of these recommendations on their own. Municipalities may support such retrofits with grants, subsidized materials and labor, and educational outreach.

This section provides an overview of important considerations in implementing floodproofing measures and provides a list of key floodproofing measures that can be implemented individually or collectively. For more information on Critical Infrastructure Planning, see 5.1 5.1 Critical Facilities.

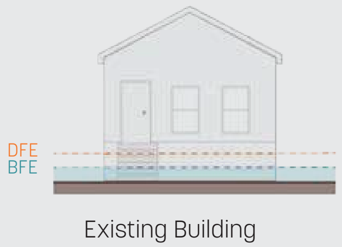
(Right) Flooding near the Our Lady of Lourdes Hospital in Binghamton, protected by a flood wall in 2011.

Flood Characteristics and Site Factors

Key Terms[1]

Base Flood Elevations (BFE): The computed elevation to which floodwater is anticipated to rise during the base (1% annual chance) flood. Base Flood Elevations (BFEs) are shown on Flood Insurance Rate Maps (FIRMs) and on the flood profiles. The BFE is the regulatory requirement for the elevation or floodproofing of structures. The relationship between the BFE and a structure's elevation determines the flood insurance premium.

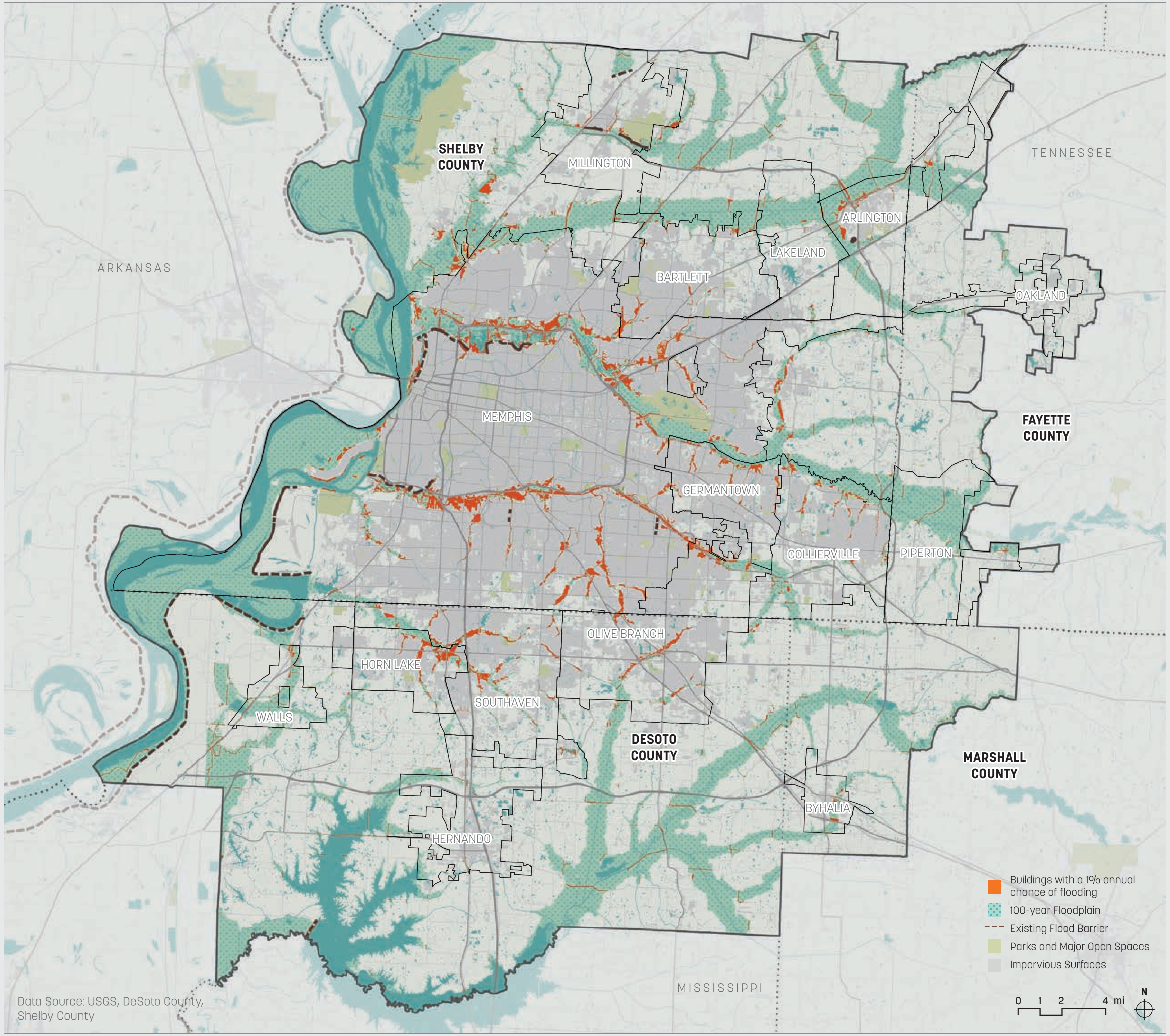
Design Flood Elevation (DFE): The specified level to which a structure will be protected from floods when it is built or retrofitted (generally 2 ft above the BFE in Shelby County).



Special Flood Hazard Area: The area that will be inundated by the flood event having a 1% chance of being equaled or exceeded in any given year. Also referred to as the base flood or 100-year flood.

Considerations

- Building location can help determine the appropriate floodproofing strategies. For example, a non-residential building adjacent to a waterway may benefit from a passive deployment system. Non-residential buildings are likely to be unoccupied for significant durations of time and local stream gauges may not provide adequate warning time for human operators to deploy a manual system.
- Building use and condition play major roles in determining appropriate floodproofing strategies. For example, buildings with occupied spaces below the BFE cannot be wet floodproofed, but some structures functionally dependent on proximity to water can be wet floodproofed. The National Flood Insurance Program does not allow residential buildings to be dry floodproofed using temporary barriers.
- Historic structures receive special considerations under the NFIP, and do not necessarily need to be brought into compliance. If voluntarily retrofitted, floodproofing should preserve the building's historic integrity.
- There may be activation time required to deploy certain floodproofing measures before flood water reaches the site. Stream gauges can automatically alert building owners of the need to monitor weather reports for the expected flood extents and cresting times. This allows them to begin deployment before their area is expected to flood.



3.1.1 Wet Floodproofing

Wet floodproofing strategies include measures that minimize damage to areas below the flood protection level of a structure that is intentionally *allowed* to flood. These strategies help mitigate damage during the flood event as well as the time it takes for the flood water to recede.

1 Elevation of Systems

Elevating vulnerable building systems equipment, such as HVAC and electric systems, above the base flood elevation is a relatively inexpensive way to protect expensive equipment and support continued operation of the building through a flood event. Electric outlets, normally placed near the floor, can be relocated in higher positions along the wall to prevent damage during floods. For buildings in areas of heightened seismic risk, heavier equipment should be raised only as far as necessary to reduce flood risk, so as not to create a "top heavy" building that is at increased risk during seismic activity.

Water Evacuation and Management

Methods to control floodwater entry and exit from building areas below the design flood elevation.

2 *Drain and Sump Pump*

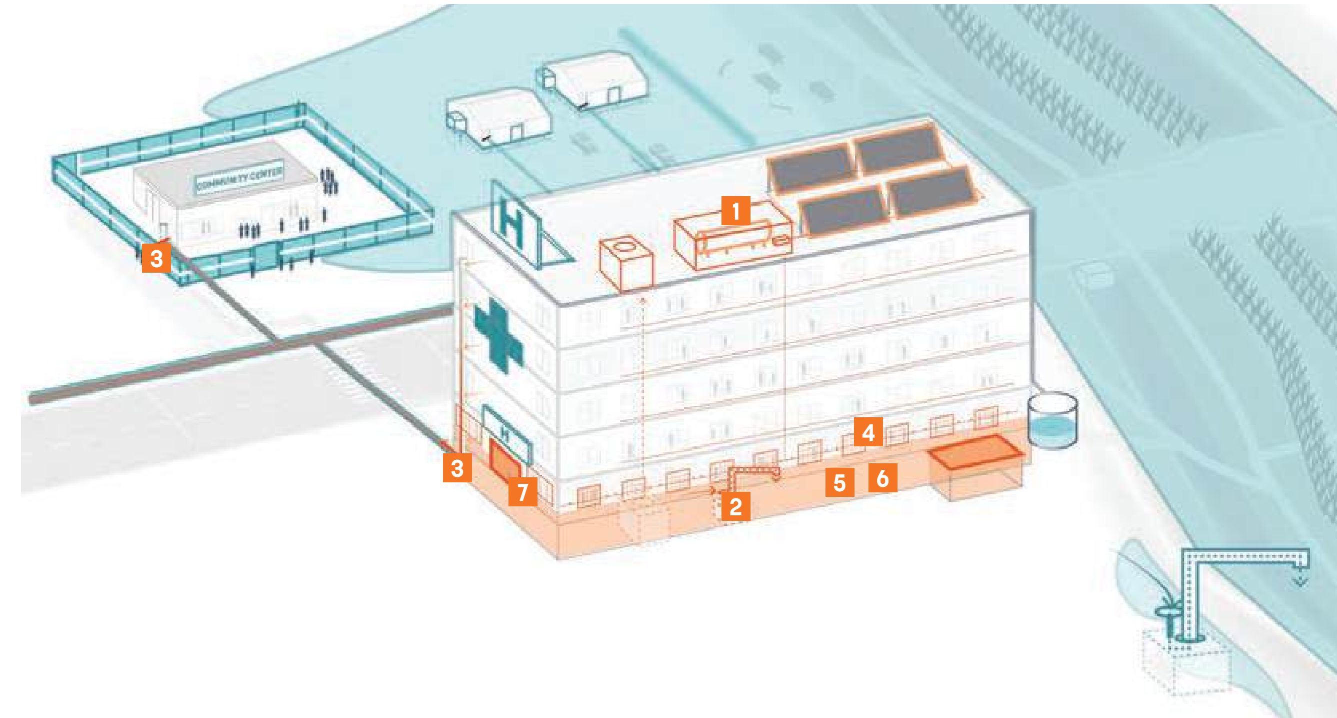
Drains can help remove water that collects in buildings below grade, particularly with the help of sump pumps. Sump pumps are installed in the lowest part of a basement or below-grade space. Water then flows through a drain to the sump pump, where it is then pumped away from the building. Sump pumps require electric power in order to operate.

3 *Non-Return Valves*

Flooding can cause sewage to be pushed back up into buildings through pipes that connect building systems to the larger sewer systems. Non-return valves block back flow during storm events, preventing sewage backups.

4 *Flood Vents*

Flood vents allow water to flow into basements, garages, and other parts of buildings that are below the DFE. Letting in floodwater reduces the risk that walls will be damaged or cave-in from hydrostatic pressure. The NFIP requires a minimum of two openings for enclosed areas under the DFE.



Water-Resistant Materials

Often building materials can withstand the initial flood event, but mold or rot and must be replaced if flood waters do not quickly recede. Water-resistant materials that will not rot or mold if they are exposed to flooding help preseve structures that remain water-logged longer than several hours. Categories include:

5 *Floor and Wall Membranes*

Floor and wall structures can be constructed out of waterproof materials. For Structural Insulated Panel wall systems, waterproofing must be done during the initial construction process to ensure that the walls are properly anchored to the foundation and can withstand hydrostatic pressure. Insulated Concrete Form systems have integrated structural capacity, but are often "finished" with materials such as drywall that are not floodproof and would need to be replaced after a flood.

6 *Water Resistant Insulation*

Water resistant insulation can help reduce the damage associated with wet floodproofing strategies. Closed cell sprayed polyurethane foam insulation can be installed in a water resistant manner. If waters recede quickly (within hours or a day), the insulation can often be dried and left in place during any needed repairs.

7 *Flood Resistant Doors and Windows*

Doors made from metal, with either hollow, wood, or foam filled cores, as well as doors made of fibergalss with a wood core, can resist flood waters. Windows can be flood resistant if the materials surrounding the glass panes are flood resistant and do not include adhesives or materials that are not resistant to flooding.[2]

3.1.2 Dry Floodproofing

Dry floodproofing measures help keep structures dry during flood events. By creating barriers between floodwater and a structure and its contents, wet floodproofing measures are not necessary. This strategy is typically most effective for limited durations and limited water depths. This solution is ideal for existing structures that cannot be retrofitted or relocated out of the Special Flood Hazard Area or other floodprone location.

Locations for Dry Floodproofing Measures:[3]

- Around low-lying buildings from all sectors.
- In front of building entrances, stairwells, and ramps vulnerable to flooding.
- Around infrastructure, including remote service buildings such as pumping or transfer stations.
- At vent and access shafts for underground infrastructure, such as utilities.
- On low-lying roadways.
- On top of levees or waterfront promenades.

Permanent Barriers

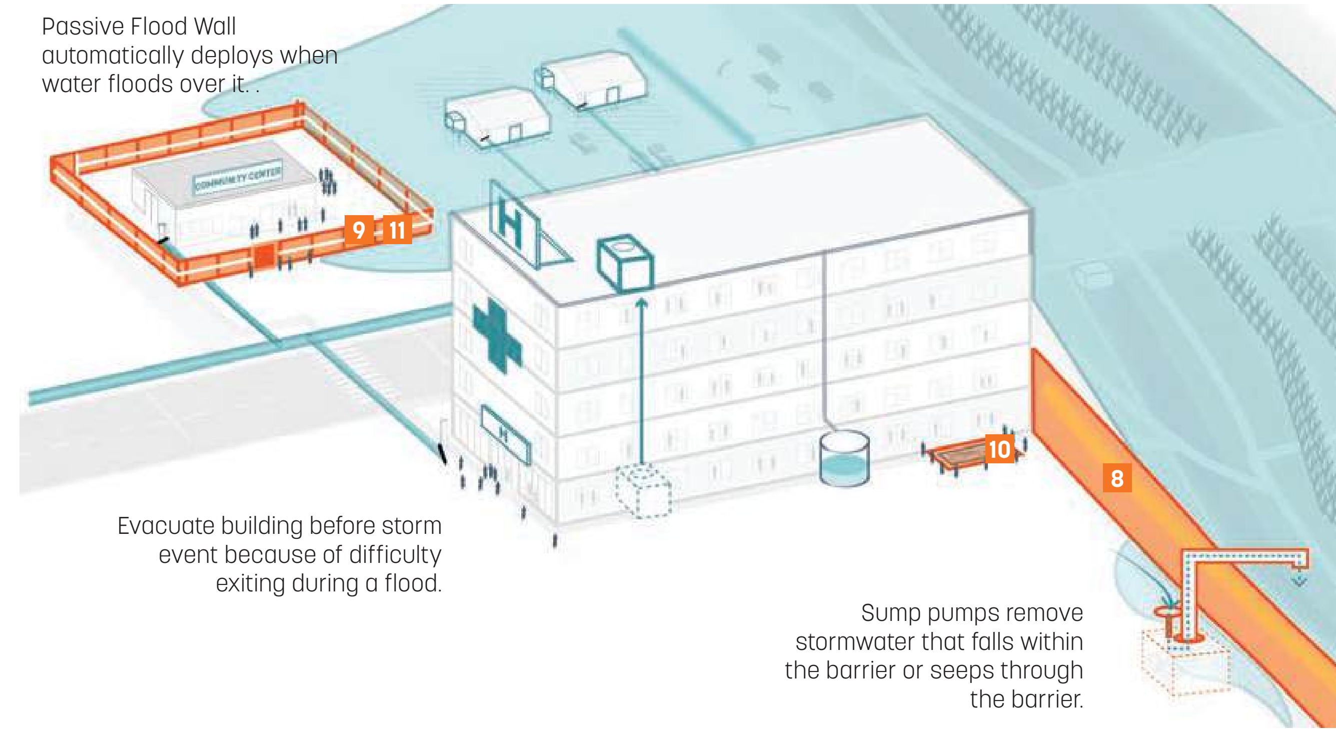
Barriers need inspection twice a year and after each flood event. Residents should not occupy buildings with barriers, as it may be difficult to leave in an emergency or if the barrier is over-topped. Pumps are needed within barrier walls to remove water that may seep into the barrier.

8 *Berms*

Berms are mounds of compacted earth around a site or sites that hold back floodwater. They can protect a single structure or several structures by blocking a flood pathway.

9 *Floodwalls*

Floodwalls are offset barriers often used to protect larger commercial/industrial properties, potentially with multiple structures.



Temporary Barriers

Barriers can also be temporary. They can be manually or automatically deployed before a storm event. Temporary barriers are most effective during shorter periods of lower levels of inundation. They are best used when flooding lasts for less than one day and is less than one foot high.[4]

10 *Shields for Openings*

Shields are smaller barriers applied to structures, or closely offset from structures, that prevent flood water from penetrating openings below BFE. They are suitable for doors, garages, gates, and ground-level windows.

11 *Deployable Barriers*

Deployable barriers can be used on larger areas such as lawns or roads to form a wall around the site, or to connect two dry floodproofed buildings and serve as a barrier for structures beyond. Deployable barriers are typically effective for up to three feet of floodwater. Some must be temporarily constructed in place by trained staff in advance of a flood. Others are passive flood walls, permanent installations that lay flush with the ground on dry days and are triggered by the presence of water, removing the labor requirement typically associated with deployable barriers.

Implementation

There are many considerations to make when deciding to retrofit a structure. An overall cost-benefit analysis of implementing floodproofing measures is a good place to start. This should include consideration of relocating the structure out of the floodplain or hazard zone. If this is not feasible, there are several other steps to take in considering what options to implement.

Process

1 Identify Building Flood Risk	Locate site within Flood Hazard Area, identify building's material and structural conditions
2 Identify Flood Level	Determine Base Flood Elevation (BFE) and required Design Flood Elevation (DFE) as well as lowest adjacent grade and lowest floor elevation
3 Review Relevant Codes, Regulations, and Planning Context	Look for up-to-date regulations and codes such as the NFIP as well as relevant state and local floodplain regulations
4 Identify Relevant Mitigation Strategies	Explore the pros and cons of various wet and dry floodproofing measures
5 Funding and Design Strategy	Understand the cost and economic factors as well as other design considerations in implementing certain measures

1 Identify Building Flood Risk

To identify the potential risk of flooding to a building, first locate the building in relationship to FEMA's Flood Insurance Rate Maps (FIRMs). FIRMs classify the potential type of flood hazard into categories such as Special Flood Hazard Area (Zone A) or a Regulatory Floodway (Zone AE). These areas are considered at high risk. Included in this classification is a 0.2%-1% Annual Chance of Flood Hazard (Zone X) which indicates the flooding levels of a "500- to-100 year flood event." If a building is located within this datum, it does not necessarily mean it is protected from flooding.

Other factors in determining the viability of a retrofit of a critical building are its material and structural conditions. These factors are determinative of its ability to support features such as elevation of critical systems, or even resistance to lateral loads, not only from floodwaters, but also from higher wind loads and earthquakes. This assessment should be done by a qualified engineer.

2 Identify Flood Level

There are a few key pieces of information when beginning a retrofit assessment. Once a building has been identified as being in a flood-prone location, the BFE should be identified. Additionally, the required DFE as well as lowest adjacent grade and lowest floor elevation should also be identified. These are all critical pieces of information in designing a retrofit. The DFE is usually given in the building code or local flood mitigation plan. The lowest adjacent grade and lowest floor elevation can help to indicate the type of retrofit needed (such as the need to elevate critical systems or install a flood wall) as well as assess the cost of the retrofit type. This could range in cost depending on needs, including filling in a basement level that is at high risk for flooding or additional structural reinforcement.

3 Review Relevant Codes, Regulations and Planning Context

FEMA plays a major role in how buildings may be retrofitted by promoting emergency management services at the local level and setting minimum requirements for building-scale retrofits. These regulations should be thoroughly reviewed.

National Flood Insurance Program (NFIP)

The entire Mid-South Region participates in the National Flood Insurance Program (NFIP), which offers subsidized flood insurance policies for individual land owners. Homeowners who reside in a floodplain with a 1%(or greater) annual risk of flooding and have a mortgage managed by a federally insured bank are required by law to purchase flood insurance.

Communities that participate in the NFIP are required to incorporate flood-resistant construction standards and techniques into their building codes for areas located in mapped Special Flood Hazard Areas (SFHAs). FEMA may require non-residential building owners who implement dry floodproofing retrofits to obtain a FEMA Floodproofing Certificate for Non-Residential Structures.[5] This requirement also applies to mixed-use buildings with residential units above the floodproofing design elevation.

Additionally, FEMA regulations in 44 CFR Part 9 establishes policies and procedures for FEMA to address the potential risks to facilities of critical concern located (at minimum) in the 0.2-percent-annual-chance (500-year) floodplain. These facilities include those that "produce, use, or store highly volatile, flammable, explosive, toxic or water reactive materials; hospitals, nursing homes, and housing for the elderly; emergency operation centers, data storage centers; utility systems and power generating plants."[6]

Local Codes

In addition to NFIP regulations, many communities in the Mid-South have adopted codes responding to floodplain regulations. For example, under the Memphis and Shelby County Unified Development Code, an Elevation Certification[7] is required for new buildings under construction. One must be obtained "upon placement of lowest floor" and "prior to further vertical construction" in the flood hazard areas. The Unified Development Code also establishes a Flooplain Overlay District[8] within its development code. It regulates building use, flood-mitigation construction techniques, and implementation of flood barriers. Buildings within this zone must obtain a permit certifying conformity to the regulations of the Floodplain Overlay District. This code generally requires dry floodproofing techniques be designed to protect to levels above 2 ft the level of the base flood elevation. DeSoto County's Flood Damage Prevention Ordinance also regulates areas within the SFHAs and Community Flood Hazard Areas (CFHA). Building owners seeking to voluntarily retrofit their structures should consult these local codes for guidance before proceeding with their project.

Flood Mitigation Plans

In order to receive funds under the Flood Mitigation Assistance (FMA) Program, FEMA requires communities to develop Flood Mitigation Plans (FMPs). Retrofits and other design considerations must conform with the Flood Mitigation Plan. The 2016 Shelby County Hazard Mitigation Plan and the 2010 Mississippi State Hazard Mitigation Plan should be referenced for these purposes.

Key Federal Guidance Documents

- NFIP Technical Bulletin 3-93, NonResidential Floodproofing: Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program.[9]
- USACE's Flood Proofing Regulations (EP 1165-2-314), a technical model for floodproofing-related regulations but not a regulation.[10]
- NFIP Technical Bulletin 7-93, Wet Floodproofing Requirements.[11]

4 Identify Relevant Mitigation Strategies

There are benefits and drawbacks to various floodproofing measures (see table to right). Every building is in a different context and will have different needs based on its age, material and structural conditions, siting, assessed risk, and others. A thorough assessment of potential options should be included in a cost-benefit assessment.

5 Funding and Design Strategy

Typical Costs for Floodproofing Measures

Typical Cost Aspect	Typical Cost
Permanent Barriers	
Levee/Berm	
2 ft above ground	$60/ft
4 ft above ground	$106/ft
6 ft above ground	$170/ft
Flood Wall	
2 ft above ground	$92/ft
4 ft above ground	$140/ft
6 ft above ground	$195/ft
Flood Gates	
Floodbreak (up to 300 ft wide, 10 ft 8 in tall)	
6 ft x 3 ft pedestrian gate	$14,000/item
25 ft x 3 ft vehicle gate	$70,000/item
Self-activating Flood Barrier	$109,800/sqft
Aqua Fragma	$53,800/sqft
Temporary Barriers	
Sand Tubes	
2 ft above ground	$30/ft
4 ft above ground	$60/ft
Concertiner/Floodline Unit	
4 ft above ground	$27/ft
Rapid Deployment Flood Walls (RDFW)	
2 ft above ground	$84/ft
4 ft above ground	$168/ft
6 ft above ground	$252/ft
Metalith H_2O Panels	
3 ft above ground	$32/ft
6 ft above ground	$64/ft
Water Evacuation	
Backflow Valve	$600-1,400/item
Drain and Sump Pump	$400-1,800/item
Flood Vent	$100-300/item
Water-resistant Materials	
Floor and Wall Membranes	$5-10/sqft

*Costs will vary based on local factors

Typical Cost and Economic Factors

Construction Costs include factors such as materials and labor which depend on the measure type and local conditions. Labor costs can vary greatly depending on measure type.

Professional Fees are typical costs for design and engineering of systems and measures that require expert knowledge to ensure safety and effective construction. These fees are often proportional to the total cost of construction.

Loss of Floor Area is particularly costly for commercial buildings, but can be a factor for the operations of any facility where space is limited. Additional space may have to be constructed, or facility operations may have to operate with less space than before which may have efficiency costs.

Decrease in Flood Insurance Rates through implementing flood mitigation measures can help with long-term costs associated with a particular building.

Mitigation Strategies

Measures	Benefits	Drawbacks
Dry Floodproofing Measures		
Permanent Barriers	Can limit retrofit impact on building design Reduces related insurance premiums Can be combined with other flood mitigation measures	Structural aspects of permanent barriers can be costly Can create barriers for travel and may require gates or alternative means of egress
Temporary Barriers	May have limited impact on building's appearance or structure Can be combined with other adaptive floodproofing measures Can be scalable	Not approved for use in residential buildings by FEMA Protects against short-term flooding Requires advance notice of potential flooding Requires set up that can result in human error
Wet Floodproofing Measures		
Elevation of First Floor	Reduces flood insurance premiums Reduces risk to structure and interior	Difficult for attached buildings Expensive and can require substantial construction Requires temporary relocation of inhabitants Infeasible for most non-residential types May have negative impact on visual aesthetics
Elevation of Systems	Reduces cost of repairs after flooding Reduces time for re-use of building after flooding Can be easier to implement than other measures Provides credits for flood insurance policies	May lose useable floor area May require structural reinforcement and code compliance measures that increase cost
Water Evacuation	Can be combined with other floodproofing techniques May be inexpensive Addresses issues related to hydrostatic pressure	Can be difficult to retrofit existing structures to meet requirements
Water-resistant Materials	Can be combined with other floodproofing techniques May be inexpensive	Can be difficult to retrofit existing structures to meet requirements May have negative visual impact

External Funding Sources

FEMA provides assistance through "Hazard Mitigation Assistance." Applications must be done through an entity's local government for funding for each of these programs:

- Flood Mitigation Assistance (FMA) Program
- Pre-Disaster Mitigation Program
- Hazard Mitigation Grant Program: Grant money is made available only after a federally declared disaster

To apply for funding through these programs, communities must have a FEMA-approved mitigation plan for their jurisdiction that conforms to the Code of Federal Regulations (44 CFR 201.6) and the State Hazard Mitigation Plan. The Tennessee Emergency Management Agency provides funding for communities to develop Flood Mitigation Plans (FMPs). Under Section 1366 of the National Flood Insurance Reform Act (NFIRA), an approved FMP is required in order for a State or community to receive an FMA project grant. There are several eligibility requirements.

Within the FMA program, FEMA is obligated to contribute up to 75% of the cost of eligible activities. The remaining 25% must be met by non-Federal sources.

Local Funding Sources

Taxes and impact fees are also important sources for supporting regulatory systems and funding public projects that help to mitigate flood risks. Where critical services are embedded within communities at risk, a larger scope of measures should be considered within a cost-benefit analysis.

Design Considerations

Access requirements are important and necessary considerations when applying floodproofing measures to a facility. Some measures may require the replacement of exits to other parts of the building, However, evacuation and entry routes should be reappropriated based on building code requirements.

Parking is also an important consideration in terms of access to the site. This may include employees who are critical to maintaining the function of a critical facility or allow for access to the site for reasons of an emergency such as the access to a site to implement temporary measures for flood mitigation.

Visual Aesthetics are important in contributing to an overall sense of place at a human-scale. There are many creative design solutions that can preserve the character of an area and maintain visual aesthetics without imposing flood walls along streets and sidewalks.

Case Study

Our Lady of Lourdes Hospital, Binghamton, NY

In 2006, powerful flooding of the Susquehanna River shut down the operations of the Our Lady of Lourdes Hospital in Binghamton, New York. The entire first level of the hospital was filled with 16 to 20 inches of flood water contaminated with raw sewage, shutting down the hospital for several days. The hospital worked closely with New York State Emergency Management Office (NYSEMO) and the Adjusters International (consultants) to propose hazard mitigation measures with a cost-benefit analysis to FEMA.

In November 2007, $5.2 million was awarded to the hospital to construct a new flood wall, flood gates and pumping system. This was the entire 75% cost share that FEMA was obligated to provide DR-1650-NY. In 2011, when a storm caused the Susquehanna River to flood again, the flood wall effectively protected the hospital from the water.

(Left) Flooding of the Our Lady of Lourdes Hospital in Binghamton, 2007.

(Above) Flooding of the Our Lady of Lourdes Hospital in Binghamton, protected by the flood wall, 2011.

Endnotes

1 Wayne Blanchard, *Guide to Emergency Management and Related Terms, Definitions, Concepts, Acronyms, Organizations, Programs, Guidance, Executive Orders & Legislation*, (FEMA: 2008), last accessed February 26, 2019, https://training.fema.gov/hiedu/docs/terms%20and%20definitions/terms%20and%20 definitions.pdf.

2 *Passive Flood Barrier Overview and Product Comparisons*, A Better City, Report, (September 2015), last accessed March 25, 2019. https://www.abettercity.org/docs-new/2015.09.09 Passive Flood Barrier Publication.pdf.

3 Ibid.

4 Federal Emergency Management Agency, *National Flood Insurance Program Technical Bulletins*, https://www.fema.gov/nfip-technical-bulletins.

5 Federal Emergency Management Agency, *Non-Residential Floodproofing Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the NFIP*, document number FIA-TB-3 (FEMA and FIA: 1993).

6 44 CFR Part 9, "Floodplain Management and Protection of Wetlands," (FEMA 2013), last accessed February 3, 2019, https://www.law.cornell.edu/cfr/text/44/part-9.

7 See: *2012 Building Code Local Amendments* (Shelby County Commission and Memphis City Council 2012) reference to "Section 1612.5" of: International Code Council, *International Building Code* (Falls Church, VA: 2018) on "Flood Resistant Design and Construction."

8 *Memphis and Shelby County Unified Development Code*, "Article 8.8 Flooplain Overlay District," (Shelby County Board of Commissioners and Memphis City Council: 2010).

9 Federal Emergency Management Agency, *Non-residential Floodproofing*, NFIP Technical Bulletin 3-93 (1993).

10 United States Army Corps of Engineers, *Flood Proofing Regulations*, EP 1165-2-314, (1995)

11 Federal Emergency Management Agency, *Wet Floodproofing Requirements*, NFIP Technical Bulletin 7-93 (1993).

Resources

Federal Funding

"Benefit-Cost Analysis." *FEMA* online. Last updated June 1, 2018. https://www.fema.gov/benefit-cost-analysis.

Hazard Mitigation Assistance

"Hazard Mitigation Assistance." *FEMA* online. Last updated December 18, 2018. http://www.fema.gov/hazard-mitigation-assistance.

"Hazard Mitigation Grant Program." *FEMA* online. Last updated December 3, 2018. http://www.fema.gov/hazard-mitigation-grant-program.

"Flood Mitigation Assistance Grant Program." *FEMA* online. Last updated December 3, 2018. http://www.fema.gov/flood-mitigation-assistance-program.

"Pre-Disaster Mitigation Grant Program." *FEMA* online. Last updated December 3, 2018. http://www.fema.gov/pre-disaster-mitigation-grant-program.

Additional Federal Resources

FEMA Building Science Branch. http://www.fema.gov/building-science.

FEMA Library. http://www.fema.gov/library/index.jsp.

National Flood Insurance Program. http://www.fema.gov/national-flood-insurance-program.

International Code Council Codes and Standards. http://www.iccsafe.org/cs/.

3.2 Earthquake Resilient Buildings

Update Codes and Building Stock to Provide Seismic Resilience

Key Benefits

1	**Low cost interventions may provide real protection**
2	**Protected emergency services buildings help ensure continuity of services**
3	**Protected civic buildings provide short-term shelter for all**

Limitations

1	**Potentially high expense for certain interventions**
2	**Insufficient data to ensure adequate protection**
3	**Most regional buildings cannot withstand a major earthquake, leaving most community members without shelter in the long term**

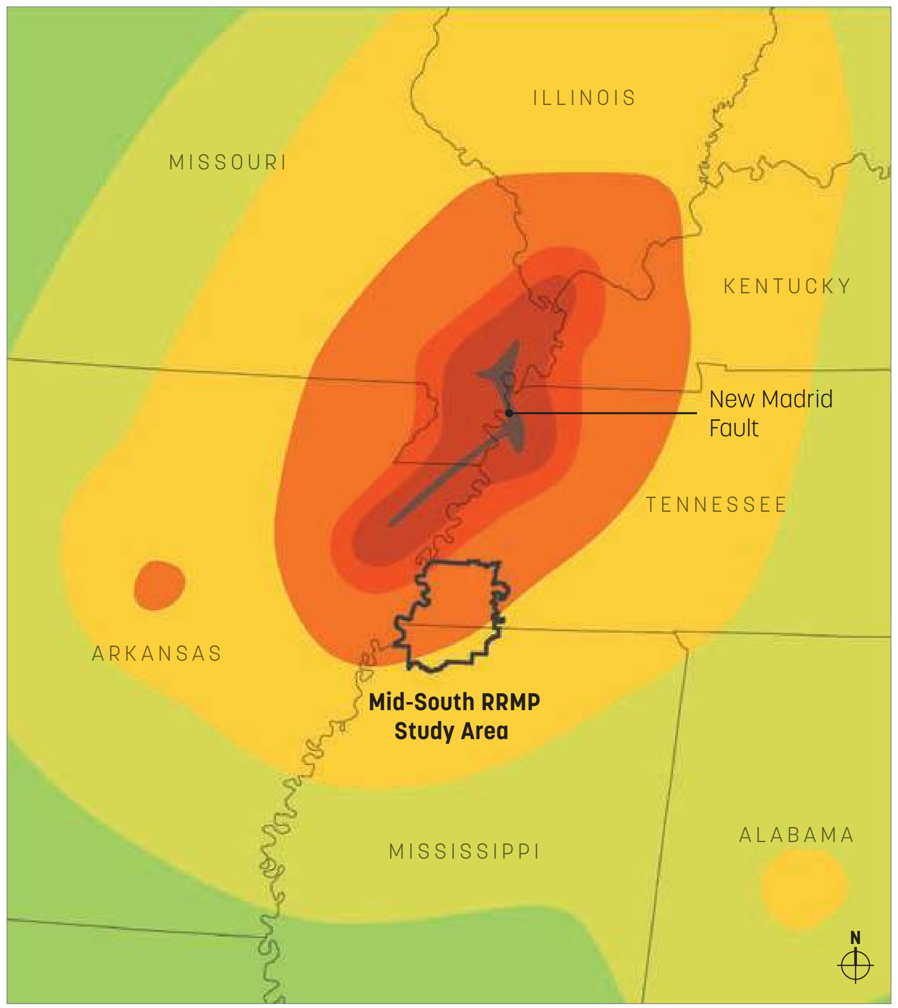
Overview

The Mid-South region's proximity to the New Madrid Fault puts it at risk for experiencing a major earthquake. Large, unreinforced buildings are particularly vulnerable to damage during earthquakes. Many of these buildings are either places of gathering, such as schools, arenas, and community centers (Risk Category 3 buildings) or places that provide critical services, such as schools, arenas, fire stations, police stations, and hospitals (Risk Category 4 buildings).

In the event of an earthquake, it is necessary to limit damage to these buildings to ensure the safety of those within and to enable their use during the post-quake recovery period. Seismic retrofits can help existing civic buildings perform during an earthquake, while updated building codes can help ensure that all types of new buildings perform to desired standards.

(Left) In 1989, a 7.1-magnitude earthquake struck the San Francisco Bay Area, causing an estimated $5 Billion in damages. Source: Time

Ultimately, the region's resilience to seismic threats is based on the ability of all buildings to withstand earthquakes. Many of the recommendations in this section can be undertaken by private property owners. Privately owned buildings can be retrofitted at the owners' expense and often qualify for reduced insurance premiums.



Peak Ground Acceleration Seismic Map

(10% in 50 years exceedance)

Earthquake risk in the Mid-South Region is based on distance from the New Madrid Fault. The concentric shapes represent peak ground acceleration zones and dissipate radially away from the fault. Most of the region lies within a "severe" zone, while the northwest corner has a "violent" designation and the southeast part of the region has a "very strong" designation from the United States Geological Survey.

Peak Acceleration as Fraction of Standard Gravity (g)

- 0.4 (Extreme)
- 0.3 (Violent)
- 0.2 (Severe)
- 0.15 (Very Strong)
- 0.1 (Strong)
- 0.05 (Moderate)

Source: USGS

3.2.1 Retrofit Memphis International Airport[1]

In the event of a major earthquake in the New Madrid Seismic Zone it is unlikely that many buildings or even roads will remain in operational condition. To aid rescue and recovery efforts, emergency services and supplies will need to be flown to the Mid-South region from surrounding states. The Central United States Earthquake Consortium (CUSEC) has developed, improved, and integrated earthquake response plans in Tennessee and Mississippi as well as Alabama, Arkansas, Illinois, Indiana, Kentucky, and Missouri. The plans coordinate mobilization, staging, deployments, and tracking of response resources. Workshops have been held to address response protocols, and the response plans have been tested during major flooding and tornado events. These efforts rely on the continuing functionality of core services at the Memphis International Airport.

An update to the Memphis International Airport Master Plan was completed in 2010 and identifies the airport's seismic vulnerability and the expected building performance "as is" during earthquakes of varying degrees. The report makes recommendations for improvements that would minimize disruptions to the airport's functionality in the event of an earthquake, including strengthening of foundations, installation of shear walls, and bracing of plumbing and electrical conduits in the terminals. Many of these retrofits are considered voluntary and are not required by code. The 2010 Master Plan recommends seismic performance objectives similar to "Basic Performance" in the International Building Code 2006 based on a Benefit Cost Analysis. Today, the City of Memphis and Shelby County follow the International Building Code 2012 for earthquake standards. It is recommended that any planned seismic retrofits meet "Basic Performance" in contemporary code standards.

Specific retrofits and recommended phasing are included in Appendix D of the Master Plan Update. Structural retrofits should be done during planned renovations to minimize disruption and cost, with the exception of required retrofits for current safety issues. Non-structural retrofits associated with anchoring and bracing key communications, information systems, and electrical equipment should be done sooner as disruption is minimal. Seismic retrofits began in 2015 and are expected to continue through 2021.

(Above) Memphis International Airport

3.2.2 Retrofit Critical Civic Buildings

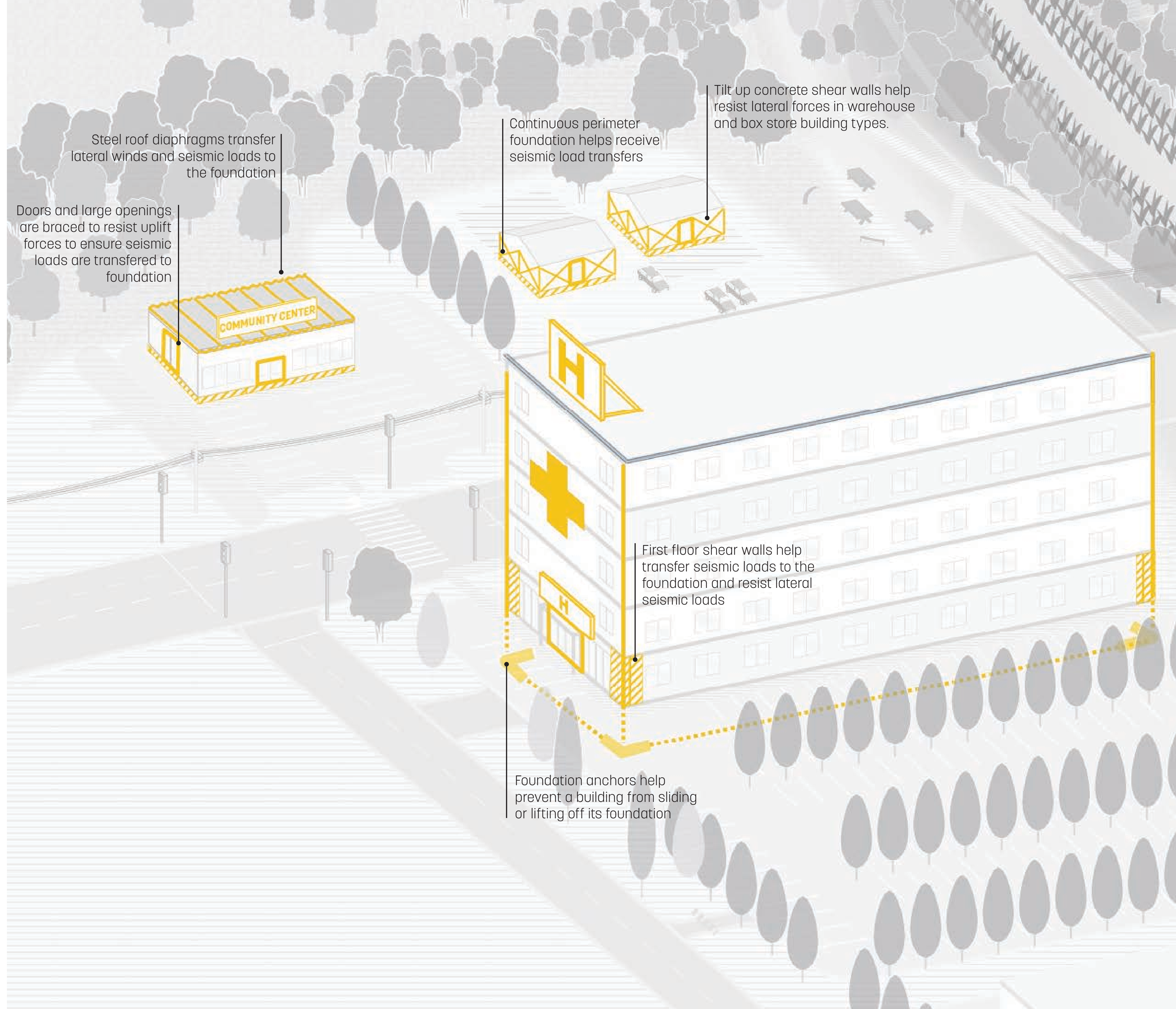
Retrofits that enhance a building's ability to withstand a seismic event range from inexpensive and simple modifications to more expensive major undertakings. Relatively inexpensive and simple retrofits are often non-structural and include tactics like securing appliances and emergency equipment to reduce the risk of failure or damage during an earthquake. Structural changes to improve the building's performance during an earthquake have a range of costs. Newer wood frame buildings are less expensive to retrofit with wood shear walls, wood bracings for large openings, and foundation anchorings. Older masonry buildings require more expensive retrofits, including concrete shear walls, steel diaphragms, and continuous perimeter foundations. The Federal Emergency Management Agency has published a comprehensive list of appropriate techniques for common building types, and this should be used as a guide when beginning a specific retrofit project.[2]

Some retrofits also help protect against other natural disasters like flooding and severe winds. Shear walls, steel roof diaphragms, and braced openings help protect against severe winds. Foundation anchors help secure buildings against both severe winds and fast-moving flood water. Other seismic retrofits are not recommended for buildings that are at risk of flooding; a continuous perimeter foundation does not allow flood water to equalize on both sides of the foundation wall, which can cause the walls to collapse. Similarly, buildings that have been elevated to protect from flood hazards are often susceptible to damage from seismic activity as they are top-heavy and vulnerable to overturning.

There have been no major earthquakes in the New Madrid Seismic Zone in recent history. As a result, data about the performance of buildings on geological conditions specific to the Mid-South are largely unavailable, though many scientists consider it to be an active fault. Seismologists studying the region disagree about the degree of seismic hazard in the region and what the likely impacts of a major seismic event might be. Due to the current lack of consensus on the local threat or impacts, precise code recommendations cannot be made. However, though regional soils and geology differ, and an earthquake in the New Madrid Seismic Zone would likely lead to more widespread damage than an earthquake of the same magnitude in California, some of the basic tenets of seismic building resilience are consistent across regions and are recommended for the Mid-South.

Given the severity of the potential damage, the lack of data around local building performance during an earthquake, and the wide range of costs for building retrofits, it is recommended that most civic buildings be retrofitted with low-cost improvements to provide "life and safety" protection, allowing building occupants to safely evacuate in the event of an earthquake. Some civic buildings, in low-risk zones, could be targeted for more intensive retrofits to withstand a seismic event and enable continuity of emergency services after an earthquake.

Sample Retrofit Techniques



Retrofitting buildings involves a combination of adding elements to increase strength, enhancing the performance of existing elements to increase strength, or improving connections between components to ensure the load path is complete.

The retrofitting techniques selected are based on technical considerations, such as building type and construction, as well as non-technical considerations such as cost, disruption to occupants, and aesthetics.

(Above) Plywood shear walls reinforce the first floor of a wood frame building. They help prevent lateral shifts and transfer seismic loads. They can be made from plywood, masonry, or concrete.

(Above) A hot water heater is strapped to the wall, securing its position in the event of an earthquake or major flood event. This increases the possibility that the appliance will not fall over and cause more damage or is damaged and needs to be replaced.

(Below) Foundation anchors help keep the building tethered to its foundation during a seismic event. Ideally they are coupled with a continuous perimeter foundation.

3.2.3 Provide Seismic Resilient Design Guidelines for New Development

As of December 2018, the State of Tennessee and the State of Mississippi do not have state-wide building codes. Each jurisdiction is responsible for adopting their own building codes and hiring building inspectors to enforce the code. It is recommended that all local governing bodies adopt seismic resilient design guidelines for new development, using the 2015 International Building Code as the minimum standard. Local building codes are in place to protect public health and safety. They evolve over time to account for new building strategies and technologies as well as better information about building performance. Adopting standard building codes, such as the International Building Code, efficiently provides a reliable baseline standard for development. These standard building codes may be adopted in whole or in part, and can be strengthened with local amendments. At the time of this report's writing, the International Building Code 2015, part of the International Code Council family of codes, is the leading standard building code with regard to earthquakes in the United States. FEMA collaborated with the International Code Council and industry experts to develop these disaster-resistant codes and standards.

After much debate, the City of Memphis, Shelby County, DeSoto County, City of Hernando, City of Southaven, City of Olive Branch, and City of Horn Lake have all individually adopted the seismic building standards in the International Building Code 2012 edition. While there was some concern that the more stringent code would increase the cost of development and inhibit growth or incentivize growth in less-regulated areas, studies have shown that the marginal cost increase of seismic-resistant new construction is not significant, and regional adoption of the code would not artificially incentivize development in undesirable areas.[4]

Over time, FEMA may continue to develop stricter or more specific seismic building codes. These should be adopted to replace older seismic design standards given the high degree of vulnerability within the region.

Tohoku Tsunami: Cultural Ties and Resilience[3]

After a series of disasters struck Japan in 2011, communities with stronger social ties experienced notably lower rates of mortality. During a disaster, a community with strong social networks will work together to provide support to vulnerable populations, helping everyone's chances for survival.

For the Mid-South Region, where large numbers of existing privately-owned buildings may not be retrofitted, social ties will play an important role in community members' survival and recovery after an earthquake.

(Above) Earthquake survivors helped carry vulnerable community members to safe locations.

Implementation

Process

1 Select Building for Retrofit	Select civic buildings to retrofit based on Hazard Mitigation Plans, order of magnitude cost estimates, and/or location
2 Structural Evaluation	Work with a structural engineer to identify building deficiencies
3 Identify Potential Mitigation Techniques	Based on technical and nontechnical realities, identify potential building-specific retrofits
4 Secure Funding	Issue a bond, apply for a grant, or incorporate into general capital improvement plan
5 Finalize Design and Begin Construction	Finalize design based on performance objectives, Benefit Cost Analyses, available funds, and tolerable disruption

1 Selecting a Building for Retrofit

First priority buildings for retrofit are the Memphis International Airport terminal and the Risk Category 3 and 4 buildings identified for retrofit in the 2016 Shelby County Hazard Mitigation Plan. Following the successful retrofit of these buildings, other emergency services and community gathering spaces should be retrofitted. To aid in this, owners of civic buildings in the Mid-South Region should compile an inventory of civic buildings under their purview, if one does not yet exist. The inventory should identify any hazard mitigation strategies currently in place and any known vulnerabilities. It should also include basic information relative to the age, size, number of stories, and construction strategy of the building. For emergency services buildings, the service area and any unique capabilities or equipment should also be identified. Newer single-story buildings are most cost-effective to retrofit, and these should be completed first. In addition, buildings with major planned renovations should similarly be upgraded with seismic retrofits. Finally, buildings that offer a unique, necessary service or service a greater number of people or extend services to an otherwise unserved area should be targeted.

All other civic buildings should then undergo seismic retrofits as cost allows during planned capital improvement cycles. It may not be cost effective to retrofit older buildings with many stories; as such, these buildings should be considered for replacement or repurposing rather than major renovation.

2 Structural Evaluation

Structural engineers specialize in evaluating existing buildings for vulnerabilities and deficiencies, and are often capable of making recommendations to eliminate or reduce vulnerabilities. Building owners may hire a structural engineer to provide this evaluation for all civic buildings within their purview as a means of prioritizing buildings for retrofit, either based on critical services provided or cost effectiveness.

3 Identify Potential Mitigation Techniques

During the structural evaluation, the structural engineer might identify potential mitigation techniques. After the structural evaluation, the evaluating structural engineer or a specialized architecture and engineering firm with experience working on seismic retrofits will identify potential mitigation techniques and associated costs. These may include structural recommendations such as installation of shear walls, or non-structural recommendations such as securing appliances or other equipment. It should be noted that structural improvements to improve seismic resilience may trigger other required improvements to meet current building code.

4 Secure Funding

Most civic building renovations are locally funded, either through the operating budget or a bond issue. Seismic retrofits should be timed to coincide with other planned building renovations to maximize cost efficiency. If retrofits occur after an earthquake, disaster recovery funds may be available as well.

5 Finalize Design and Construction

Once funding is secured, or at least concretely identified, a final design strategy should be selected and construction may begin. The final design should be based on a Benefit Cost Analysis, performance objectives, and available funds. Consideration should be given to tolerable amounts of disruption during construction.

Certain architecture, engineering, and construction firms specialize in seismic resilient buildings, and consultants and contractors should be hired from this qualified pool.

Retrofit Memphis International Airport Cost Estimates

The 2010 Memphis International Airport Master Plan Update provides estimated project costs for seismic retrofits to the facility based on "Basic Performance" during a seismic event, using the 2006 International Building Code 2006. These cost estimates are provided in the table on the right. Today, the City of Memphis and Shelby County follow the International Building Code 2012 for earthquake standards, so it is recommended that upcoming seismic retrofits meet this new standard, which may impact the estimated project cost.

MIA Seismic Retrofit Estimated Project Cost[5]

Terminal	$37,047,000
Airfield	$2,546,000

Civic Building Cost Estimate Methodology

The National Institute of Standards and Technology presented a methodology for estimating seismic retrofit costs in a September 2017 report. The methodology is derived from FEMA 156 and 157, reports from the 1990s, and provides updated cost estimates in 2017 dollars. The methodology is intended to be used by building owners who wish to see an order of magnitude cost estimate for seismic retrofits before embarking on a retrofit project.

Civic Building Seismic Retrofit Estimated Project Cost[6]

Measure	Project Type	Estimated Cost
Minimum	New building, less than 200 SF, single story	$0.30 per SF
Mean	44 year-old building, 65,000 SF, three stories	$29.7 per SF
Max	153 year-old building, 1,430,000 SF, 38 stories	$1,011.40 per SF

Cost Estimates for Mitigation Projects

The 2016 Shelby County Hazard Mitigation Plan lists mitigation projects and associated project priority, estimated cost, and additional information.

Specific mitigation projects that relate to seismic resilience of civic buildings are also identified here.

Shelby County 2016 Hazard Mitigation Plan Mitigation Project Cost Estimates[7]

Priority	Project	Jurisdiction	Estimated Cost
High	Seismic retrofit of City of Memphis owned or operated buildings/ structures	City of Memphis	$20,000,000
High	Seismic Retrofit Fire Station - Upgrade at risk buildings and install emergency generators	Shelby County	$2,000,000
High	Public Build Seismic Study	City of Bartlett	$100,000
High	Retrofit Fire Station for Earthquake	Town of Arlington	$75,000
High	Retrofit Town Hall for Earthquake	Town of Arlington	$75,000
Medium	Fire Station 2 and 3 Retrofits	City of Germantown	$900,000
Medium	Seismic Retrofit of Fire Station	City of Barlett	$500,000
Medium	Government Building Retrofit	Shelby County	$20,000,000
Low	Bellevue Solid Waste Transfer Facility	City of Memphis	$9,000,000
Low	75,000 and 500,000 Gallon Water Tank Upgrades	City of Germantown	$1,000,000

Case Study

Fire Station 63, Federal Way, WA[8]

The South King County Fire and Rescue Department of Federal Way, Washington proposed to renovate all eight fire stations within their jurisdiction to provide necessary upgrades and seismic retrofits. Fire Station 63 is a relatively standard station. The two story station has three bays to house three apparatus. The fire station was constructed with masonry walls and wood framed floors and roof. Planned seismic improvements included adding shear walls and steel diaphragms to the floor and roof. Other planned improvements included fire sprinklers, a new alarm system, some equipment, a new roof, a new HVAC system, and site work. The building was able to remain occupied during construction.

Upgrades to all of the fire stations were funded through a $39 million bond issue, and the estimated total cost of all upgrades to Fire Station 63 is $1.266 million. This included improvements unrelated to seismic resilience.

(Below) Photo of Fire State 63, Federal Way, WA

Endnotes

1 Jacobs Consultancy, *Memphis International Airport Master Plan Update Final Technical Report*, (Memphis: 2010)

2 U.S. Department of Homeland Security, Federal Emergency Management Agency, *Techniques for the Seismic Rehabilitation of Existing Buildings* (California, 2006).

3 Aldrich, Daniel P. *"Recovering from disasters: Social networks matter more than bottled water and batteries."* TheConversation online, February 13, 2017.

4 Jacobs Consultancy, *Memphis International Airport Master Plan Update Final Technical Report*, (Memphis: 2010)

5 Juan F. Fung et al., *A Methodology for Estimating Seismic Retrofit Costs*, (National Institute of Standards and Technology. US Department of Commerce, September 2017).

6 *2016 Shelby County Hazard Mitigation Plan*, News Release, Shelby County Office of Preparedness, July 5, 2016.

7 *South King Fire & Rescue Facility Improvements Station 63 Project Manual*, Advertisement for Bids, (Rice Fergus Miller INC, 2018).

8 NEHRP Consultants Join Venture, *Cost Analyses and Benefit Studies for Earthquake-Resistant Construction in Memphis, Tennessee*, Document Number NIST GCR 14-917-26, (National Institute of Standards and Technology US Department of Commerce, December, 2013).

Resources

CUSEC After-Action Report (AAR), (Central United States Earthquake Consortium, 2011), available at http://www.cusec.org/documents/aar/cusec_aar.pdf.

FEMA Building Code Toolkit: Building Codes Fact Sheet, (FEMA Building Science Branch, 2013).

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Recommended Seismic Provisions: Design Examples, document number FEMA P-1051/July 2016, (National Earthquake Hazards Reduction Program, 2016), available at https://www.fema.gov/media-library-data/1474320077368-125c7a1d1a3b864648554198526d671f/FEMA_P-1051.pdf.

2015 International Building Code. (International Code Council, INC, 2015). https://codes.iccsafe.org/content/IBC2015/.

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"Before an Earthquake." *Central United State Earthquake Consortium* online. http://cusec.org/earthquake-safety-preparedness/before-an-earthquake/.

CUSEC After-Action Report (AAR). (Central United States Earthquake Consortium, 2011). available at http://www.cusec.org/documents/aar/cusec_aar.pdf.

"Step 4: Minimize Financial Hardship," *Central United States Earthquake Consortium* online. available at http://cusec.org/earthquake-safety-preparedness/before-an-earthquake/4-minimize-financial-hardship/.

3.3 Emergency Shelters

Ensure Adequate Emergency Shelter Capacity

Key Benefits

1. Provides shelter during and after a disaster
2. Provides temporary relief during extreme heat or cold events
3. Provides access to social services for populations in need

Limitations

1. Inhibits normal functionality of civic buildings after a disaster
2. Does not mitigate physical damage to community

Overview

Over time, many civic buildings may be retrofitted to either maintain operations through a disaster (such as an emergency services facility or hospital) or withstand a disaster and be able to resume operations immediately after the disaster event. However, many privately-owned buildings may not be able to withstand a disaster, much less maintain operations during a disaster event, leaving inhabitants without a place to go during or after a disaster event. Many non-essential civic buildings can be retrofitted to withstand a flood, extreme wind, or earthquake and serve as a relief shelter. Community centers, libraries, and recreation centers often already serve as informal relief shelters during periods of extreme heat and extreme cold, when vulnerable populations need to find respite in places with reliable free air conditioning or heating.

A comprehensive plan for emergency sheltering based on population, demographics, and expected risk is needed to identify the number of shelters and shelter spaces required to adequately house the region in the event of a disaster. Studies have indicated that 15-25% of evacuated populations will seek public shelter.[1] It is likely that non-essential civic buildings cannot fully meet the sheltering needs of the population in the event of a major disaster, and other civic buildings such schools or arenas may need to be used. This would inhibit the ability to operate those facilities for their intended purpose, therefore these facilities should be part of a major disaster shelter strategy but not a minor disaster shelter strategy.

(Right) Shelter Box Privacy Tent (Shelter Box USA)

3.3.1 Create a Regional Shelter Coordination Plan

The American Red Cross estimates that in order to meet demand for emergency shelter in the event of a disaster, there must be beds for approximately 15-25% of the affected population.[2] In the Mid-South, this estimate should be applied to disasters such as mild-to-moderate earthquakes, flood events, straightline wind events, and tornadoes. With the exception of flood events, these disasters do not predictably affect specific areas and the affected population cannot be predicted. For flood events, a 2015 Hazus model using data from the 2010 Census estimated that during a 100-year flood event, 39,944 people in Shelby County would seek temporary shelter in a public shelter.[3] Similar estimates should be developed for DeSoto County, Fayette County, and Marshall County as part of the Regional Shelter Coordination Plan in order to understand the demand for public shelters in the region during flood events.

For severe earthquakes of magnitudes last seen in the 1800s, it is unlikely that many, if any, existing shelters will remain standing. While surviving regional residents will need shelter, it is recommended that this population be served by imported shelters coordinated as part of the Central United States Earthquake Consortium plans. Due to the potentially extreme high demand, and relatively unknown risk, it would be impractical to build permanent emergency shelters to house the estimated surviving population of the Mid-South.

Goals of a Regional Shelter Coordination Plan

The Regional Shelter Coordination Plan should ensure that the regional distribution of public shelters relates to the regional population distribution but prioritizes the need to provide shelters in safe locations that are accessible after a disaster (away from very high soil liquefaction areas and floodplains). As in many parts of the United States, much of the Mid-South population is clustered around water bodies. Shelters that provide relief during flood events must be located outside of the floodplain but should be proximate to residents within the floodplain who are the likeliest candidates to seek shelter during a flood event.

Beyond considering the quantity and distribution of shelter beds, the Regional Shelter Coordination Plan should address the required resources to accommodate special needs through the region, specifically the ability to accommodate the elderly, infirm, children, and service animals. Approximately 10% of the regional population is over age 65, and over 26% of the population is under age 18. Public shelter bed counts should include accommodations for these groups.

In order to accomplish this, a Regional Shelter Coordination Plan should be created. This can be done by or in collaboration with emergency management offices. Several existing publications exist to assist with this effort, including resources from the Center for Disease Control, Federal Emergency Management Agency, and the American Red Cross. Specific documents are identified on the resources page of this section.

Shelter Types

The regional shelter plan will consist of a network of three types of shelters, operationalized at specific events. The three shelter types are summarized here:

Personal Care Shelters

- Open for many hours, but not overnight
- Offer heating, cooling, and electric charging stations (supported by a backup generator), snacks and hydration, and support services
- Resources to direct people to overnight facilities if needed; Can be a preliminary intake survey location

Emergency Shelters

- Open overnight for a single night to a few days
- Offer the same as personal care shelters, as well as food (pantry items), toilet and shower facilities (1 toilet per 40 people), and beds
- Meets sheltering needs during and after a flash flood or extended power outage due to wind or ice

Temporary Shelters

- Open for a few weeks
- Offer the same services as emergency shelters, but also require food preparation spaces, laundry, and potentially mental health services, spiritual care, and childcare
- Meets sheltering needs during a major riverine flood or a major earthquake
- It may be most efficient to establish a partnership with owners of large gathering spaces (5,000+) to use these spaces in the event of a major disaster

3.3.2 Retrofit Identified Civic Buildings As Shelters

Overtime, existing buildings identified to serve as disaster relief shelters in the Regional Shelter Coordination Plan will need to be retrofitted in order to effectively serve in that capacity. All shelters will need to withstand major or moderate flooding and seismic activity.

Depending on the type of shelter that the building is supposed to provide (Personal Care Shelter, Emergency Shelter, or Temporary Shelter), specific additional retrofits will be needed. Nonetheless, all retrofits will need to address power supply, waste and water system operations, support services, and access in the event of a disaster.

FEMA, the American Red Cross, and several state-level emergency services organizations provide guidance on the design and operation of disaster relief shelters. An overview of the major recommendations is provided here, aggregated from publications that specifically address one or more threats. The retrofits on the following page address the natural disasters identified as threats for the Mid-South Region.

There are several federal funding streams designated for these kinds of retrofits. To maximize the benefits of this funding, the retrofits should be done in order of need as identified in the Regional Shelter Coordination Plan.

Accessibility During/After Disasters

- Multiple access roads and points increase the likelihood that the shelter can be accessed during a disaster, even if one road becomes impassable
- Temporary flood barriers can ensure the building remains operational after floodwaters subside, allowing civic buildings in floodplains to serve as Temporary Shelters in the days following a flood, relieving pressure on Personal Care and Emergency Shelters.

Power Supply

Building codes stipulate some emergency power functionality, often to support safe evacuation rather than maintaining building operations through a power outage. Disaster relief shelters will require more substantial emergency power. These needs must be identified as part of a specific retrofit project.

Maintaining a power supply to a building during a power outage requires energy generation and on-site energy storage. The amount of generation/storage capacity needed is directly linked to the duration of the power outage. A key consideration is the elevation level of all backup power supply system components. They should be located above the designed flood elevation to prevent damage during a flood event, but not located on the roof, which makes a building top-heavy and more susceptible to damage during an earthquake.

- A natural gas emergency generator can serve as a backup electric energy source after a brief interruption. Natural gas is cleaner than many alternatives. Generators often turn on after a brief interruption in power supply, but can be sufficient for disaster relief shelters. If immediate power with no interruption is required, an energy storage system is also needed.
- A photovoltaic power generation system with an energy storage system (battery) is a renewable power supply that can provide power during non-emergencies as well.

Minimizing the need for electric power can extend the emergency power supply. The methods below can help minimize energy use (these also offer cost-saving benefits during non-disaster events):

- Operable windows help buildings remain habitable during power outages in the summer heat, requiring less use of air conditioning, which requires significant energy loads.
- Good insulation helps keep heat in during the winter and out during the summer, reducing the amount of energy required to operate heating or cooling equipment while using backup power.

Waste and Water Systems

For buildings to remain operable, waste and water systems must remain functional during a disaster or emergency. Several strategies can help ensure continued functionality:

- Sewage valves help prevent backflow during riverine and flash flood events
- Manual overrides or long lasting batteries for automatic toilets ensure that they still function during power outages (and relieve the energy burden placed on backup power supply systems)
- Drinking water sources that are supplied directly through pressure in the public water main do not rely on power or burden backup power supply systems.

Services

Beyond the continued functionality of building systems, many seeking shelter during a disaster will require special services that may not be part of the building's normal operations. Consideration should be given to the following in the design/operation of a Personal Care Shelter:

- Intake procedures to address any special needs and adequately provide necessities for temporary occupants.

Emergency Shelters should include items listed above as well as the following:

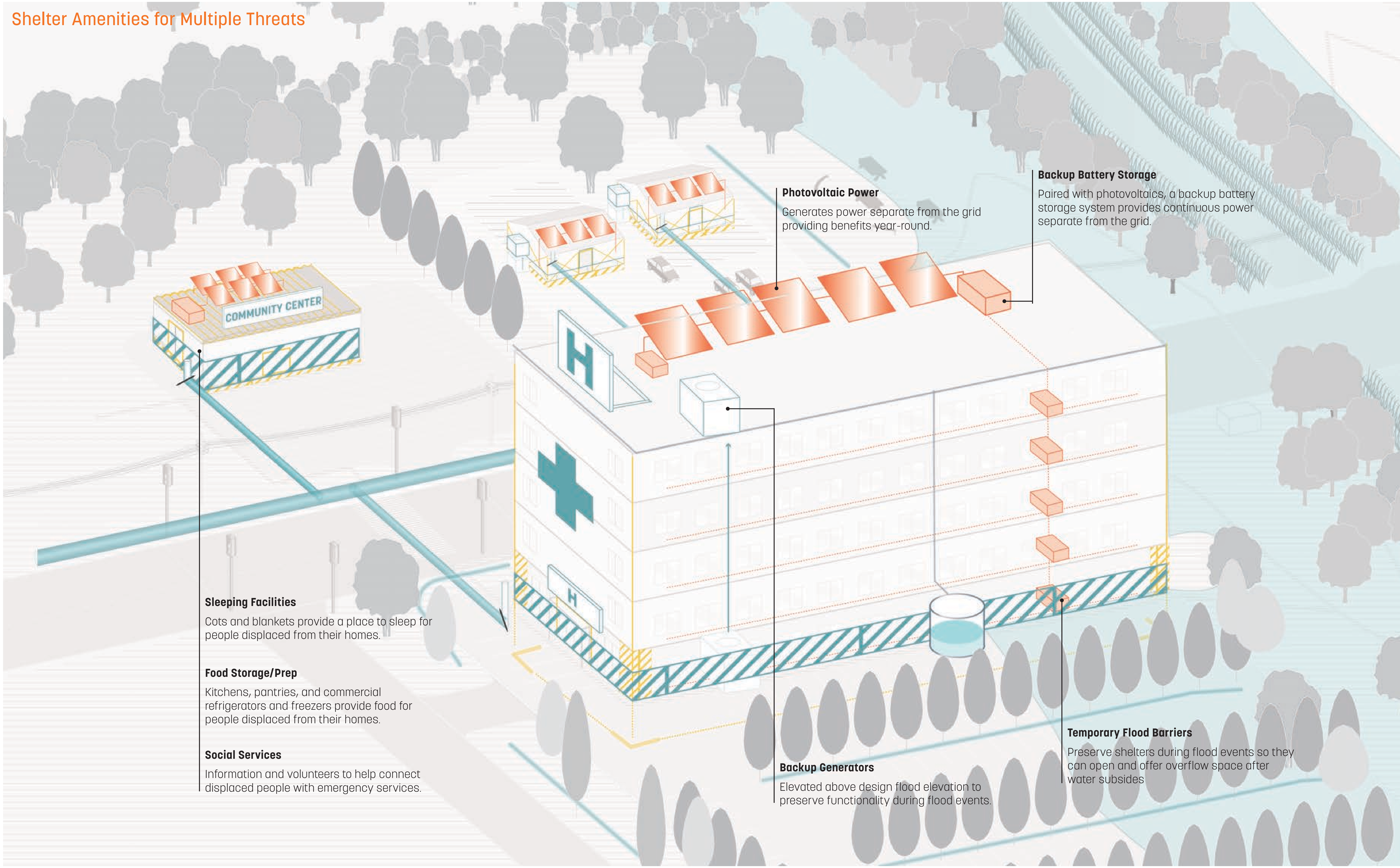
- Health services, mostly for functional needs like consumable medical supplies and durable medical equipment (first aid, lost prescription refills, lost eyeglass replacements)
- Medical services ranging from basic to more expanded services (infection prevention, substance abuse support, respite care)
- Food storage for pantry items, including potable water.
- Dormitory needs, including cots with blankets
- Reunification services for unaccompanied minors and adults requiring assistance or supervision
- Communication supplies such as a NOAA weather radio, a ham radio, a satellite phone, or cell phones
- Emergency supplies, such as flashlights, fire extinguishers, and batteries

Temporary Shelters should include items listed above as well as the following:

- Food preparation facilities for non-pantry items
- Social services including permanent housing relocation support and rebuilding services

The American Red Cross Shelter Operations Workbook provides guidance on this.[4]

Shelter Amenities for Multiple Threats



Implementation

Process

1 Identify Shelter Managers	Building owners, emergency management staff, American Red Cross employees, or volunteers
2 Inventory Existing Shelters	Include all ownership/operator models and resources available at each shelter
3 Document Shelter Demand	Identify spaces needed for adults, children, seniors, special needs populations, etc.
4 Gap Analysis	Identify the need for new shelters, specified by bedcount, type, location, and services provided
5 Select Sites for New Shelters	Identify existing buildings for retrofit and sites for new building construction Begin project planning for retrofits and new construction, including prioritizing projects
6 Design and Construction	Work with a structural engineer and an architect to design the building to current FEMA and American Red Cross shelter standards Secure funding and begin construction
7 Create an Implementation Strategy	Formalize regional shelter manager communications, operation instructions, and supporting agency roles
8 Operations	Purchase and store emergency supplies Train building owners how to operationalize shelters and support the American Red Cross and volunteers

1 Identify Shelter Managers

The first step in creating a regional shelter coordination plan and retrofitting civic buildings as disaster relief shelters is to identify current emergency shelter managers. Additional managers may need to be added during the process, but managers of existing shelters will serve as a valuable resource during the planning process.

2 Inventory Existing Shelters

The second step is to create an inventory of shelters in the region, specifying the type of shelter (personal care, emergency, or temporary), the number of people served, services provided, location, operator type (public, private, volunteer, faith-based), and whether the facility does (or could) meet the American Red Cross safety guidelines for disaster relief shelters, based on building construction type/materials, quantity of toilets/showers, availability of parking areas for staging delivery of supplies and staff, and absence of hazards. Mid-South Emergency Management Agencies may already have inventories of shelters in the region. These should serve as the foundation for any new inventories that are being developed.

3 Document Shelter Demand

Step three is to document the region's demand for shelters, including total population, number of children, elderly, or those with special needs that may need special accommodation. The demand survey will need to address several possible scenarios, including a major disaster that displaces a large number of people across the region, a moderate disaster that displaces a large number of people in a few communities, a moderate disaster that displaces a moderate number of people across several communities, or a moderate or minor disaster that displaces socially vulnerable populations. It is impossible to plan for every contingency, so it is better to have a flexible network of shelters that can be adapted.

4 Gap Analysis

Step four is to conduct a gap analysis, documenting the need for additional shelters by bed count and by services provided.

5 Select Sites for New Shelters

Step five is to select sites for additional shelters; additional shelter spaces could be in existing civic buildings retrofitted to withstand disasters or in new, standalone facilities depending on the identified need as well as demand for community spaces that could serve multiple benefits. Site selection criteria should include:

- Location outside the floodplain
- Location outside of very high soil liquefaction zones
- Accessibility by at least two roadways
- Accessibility to those in wheelchairs or with limited mobility

6 Design and Construction

Once a site is selected, the appropriate engineering and architecture partner should be selected to complete the design for the disaster relief shelter. The design should meet or exceed the shelter requirements from FEMA and the American Red Cross.

Before construction may begin, funding must be secured. If the disaster relief shelter construction or retrofit is being completed in the aftermath of a disaster, FEMA disaster relief funds may be used for this purpose. If construction is happening prior to a disaster event, several different funding sources may be available through FEMA's Hazard Mitigation Grant Program. For sheltering homeless families and individuals, the Department of Housing and Urban Development's Emergency Solutions Grant (ESG) Program also provides funds and is administered by the Tennessee Housing Development Agency, the Mississippi Development Authority, and the City of Memphis, which receives its own allocation of Emergency Solutions Grant funding because it is a designated entitlement community. Once funding is secured, construction may begin by a qualified contractor selected through a standard governmental bid process.

7 Create an Implementation Strategy

Step seven is to create an implementation strategy. This will include a formal communications process and shelter operation instructions. This will enable shelter managers to operationalize quickly in the event of a disaster; a communications strategy will allow for coordination between disaster relief shelter providers so they can allocate and share resources. This can be formalized through a Memorandum of Understanding (MOU). With this in place, a community unaffected by a localized disaster elsewhere in the region can quickly provide shelter to those in the region who were affected. An MOU should also identify who can operationalize a shelter. The coordination strategy should also include a regional evacuation plan, so that large numbers of individuals can quickly find shelter. This needs to be accessible to those requiring special assistance, such as seniors, infirm, those with limited English or mobility, and unaccompanied minors.

8 Operations

Step eight, the final step, consists of operations. The purchase of emergency supplies, including food, water, cots, medical supplies, and communication equipment, can be done in accordance with public bidding processes from suppliers who specialize in manufacturing and distributing emergency supplies. Supplies storage should be on-site or close by, and shelter operators should have access to this storage.

As part of the planning process, shelter operators should be identified and prepared with a training plan for shelter volunteers.

Other Considerations

Partners

Many partner organizations exist to assist with disaster relief shelter construction, maintenance, and operation.

- Tennessee Emergency Management Authority (TEMA), Mississippi Emergency Management Authority (MEMA), and Federal Emergency Management Authority (FEMA)
- Local Offices of Emergency Management
- American Red Cross
- Faith-based and non-profit organizations
- Private sector organizations who can offer large shelters (arena owners, etc)

Costs

New construction costs will vary significantly based on the type of structure built and planned program, but the marginal increase in construction costs to improve the structural integrity of the building are expected to be approximately $50 per square foot.[5] Retrofit costs will be very specific to the unique structure to be retrofitted. For more information, see 3.1 Floodproofing Buildings and 3.2 Earthquake Resilient Buildings.

3.1
3.2

The cost of emergency supplies for the operation of the shelters are listed below:

Supplies	Cost[6]
New construction (marginal $)	$50/sqft
Cots + bedding	$64/person
First Aid kits	$100/150 people
Food	$2 - $3/meal
150 kWh natural gas standby generator	$32,000
10 kW solar PV array with 40 kWh battery	$90,000

Case Studies

Florida Statewide Emergency Shelter Plan

Since 1999, the State of Florida has been working to reduce the deficit of safe disaster relief shelters in the state.[7] The primary threat facing the region is from hurricanes, so shelters are designed to provide shelter from flooding and extreme straight-line winds. The Division of Emergency Management is employing a combined strategy of retrofits and new construction to ensure that the number of general and special needs shelter spaces is adequate for the state.

In the last 20 years, the Governor and State Legislature has allocated approximately $3 million for priority shelter rehabilitation projects annually. FEMA's Hazard Mitigation Grant Program has also committed more than $45 million for this purpose. Finally, Public Shelter Design Criteria stipulated by the Florida Building Code require new public schools to be constructed to shelter standards. These buildings are paid for by the state Department of Education. As a result, the statewide capacity is 13% higher than the estimated demand (though several regions have unmet demand, and new flood maps may change evacuation routes, the population at risk and potentially in need of shelter space, and the continued viability of existing shelters). Since 1999, approximately 529,450 new shelter spaces have been funded.

The most recent bi-annual report documents planned retrofit projects that cost between $80,000 for a shelter that only needs an additional generator to meet recommended design criteria, to more than $1,000,000 for a more significant retrofit to a shelter with a proposed capacity of 3,748.

(Below) After Hurricane Irma, when 300,000 people were told to evacuate, 35,000 people sought emergency shelter, mostly at local public schools which had been retrofitted for that purpose.
Source: The News-Press[8]

Oregon Public Schools Emergency Shelters

The State of Oregon's emergency planning strategy relies heavily on the use of public schools as community disaster relief shelters.[9] Two major threats face the region: tsunami inundation and seismic activity. New public schools are being sited outside of the tsunami inundation zone and are being designed to structurally withstand an earthquake. Existing schools are being retrofitted to withstand seismic activity through a state-run grant program, which has awarded more than $225 million for that purpose.

To help operationalize the public schools as emergency shelters, an emergency management advisory commission is recommending the creation of preparedness messaging and designating storage areas for food, water, and medical supplies in or near schools. Retrofits are very building-specific, but include installing continuous perimeter foundations, additional perimeter anchors, additional roof anchors, and steel diaphragms.

The Whitworth Elementary School retrofit project, pictured below, has a planned construction period of three months, will cost $700,000, and will include life and safety upgrades for the entire building as well as upgrades that allow the gymnasium to be used as an emergency shelter.

(Below) Photo of interior retrofit work at Whitworth Elementary School.

Endnotes

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3.4 Roof Design

Encourage Green and Cool Roofs for Thermal Regulation and Resource Efficiency

Key Benefits

1. Cools city buildings and reduces the urban heat island effect
2. Helps prevent blackouts during hot summer days
3. Saves money by reducing air conditioning demands
4. Decreases runoff and flooding (green roofs)
5. Extends the life of the roof
6. Reduces greenhouse gas emissions

Limitations

1. May increase winter heating costs (cool roofs)
2. Options are limited or infeasible on certain building types
3. Retrofits may invalidate existing roof warranties

Overview

Though largely unseen from the street, roofs cover over 25% of many American cities. Conventional roofs cause two major unintended negative consequences: increased temperatures and stormwater runoff.

Developing more resilient buildings includes addressing the drawbacks of conventional roofs. In the Mid-South, municipalities, water departments, and electrical utilities can reduce heat and stormwater issues by encouraging building owners to install green and cool roofs. Encouragement in this case takes the form of education, assistance, and incentives. Education raises awareness of the issues and solutions. Assistance helps building owners determine if their building would benefit from an upgrade, and if so, how to do it. Finally, incentives, such as tax breaks or reduced utility fees provide financial motivation for building owners to carry out green and cool roof projects.

(Right) Memphis Bioworks Foundation Green Roof

How Roofs Impact City Environments

Conventional roofs can be up to 50 degrees Fahrenheit hotter than the air on a sunny day, causing deleterious effects on buildings and the overall urban environment. Higher roof temperatures increase the need for air conditioning inside, adding strain to the electrical grid. Outside, hot roofs contribute to the already above average temperatures around buildings, a phenomenon known as the "urban heat island." On the roof itself, high temperatures increase the stress and deterioration of the roof material.

The Urban Heat Island Effect

The dark roofs, pavement, concrete, and other building materials of the urban environment absorb heat from the sun and radiate it back out throughout the day. Without vegetation cover, there is less shade and less cooling from plant evapotranspiration. In addition, rainfall runs off into the sewer system, leaving less water to cool and evaporate heat. The overall effect creates a "heat island" averaging 10 degrees Fahrenheit hotter than the surrounding area. This effect is seen in developed areas around the world.

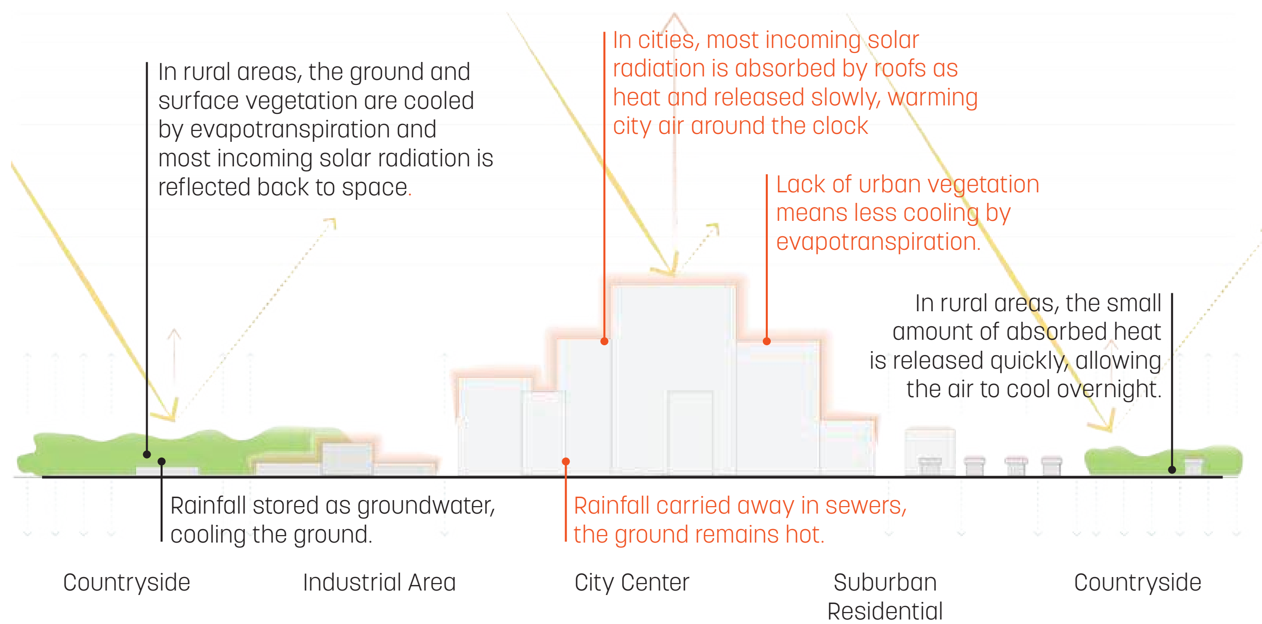
The excess heat affects the health and well being of people within cities. The increased electricity production for air conditioning results in more pollution (such as sulfur dioxide, nitrogen dioxide, particulate matter, mercury, and carbon monoxide) and its byproduct, ground-level ozone. The heat itself causes heat stress or stroke, difficulty breathing, and endangers vulnerable populations, children, the elderly, and those with preexisting conditions such as asthma.

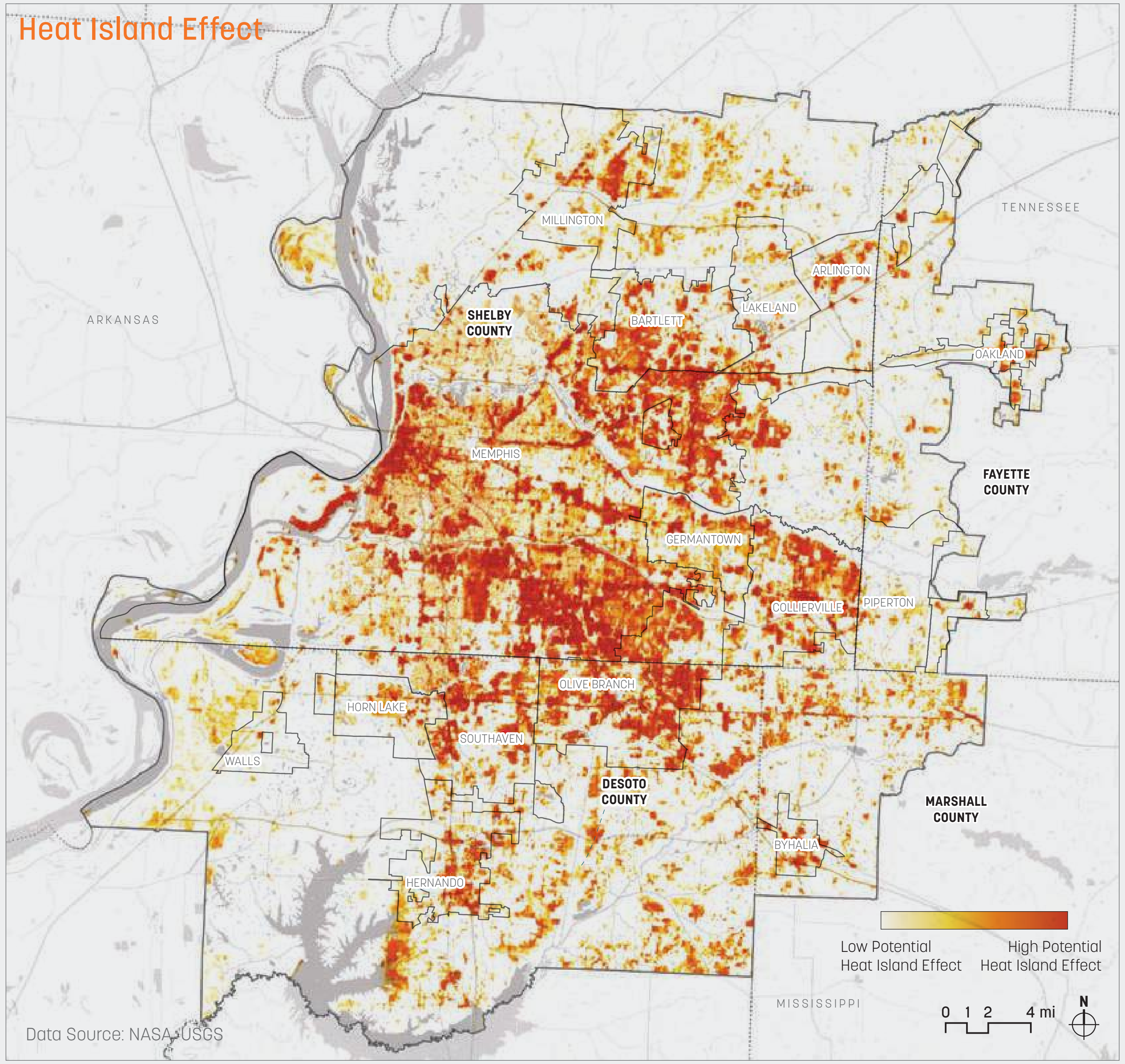
In terms of the broader environment, hotter land and stormwater runoff disrupts ecosystems, causing species migration and potentially deaths.

"In Memphis, there are 21 more summer days above 90°F than in the surrounding rural areas. The city can be hotter by up to 16 °F."

From Climate Central[1]

How Roofs Contribute to the Urban Heat Island Effect





Energy Use

Air conditioning uses approximately 10% of the total electrical consumption of buildings in Tennessee, primarily during the summer months. Aside from being costly, air conditioning also tends to contribute noise and heat to the urban environment. The cooler a building remains during the heat of the summer, the less energy it consumes for air conditioning. Reduced air conditioning use results in lower electricity bills for consumers, a more comfortable urban environment, and reduced greenhouse gas emissions.

Runoff and Flooding

In addition to higher temperatures, standard roofs contribute to stormwater runoff issues in urban areas much like other impervious surfaces. Stormwater landing on a standard roof is directed to gutters, drains, and the stormwater system, increasing the risk of flash and river flooding.

"Excessive heat has contributed to more deaths than natural disasters in the period from 1979-2003, when heat played a role in over 8,000 deaths."

From EPA Heat Island Impacts[2]

3.4.1 Expand Green Roofs

Green roofs positively affect roof temperatures, building insulation, and stormwater.

Cooling Thermodynamic Properties

Green roofs have high solar reflectance and thermal emittance, meaning they reflect more sunlight and retain less absorbed heat than conventional roofs. These characteristics reduce the thermal load on the roof, indoor temperature, and nighttime air temperatures.

Insulation and Energy Conservation

Green roof structural elements, growing media, and vegetation provide additional layers of insulation, which help the building maintain a consistent temperature. This insulation saves heat in the cooler months and air conditioning in the summer.

Stormwater Management

Green roofs have the added capacity to absorb, reduce, and detain stormwater. They reduce the risk of flooding because the soil and vegetation absorb stormwater, preventing its immediate runoff to the stormwater system. Stormwater is then both taken up by the plants or released slowly over time. The result is both less stormwater overall and a reduced risk of flash flooding at peak stormwater flows, as described in 2.3 Low Impact Design. Additionally, the vegetation improves air quality through natural filtration.

2.3

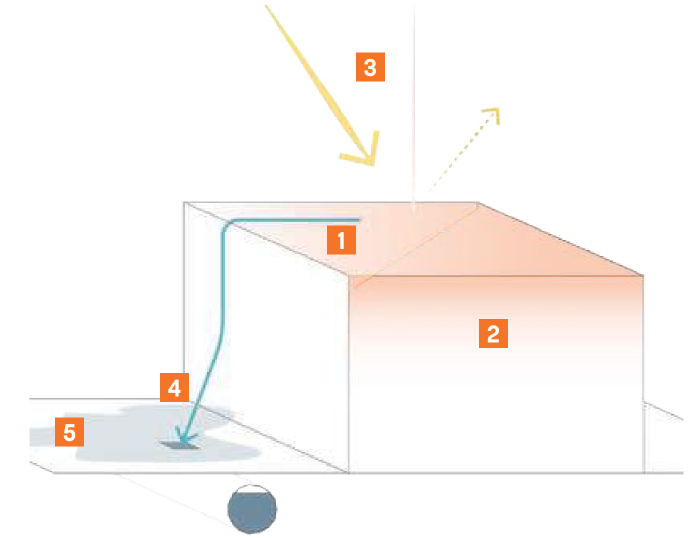
Green Roofs and Climate Change

Green roofs also reduce greenhouse gases by lowering electricity used for climate control and by absorbing CO_2. They also mitigate the effects of climate change by reducing the urban heat island effect.

(Above Left and Right) The green roof on Chicago City Hall is over 70F cooler than nearby roofs on a summer day, as seen with a Forward Looking Infrared Radiometer. Source: U.S. EPA Reducing Urban Heat Islands: Compendium of Strategies[13]

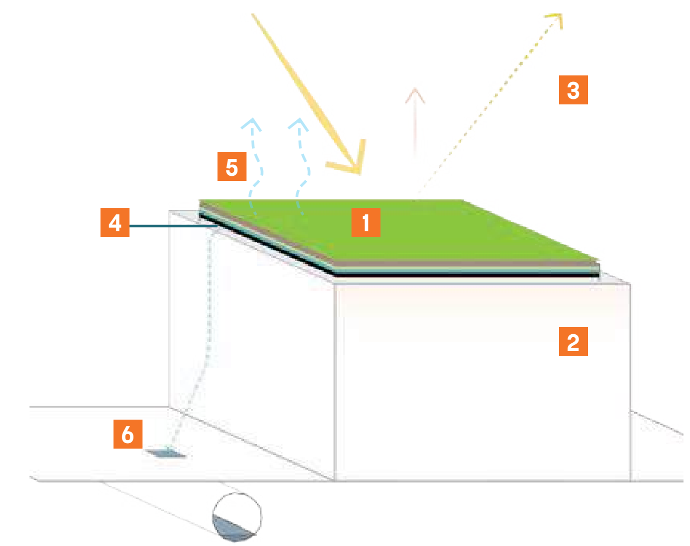
Conventional Roofs

1. The sun heats up conventional roofs to more than 50 degrees Fahrenheit higher than the outdoor temperature.
2. The building interior temperature is elevated by the hot roof.
3. The roof emits solar radiation as heat, making the urban environment hotter.
4. Stormwater immediately runs off and drains into the stormwater sewer system.
5. During intense storms, the peak volume of stormwater runoff can cause overflows, backflows, and flash flooding.



Green Roofs

1. Sunlight does not reach the roof directly, reducing roof temperature.
2. Green roof acts as insulation and moderates building temperature.
3. Roof reflects light rather than absorbing it as heat. This reduces ambient air temperature.
4. Stormwater is stored and absorbed in the green roof beds.
5. Some of the stormwater returns to the atmosphere through evapotranspiration.
6. Excess stormwater is slowly released, reducing the burden on the stormwater system.



Methods

Extensive Systems

Simple growing systems comprised of trays with 2-4 inches of growing medium and hardy plants. These systems are generally lightweight enough to require little structural support and hardy enough to require little long-term maintenance.

Intensive Systems

Complex vegetated areas that usually require high upfront investment, structural support, and regular maintenance. These roofs may be designed to be fully accessible gardens, with diverse vegetation including trees and shrubs.

Green Wall

An alternative to a green roof is a vegetated screen on a building's exterior, such as a vine trellis. Green walls help keep building temperatures down, but they do not reduce stormwater runoff as well as green roofs.

Green Roof Criteria

The following criteria indicate suitable locations for a green roof:

- A large flat roof
- Service access to roof
- New construction
- Area with flash flooding problems
- Areas with urban heat island effect
- Ability to store water on site (underground cistern)
- Need for gray water on site (irrigation, etc.)
- Roof receives both some sun and rain

Cost-Benefit Analysis

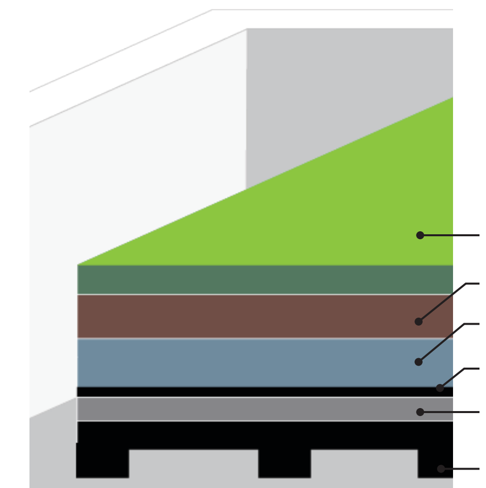
Extensive green roofs usually cost $10 per square foot or more. Intensive green roofs cost more than double that, starting at about $25 per square foot. Both systems do require annual maintenance, which typically ranges from $0.75 to $1.50 per square foot, regardless of roof type.

Overall, life-cycle cost analyses suggest that green roofs are cost effective ways to improve building performance on multi-family residences or large buildings. In these cases, the public health benefit of accessible vegetated public space raises the value of the roof to the community.

Example: A University of Michigan study calculated the upfront and life-cycle cost for a 21,000 square foot green roof. The roof would cost $464,000 to install or $129,000 more than a conventional roof. However, given that the roof could prevent $200,000 in energy, stormwater, and public health costs over its lifetime, the green-roof actually saved $71,000 compared to the standard roof.

Typical Green Roof Structure

Although green roofs come in many shapes and sizes, most have the same structural elements of vegetation, growing medium (soil), drainage, a water barrier, and an underlying structure separate from the roof itself.



3.4.2 Cool Roofs

"Cool roof" refers to a roof designed to reflect sunlight and not absorb heat. Cool roofs are made of materials that have high solar reflectance and thermal emittance. As a result the roof stays cooler. This reduces the amount of heat entering the building through its roof and reduces the thermal stress on the roof materials.

Cool roofs can be made of several different materials. Options for a low sloped roof (i.e., less than 9.5 degrees or a 2:12 slope) include single-ply membrane, built up roofs, modified bitumen sheet membranes, and spray polyurethane foam roofs. Steep-sloped roofs generally use shingles or tiles.

The Cool Roof Rating Council (CRRC) rates and labels roofing materials that meet solar reflectance and thermal emittance requirements.

Different governing and accreditation bodies have defined minimums for a roof to qualify as "cool" Typical values for solar reflectance on a low slope roof is 0.65-0.70, while steep sloped roofs can range from 0.25 to 0.65. Typical thermal emittance is generally 0.75 regardless of slope.

3.5 See 3.5 Green Building Retrofits for additional green building retrofit options.


NIH Building 10- Gravel Roof


White Metal Roof by Precise Buildings


Firestone Ecowhite EPDM

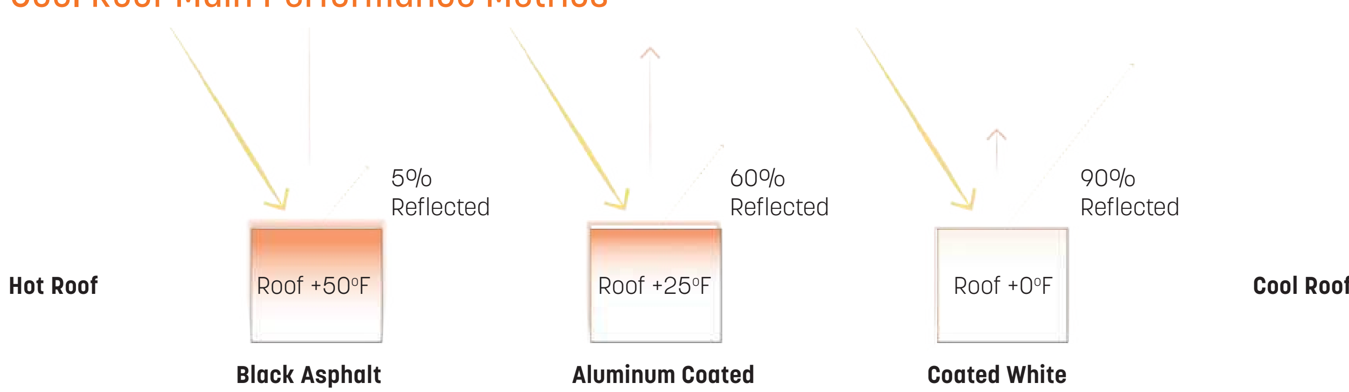

Duration Premium Cool Shingles


White Paint Covering by Jobe Roofing


Cool Roof Tile by Eagle Roofing


Radiant Barrier Sheathing

Cool Roof Main Performance Metrics



Materials

A wide array of cool roof materials are available, both in white and other colors. Materials such as paint and membranes can be installed directly over existing roofs. Materials including gravel, tiles, shingles, and metal sheets actually replace the existing roof, making them most cost effective during roof replacement or maintenance. Materials include:

- White gravel
- White/reflective coating
- White/reflective membrane
- White/reflective coating with white granules
- White/cool color paint
- White/cool color tile or asphalt
- White/cool color metal
- Radiant barrier sheathing

Cool Roof Criteria

Although nearly every new or existing roof could become a cool roof, the following characteristics indicate higher relative suitability:

- Low slope or flat roof (less than 2:12 slope)
- Hot climate
- Roof needs resurfacing or replacement
- New construction
- Single story building
- Large surface area (i.e. industrial, commercial, or office/school building)
- Located in an urban heat island area

The potential for individual buildings to achieve energy savings from a cool roof can be estimated using online programs provided by the National Laboratories (for example, roofcalc.com).

Priority Buildings

- *Public buildings*: government office buildings, schools, and public works facilities
- *Privately-owned buildings*: grocery stores, big box stores, and warehouses

Secondary Priority

- *Public buildings*: post offices and municipal buildings
- *Privately-owned buildings*: residences and small businesses

Structural Strategy

On new construction and roof replacements, structural changes can be made to roofs that will help moderate temperatures within the building and reduce energy costs.

Cost-Benefit Analysis

In areas with both hot summers and cool winters, the money savings from a cool roof during the summer are usually balanced out by increased heating costs in the winter. In the Mid-South, cost savings are usually realized on large and flat buildings that need year-round cool indoor temperatures, such as warehouses and big-box stores.

Cool roofs are relatively inexpensive. Cool asphalt shingles are up to $0.50 more expensive than conventional roofs per square foot, while low slope materials are up to $1.0 more expensive per square foot. On a new building, the cost is the same or slightly higher than a standard roof and the labor to install both is the same. Similarly, if a roof needs to be replaced due to wear or damage, it generally costs the same to replace a standard roof with a cool roof. To retrofit an existing building by covering or replacing an otherwise functional roof would cost approximately $1.25–$2.40 per square foot.[4]

The primary factors affecting cost are slope and material. Low-slope roofs are less expensive than high-slope roofs. Coatings, membranes, and paints are less expensive (and more effective) than most tiles.

In general, commercial buildings save more money with cool roofs (up to $0.20 per square foot). This is because commercial buildings tend to be single-story buildings with large, flat roofs.

Given the zero-to-low cost of installing cool roofs, as new or replacement roofs, these situations should be prioritized over retrofitting existing buildings with functioning roofs.

Implementation

Green roofs and cool roofs are usually implemented on a building-by-building basis at the discretion of the owner and developer. Different ways to encourage implementation across a community include education, assistance, and financial incentives, similar to LIDs (See 2.3 Low Impact Development).

2.3

Given the cost and benefits of green and cool roofs, municipalities in the Mid-South should consider encouraging developers to evaluate the benefits of installing cool roofs (particularly those developing urban, single story industrial, commercial, office, or school buildings with large roof areas).

Based on the negligible cost to install cool roofs on new construction, the lack of additional maintenance, and the anticipated operation costs savings, converting to a cool roof is not likely to be a financial burden on developers, and any reduction in the urban heat island effect has a substantial positive effect on the environmental and human health.

Education and Outreach

In general, community members and developers may not be aware of the risks posed by urban heat islands or the direct causal link between stormwater runoff and flooding. Potential activities to inform stakeholders include:

- Encouraging municipalities to include information about benefits, costs, priority building types, and implementation guidance in local design guidelines. This provides actionable information that is conveniently accessible to developers, designers, and contractors.
- Including specifications for green and cool roofs in local building codes so that designers, developers, and contractors know that these types of projects will be approved.
- Using water department mailings and bills to educate building owners on the issues associated with stormwater runoff, their causes, and relevant LID/green roof solutions.
- Implementing pilot projects and demonstrations at schools, town centers, and special events.
- Using electricity company mailings or bills to educate building owners on the issues and causes of the urban heat island as well as the cooling benefits of green and cool roofs.

Financial and Technical Assistance

Assistance reduces technical and financial barriers to implementation and encourages voluntary adoption of cool and green roofs. Offering technical assistance to eligible building permit applicants will help people determine if a cool or green roof is in their best interest.

Incorporating green and cool roofs into local building codes facilitates regulatory compliance so that such projects do not require special permitting or variances.

Offering subsidized materials or rebates for cool roof and green roof products can make these cheaper options than conventional roofs.

Funding Opportunities

Clean Water State Revolving Fund provides low-cost financing for infrastructure projects that improve water quality. Green roofs installed by any public, private, or non-profit entity are eligible for financing if they manage, treat, capture, or reduce stormwater. Applications for funding would be submitted by the developer.

Green roof projects may qualify for the **Community Development Block Grant Entitlement Program**. Projects must construct or improve sustainability in low and moderate-income areas.

EPA Clean Water Act Non-Point Source Grant (Section 319 Grants). The state non-point source agency can apply and receive funding for technical assistance, project funding, training, demonstration projects, and project monitoring. For fiscal year 2017, $167.9 million dollars were available for Section 319 Grants. Currently, the Tennessee Department of Agriculture administers the Non-Point Source Program. In Mississippi, The Mississippi Department of Environmental Quality (MDEQ) administers the Non-Point Source program. The two project areas are watershed restoration projects and education projects, however, green roofs that address non-point source pollution could be considered for funding.[5]

A **Federal Tax Credit** is available for metal and asphalt cool roofs that are Energy Star certified. The credit is for 10% of the cost of the roof materials, with a maximum limit of $500. Individual building owners apply for this tax credit.[6]

The **Low-Income Housing Tax Credit (LIHTC)** may be increased for developments that pursue third-party verified sustainability ratings. States can amend their LIHTC Qualified Action Plan to account for green building practices, including green and cool roofs.[7]

Financial Incentives

Financial incentives can be offered through water and energy utilities, as well as programs that promote various construction projects.

Water departments can offer reduced stormwater or freshwater fees to property owners that have added green roofs, since the roofs reduce the stormwater load on the sewers and treatment plants.

Energy utilities could provide credits to facilities that add cool roofs because they reduce demand during the peak hours on hot summer days. This reduces the risk of blackouts and the need to expand grid capacity.

Financial incentives can encourage developers to include green and cool roofs. For example, some municipalities offer tax incentives for buildings that qualify for LEED ratings (i.e. the City of Pittsburgh Sustainable Development Bonuses). At the state and federal level, projects including applications for Low Income Housing Tax Credits may receive additional points for pursuing verified green building certifications. See "Funding Categories" on the following page.

Major civic institutional projects can be funded through public-private partnerships or through the capital budget. Early planning will reduce the cost of any unconventional roof design. Therefore, it is possible that cool roofs will not require any additional funds, but merely a specification in contract documents.

Private Development may be encouraged through tax credits, subsidized materials, and education/consulting. Providing free or subsidized cost-benefit analysis for building owners may encourage some to pursue projects without financial assistance due to the long-term money savings. An example of this is Walmart. The company is converting many of its roofs to be cool roofs with solar panels in order to reduce air conditioning costs.

For individual homes and buildings: cool roofs and green roofs are not always financially viable or even desirable, since they may elevate winter heating costs. In this case, the focus on roof retrofits should be efficient attics or roof insulation.

Instead, to help with the urban heat island, municipalities can offer free or subsidized deciduous shade trees for local building owners. Deciduous shade trees or ivy screens on the south and west sides of small buildings have a similar cooling effect to cool roofs and can absorb large amounts of stormwater. Since deciduous trees lose their leaves in the winter, they do not block the winter sun from helping to heat buildings.

(Above) Walmart White "Cool Roof" with Solar Panels

(Above) Ballard Library, Seattle

Case Study

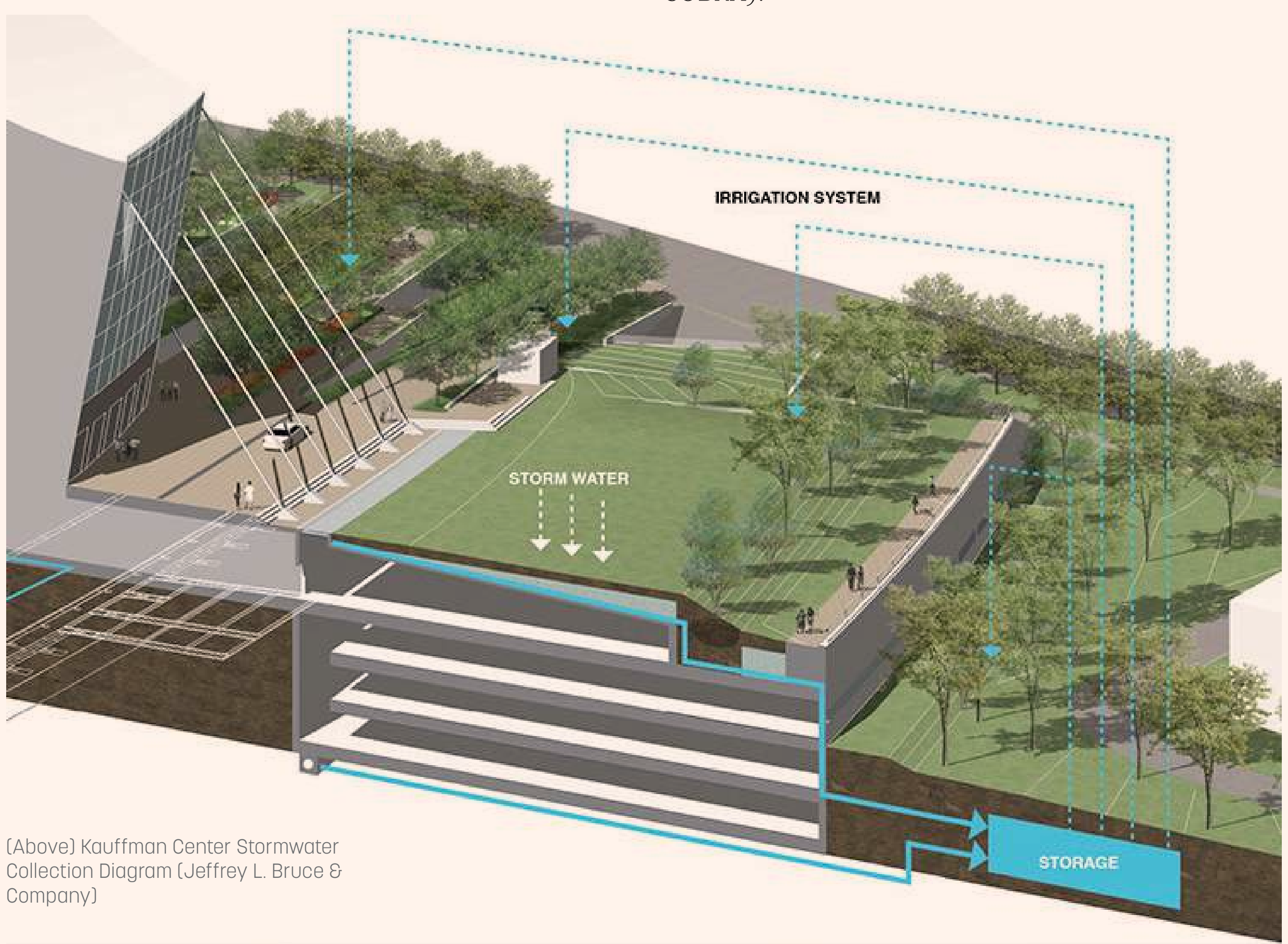
Green Roofs, Kansas City, MO

Kansas City, Missouri began building green roofs as part of a 2010 settlement with the EPA to reduce the amount of untreated sewage discharged into local waterways. Though they have humble roots, KCMO's green roofs have become award winning and innovative urban attractions.[8]

Like many older American cities, Kansas City has a combined sewer system. During large rain events, the sewer system is overwhelmed by stormwater causing stormwater and sewage to mix and overflow into streams and rivers. Separating combined sewers requires an enormous cost and effort, as does increasing water-treatment plant capacities. Therefore, cities like Kansas City are turning to green infrastructure to reduce the load on the combined sewer.

Three major projects have been completed to date and 16 more are underway. The Kaufman Center for Performing Arts has one of the largest green roofs in the country—a full 4.4 acres that covers both part of the building complex and the underground garage. The roof is designed to drain stormwater that is not needed for its own irrigation into a cistern for storage and recycling. Overall, the system saves $56,000 in water costs. The green roof is also a local amenity—it is accessible to the public, made from local materials and native vegetation, and provides habitat for local bird species.

In addition to stormwater, the green roofs in Kansas City have correlated with reductions in ground-level ozone, particulate matter, and air pollutants. The estimated human-health value of these reductions ranges from $35,500 to $80,500 (in 2020, calculated by COBRA).[9]



(Above) Kauffman Center Stormwater Collection Diagram (Jeffrey L. Bruce & Company)

(Top) Kauffman Center, Vegetation on Structure (JBC)

(Bottom Left and Right) Kansas City Library Rooftop Terrace

Endnotes

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Resources

Green Roof Cost-Benefit Comparisons

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Funding

"Getting to Green: Paying for Green Infrastructure: Financing Options and Resources for Local Decision Makers." *U.S. Environmental Protection Agency* online. Last accessed October, 2018. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100LPA6.txt

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Clean Water State Revolving Fund (CWSRF): https://www.epa.gov/cwsrf/

Community Development Block Grant (CDBG): https://www.hudexchange.info/programs/cdbg-entitlement/

Federal Tax Credits: https://www.energystar.gov/about/federal_tax_credits/roofs_metal_and_asphalt

EPA 319 Grants: https://www.epa.gov/nps/319-grant-program-states-and-territories

Green Roof Materials

"Energy 101: Cool Roofs". : *U.S. Department of Energy* online. https://www.energy.gov/eere/videos/energy-101-cool-roofs

Cool Roof Rating Council Products Directory, http://www.coolroofs.org/.

3.5 Green Building Retrofits

Support Retrofits that Improve Building Performance and Resilience

Key Benefits

1	Makes buildings more resilient to power outages
2	Improves building comfort during extreme heat and cold weather
3	Targeted aid can lower energy burden in vulnerable communities
4	Helps users overcome high initial costs
5	Can be combined with other social assistance programs

Limitations

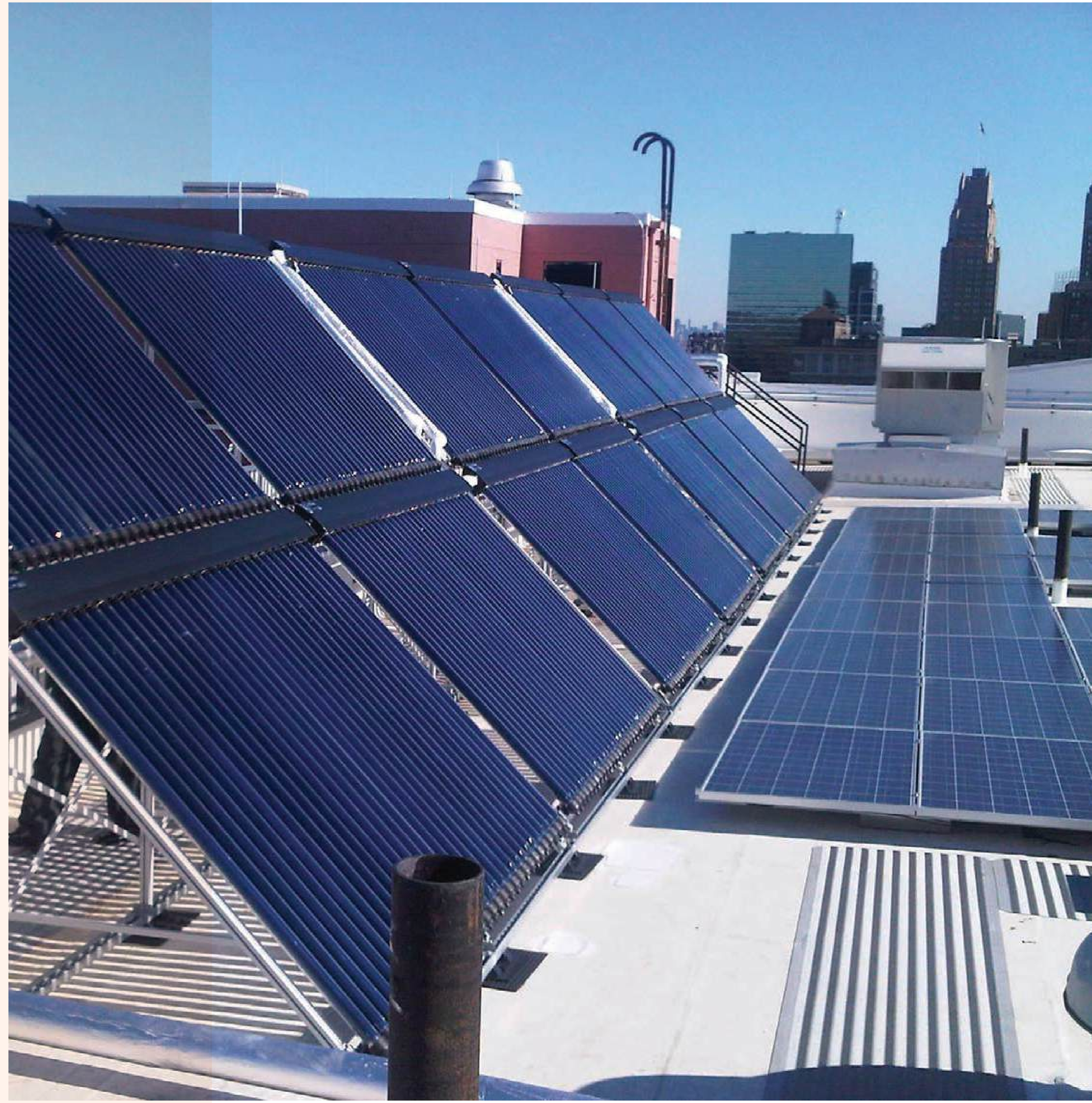
1	Green technologies may have high initial cost as compared to conventional solutions (but results in net savings over time)
2	Subsidies are not a long-term financing solution
3	Funds may be diverted from other services

Overview

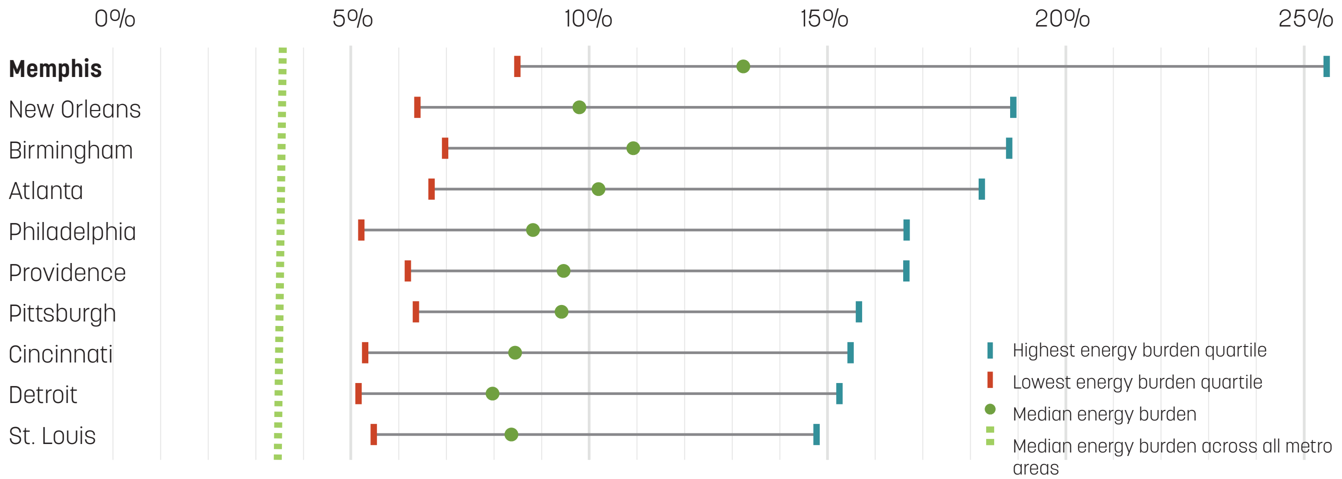
Green building retrofits are an important resiliency strategy by promoting greater energy reliability, providing better insulation during severe weather, and improving the efficiency of building-scale utilities. While green building retrofits can improve energy efficiency that leads to cost savings, they can also present a large upfront cost to homeowners and businesses. Subsidies and other incentives are a useful tool to aid in the retrofitting of older buildings with inefficient energy usage. Subsidies and other incentives are also more effective with relevant regulations employed to move the building stock of a community gradually toward sustainability.

Retrofitting buildings to improve energy performance can mean greater energy reliability by reducing the overall consumption of energy needed to heat or cool by switching to passive methods or renewable energy.

(Right) Photovoltaic (PV) panels and solar-thermal panel systems are easily implementable, but may have high upfront costs. These can substantially reduce energy costs over time, which can be made more viable through subsidies and incentives.



Top Metros by Low-income (<80% AMI) Household Energy Burden



Source: Adapted from Drehobl et al. ACEEE, 2016.

Energy Burden in the Memphis Metropolitan Area

	All Households	Low-income Households	Low-income Multifamily Households	African American Households	Latino Households	Renting Households
Overall Energy Burden	6.20%	13.20%	10.90%	9.70%	8.30%	8.60%
Highest Burden Quartile	12.80%	25.50%	21.80%	19.40%	15.90%	18.50%

Source: Adapted from Drehobl et al. ACEEE, 2016.

Using solar energy or connecting to local microgrids can keep energy on in times where the grid may be unreliable such as during a disaster event. Improving a building's energy performance is also related to its ability to regulate thermal energy through more efficient and proper insulation, meaning it can also provide better protection in cases of extreme hot or cold weather. Another component of green building retrofit is the operations of a building's utilities. Retrofitting, right-sizing, and replacing utilities can make a building more resilient to floods, while improving overall systemic efficiency.

Another vulnerability green energy retrofits can address is the cost burden associated with excessive energy use due to inefficiencies in a building's systems. Energy cost burden in the Memphis metropolitan area is one of the highest in the country. Despite having around 16.75%[1] cheaper electricity rates than the national average, factors such as lower incomes and inefficient housing stock are significant contributors to energy burden in the Memphis region. Energy burdens represent the total energy utility spending of a household and dividing it by the total gross household income. A report by the American Council for an Energy-Efficient Economy (ACEEE) found that bringing the housing stock of low-income communities up to the efficiency level of the median household would eliminate 35% of their excess energy burden. The energy burden of the median household across the US is 3.5% while the median energy burden for low-income households was around twice that at 7.2%. Low-income households with high energy burdens are more likely to be unable to afford necessary retrofits to bring their homes up to standard. Targeted investment in these communities is needed to overcome the combination of the area's high poverty rates and poor housing stock.

In the business community, there is a lack of knowledge about the value proposition of green building retrofits. The potential cost savings and returns on investment from green energy retrofits are an important point to stress and to educate all users on. Subsidies and loan programs are also becoming more prevalent, but facilitation is needed by governments at the state and local level to promote new energy standards and support financing programs for homeowners and businesses alike.

Resilience Benefits of Energy Efficiency

Benefit Type	Energy Efficiency Outcome	Resilience Benefit
Emergency Response and Recovery	Reduced electric demand	Increased reliability during times of stress on electric system and increased ability to respond to system emergencies
	Backup power supply from combined heat and power (CHP) and microgrids	Ability to maintain energy supply during emergency or disruption
	Efficient buildings that maintain internal comfort	Residents can shelter in place as long as buildings' structural integrity is maintained
Social and Economic	Reduced exposure to energy price volatility	Economy is better positioned to manage energy price increases, and households and businesses are better able to plan for future
	Reduced energy cost burden	Ability to spend income on other needs, increasing disposable income (especially important for low-income families)
	Improved indoor air quality and emission of fewer local pollutants	Fewer public health stressors
Climate Mitigation and Adaptation	Reduced greenhouse gas emissions from power sector	Mitigation of climate change
	Cost-effective efficiency investments	More leeway to maximize investment in resilient redundancy measures, including adaptation measures

Source: Adapted from Ribeiro et al. ACEEE, 2015.

Implementation Issues for Green Building Retrofits

There are many issues that may describe why many communities have trouble implementing programs to promote green building retrofits. Some of the key issues are listed below:

- *Large Upfront Costs*
  Many energy efficiency and green retrofits have large upfront costs that can dissuade initial investment for both homeowners and businesses.
- *Uneven Incentives*
  Landlords or building owners may not wish to pay for energy updates while tenants receive most of the energy savings.
- *Unknown or Limited Understanding of Value Proposition*
  Many consumers do not understand the long-term value of green energy projects or the return on investment that is possible in many retrofit solutions.
- *Lack of Viable or Compatible Time Horizon*
  The payback period for a green energy solution may exceed a business's short-term needs.
- *Lack of Technical Expertise*
  There is a lack of expertise in the building trades to carry out higher standards for energy efficiency and green retrofits as well as trained inspectors and engineers.
- *Lack of User Knowledge of Green Technologies*
  Many new technologies may disrupt ingrained (yet wasteful) patterns of living. Many technologies require different ways of use and can be difficult to learn or ingrain as habit.

Technologies

The amount of technologies coming to market these days can be overwhelming. But in retrofitting a building, these technologies can be categorized based on the particular issues each is attempting to solve. Whether the issue stems from older building components and assemblies, poor materials or inefficient utilities, there are three major 'categories' of measures most homeowners and businesses may take in retrofitting their buildings to be more energy efficient:

- technologies for renewable energy production and recycling,
- building envelope systems, and
- measures for utility efficiency.

The retrofit needs of every building is different. In some extreme cases, the long-term cost of retrofitting a building may be nearer to the cost of a complete reconstruction. An assessment of the particular conditions of each building is necessary to determine its retrofit needs, as well as the practicality of each strategy. In implementing these types of green building retrofits, there are a few major considerations to think about in selecting an approach:

- The short-, medium-, and long-term energy efficiencies from different technologies including the service life of a measure, as well as planning for maintenance over a product's life-cycle and its eventual replacement.
- The total life-cycle cost and environmental attributes such as a product's material footprint, recycled content, and use of renewable resources.
- Much of a building's energy inefficiency is due to wasteful user habits. This inefficiency can result from simply not opening up windows or lack of knowledge about cross-ventilation, or lack of daylighting use for artificial illumination. Many of these kinds of habits result in waste of energy. Education and signage to promote beneficial user habits will go a long way to improving overall efficiency.

(Right) Thermal analyses of buildings can reveal surfaces that have high thermal conductivity. This can result in high inefficiency and costs. This can reveal key attributes that need addressing, such as improved wall insulation on the house on the right.

Overview of Recommendations for Green Technology Retrofits

Type of Technology	Relative Investment	Application	Recommendations
3.5.1 Technologies for Renewable Energy Production and Recycling			
PV and Solar-thermal Systems	High	Rooftop or large surface application	Assess the viability of PV and solar-thermal systems in offsetting conventional energy sources. Determine location for solar energy collection, assess financial feasibility, and install system.
Greywater Recycling	High	Building plumbing systems	Assess the feasibility of installing greywater recycling system to reduce overall water consumption. Implement a greywater storage and piping system.
3.5.2 Building Envelope Systems			
Insulation	Low	Facade, interior material assembly	Add protective insulation layers to building facades that lack adequate insulation to prevent thermal conduction through thin or inadequate materials.
Radiant and Moisture Barriers	Medium	Facade, interior material assembly	Take measures to reduce thermal conduction through ceilings, roofs, walls, and floors by insulating and installing vapor barriers and reducing solar heat gains through roofs through reflective or light roof materials.
Windows	Medium	Facade, interior material assembly	Reduce thermal conduction, solar gain, and long-wave radiation through windows by installing high-performance, double/triple glazed windows, use exterior and interior shading, or use tinted or reflective films on windows. Reduce the amount of thermal infiltration by sealing ducts or other areas open to air penetration and caulking or weatherizing doors and windows.
3.5.3 Measures for Utility Efficiency			
Water Heating Systems	High	Building plumbing systems	Insulate hot water pipes and water storage tanks. For commercial buildings, lower hot water temperatures, install decentralized water heaters and use smaller water heaters based on seasonal use. Refer to solar-thermal and water recycling systems to help improve thermal recycling.
Lighting	Low	Electrical appliance	Promote the use and habits of daylighting over electrical methods of illumination and reduce the amount of lighting usage overall. This can also be aided by the use of energy-efficient lights such as LEDs. For larger buildings and spaces, use occupancy sensors for more efficient usage of light.
Building Utility Operations	High	Building plumbing and electrical systems	Right-size heating, ventilation, and air-conditioning (HVAC) systems for the area required. Use Demand-Controlled Ventilation (DCV) systems to increase overall efficiency. Insulate ducts and HVAC system pipes. Elevate building utility systems above design flood elevation (DFE) to prevent risk damange by flood.
Appliances	Low	Electrical appliance	Replace inefficient and old appliances with more efficient appliances. Many of these come with an ENERGY STAR label.

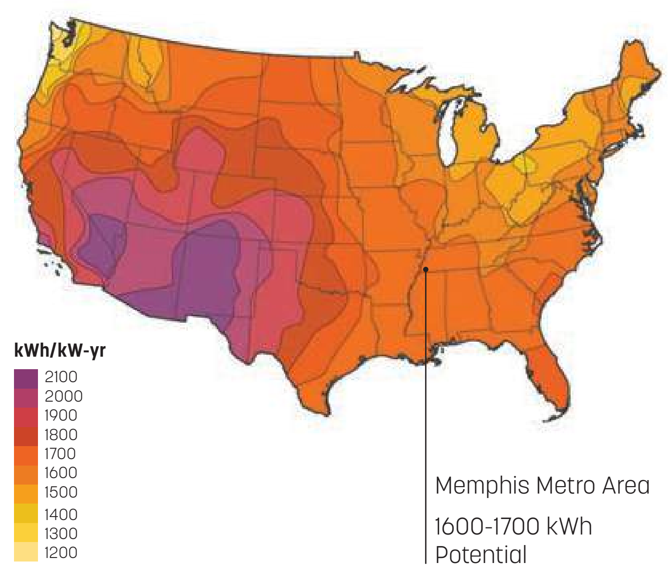
3.5.1 Technologies for Renewable Energy Production and Recycling

PV and Solar-thermal Systems

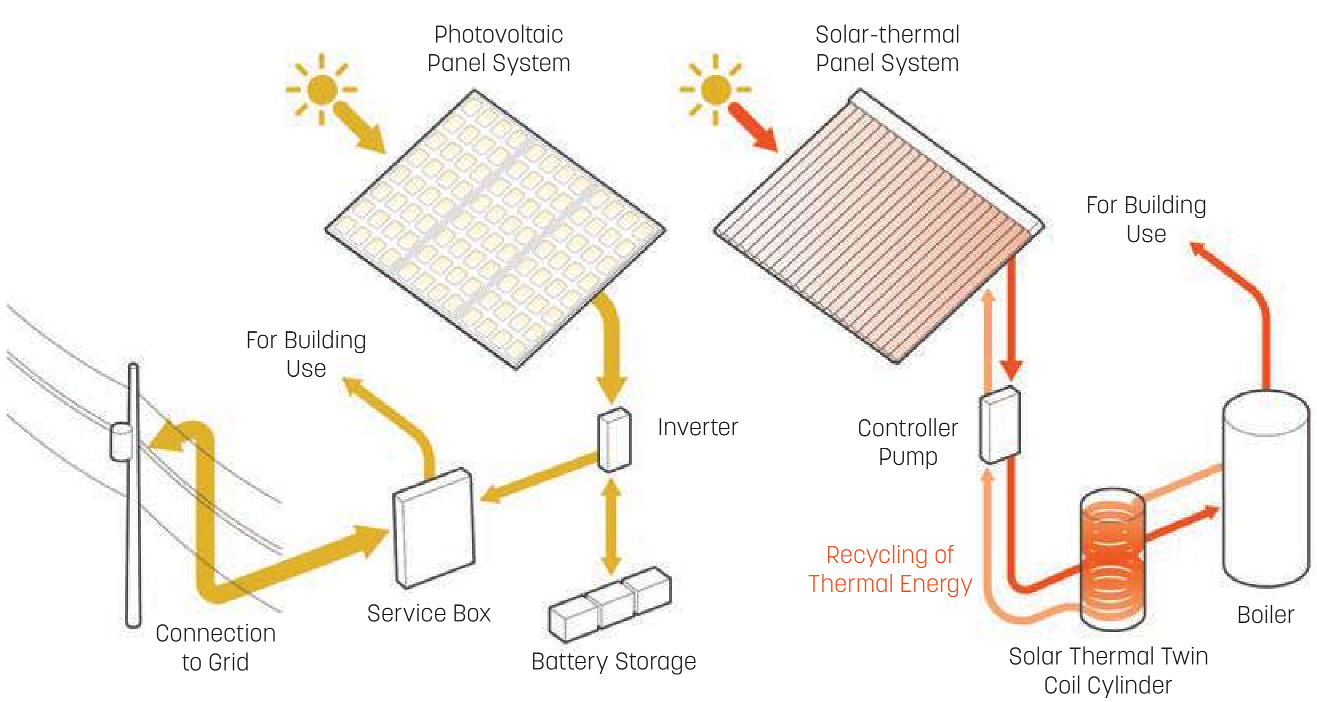
Assess the viability of PV and solar-thermal systems in offsetting conventional energy sources. Determine location for solar energy collection, assess financial feasibility, and install system.

Photovoltaic and solar-thermal systems work in a similar way by absorbing solar energy through a panelized system. These panels must be exposed to solar-thermal energy and be oriented towards the sun path to operate at peak efficiencies. Areas with low solar exposure may not yield viable amounts of energy. Photovoltaic panels work by converting solar energy into electricity and storing the harvested energy in a battery that can offset electricity use from the grid. Solar-thermal systems convert solar energy into thermal energy through the use of water or other liquid vehicles by piping water through a loop that coils under a solar-thermal collector, transferring thermal energy to the liquid and returning it for use within the building. This can offset conventional energy sources that generate heat.

Map of Solar Potential



Schematic Diagram Photovoltaic and Solar-thermal Systems

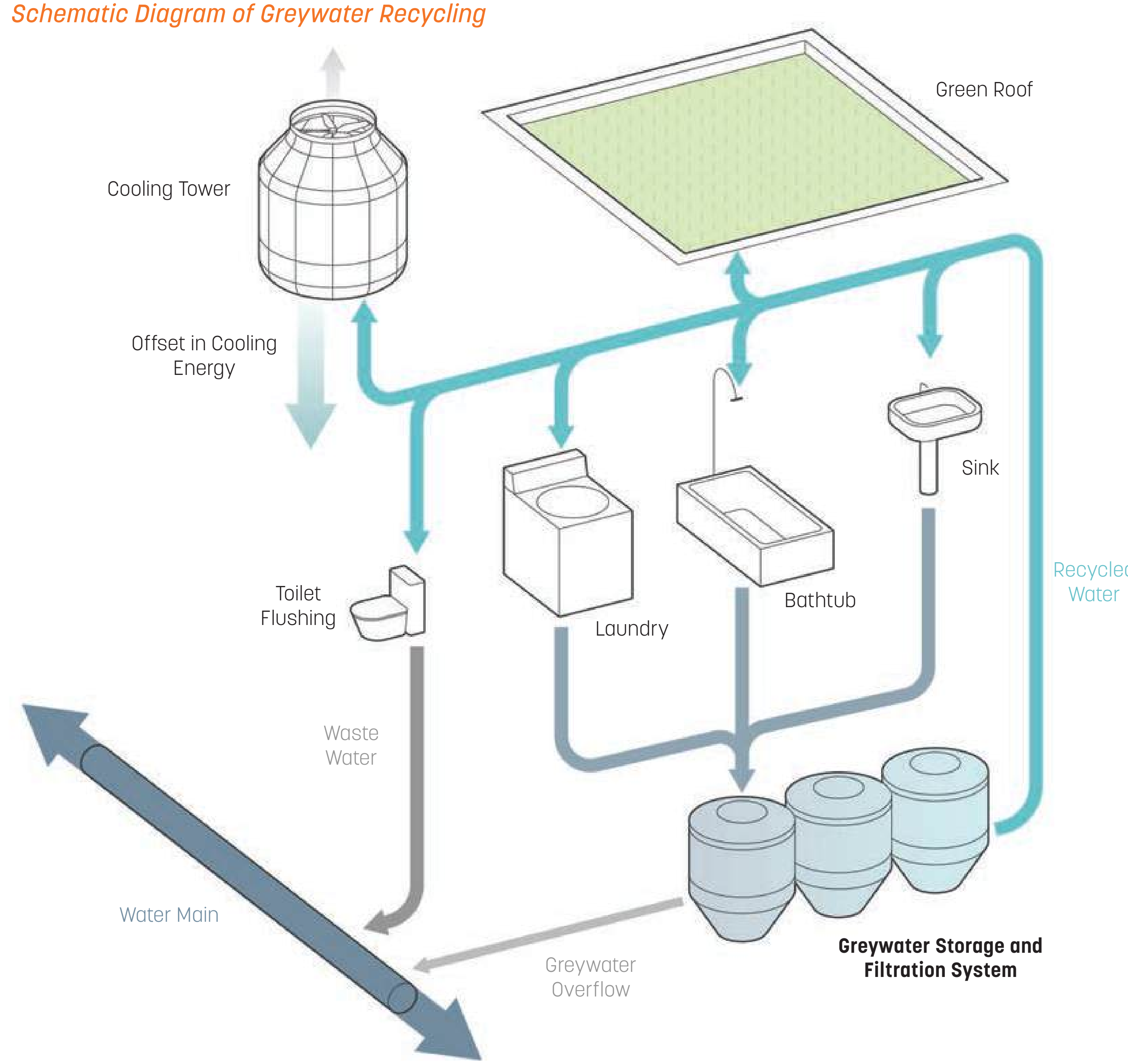


Greywater Recycling

Assess the feasibility of installing greywater recycling system to reduce overall water consumption. Implement a greywater storage and piping system.

Greywater recycling is also useful in preserving water resources by taking water used in sinks or showers and reusing it for utilities like flushing toilets. Solar-thermal systems may also be integrated with greywater recycling.

Schematic Diagram of Greywater Recycling



3.5.2 Building Envelope Systems

Insulation

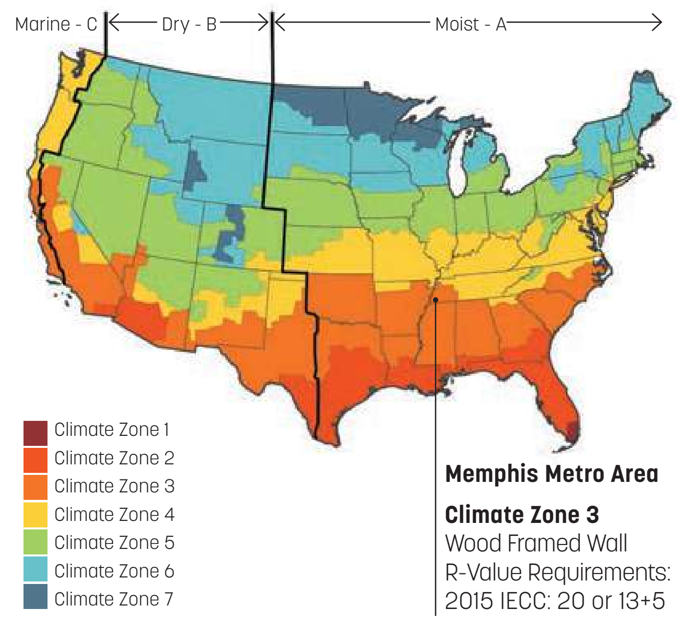
Add protective insulation layers to building facades that lack adequate insulation to prevent thermal conduction through thin or inadequate materials.

Retrofitting older and poor-quality homes with efficient insulation is a key measure to reducing energy usage and promoting energy security. Insulation prevents thermal conduction between the interior and exterior, keeping the interior cooler or warmer than the exterior when necessary for comfort. Energy Star has estimated that a typical house in climate zone 3 (where the Memphis metropolitan area is located) can save an estimated 8% on the total energy bill and around 14% on heating and cooling alone with sufficient insulation.

Interior insulation uses a variety of materials. Older materials such as fiberglass insulation may be hazardous to health. More sustainable types of insulation are now available on the market such as: sheep's wool, aerogel, denim, ThermaCork, polystyrene, cellulose, icynene.

Exterior insulation is another option that involves the application of rigid insulation panels and new siding on top of an existing facade.

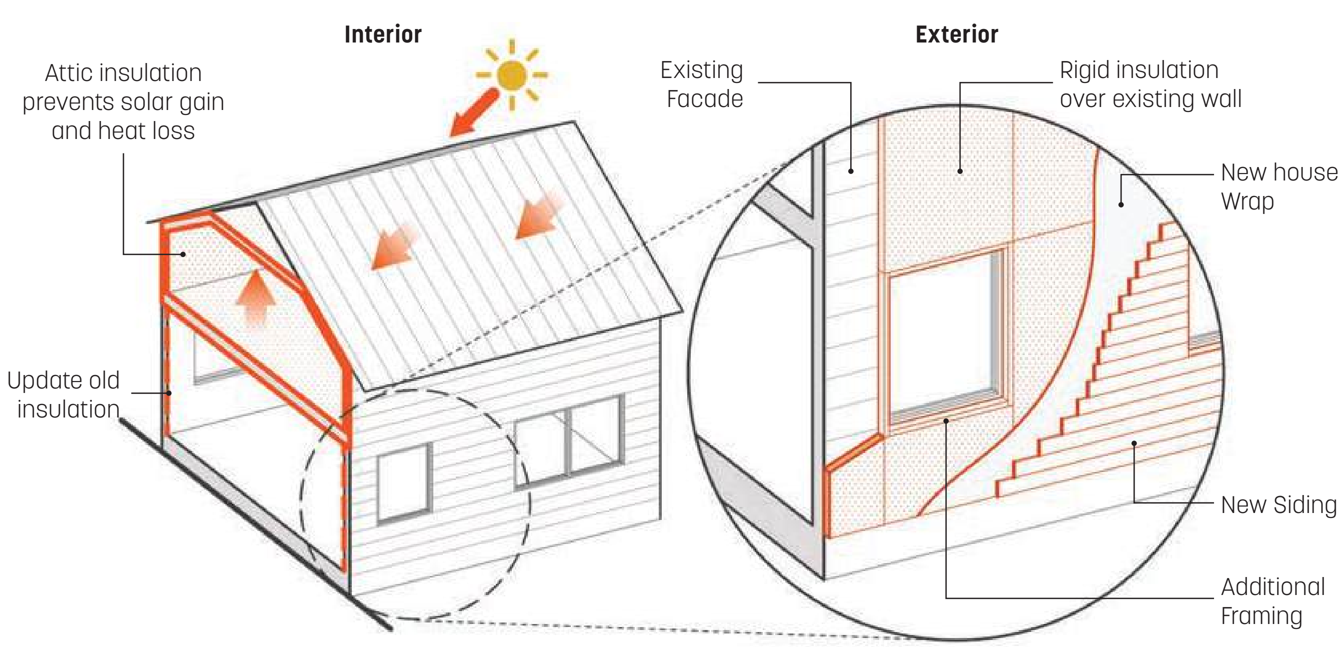
Map of Climate Zone and Suggested R-values***



*Climate zones are designated areas with like-climates to establish building efficiency standards and strategies

**R-value is an indication of a materials insulation value. The higher the R-value, the more insulating it is

Insulation Retrofit Types



External insulation is an option for cladding over the existing facade where interior retrofit may be too invasive

Radiant and Moisture Barriers

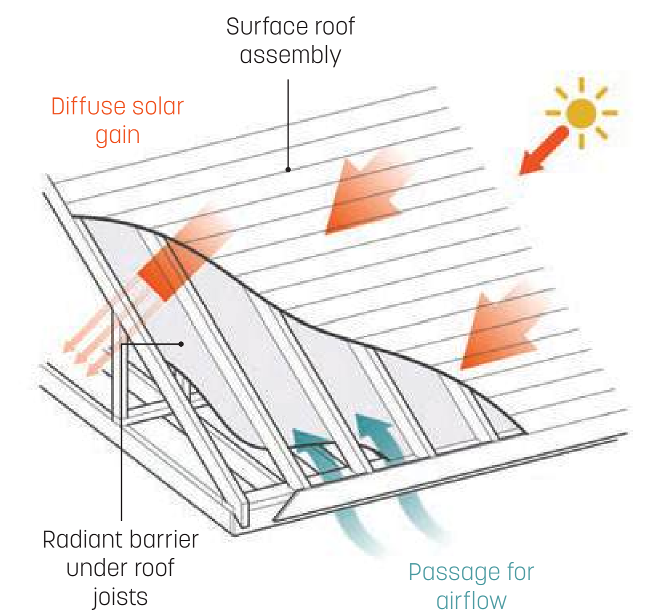
Take measures to reduce thermal conduction through ceilings, roofs, walls, and floors by insulating and installing vapor barriers and reducing solar heat gains through roofs with reflective or light roof materials.

To reduce overall thermal conduction, materials that can act as efficient radiant barriers or have colors with high solar reflectance will go a long way in reducing a building's overall heat gain and add to a building's overall thermal performance. Radiant barriers such as aluminum foils and reflective insulation work by reflecting radiant heat. These may be typically installed in the attics or roofs of buildings to prevent solar gain. Using lighter colors for roofing material also helps minimize the heat the building absorbs.

Aside from radiant barriers, it is also important to inspect the material assemblies at key joints where walls, floors, and ceilings meet. These intersections can sometimes lack efficient barriers between interior and exterior conditions. Vapor barriers should be installed to mitigate this condition and prevent thermal conduction and the infiltration of moisture.

3.4 See 3.4 Roof Design for more opportunities.

Radiant Roof Barrier



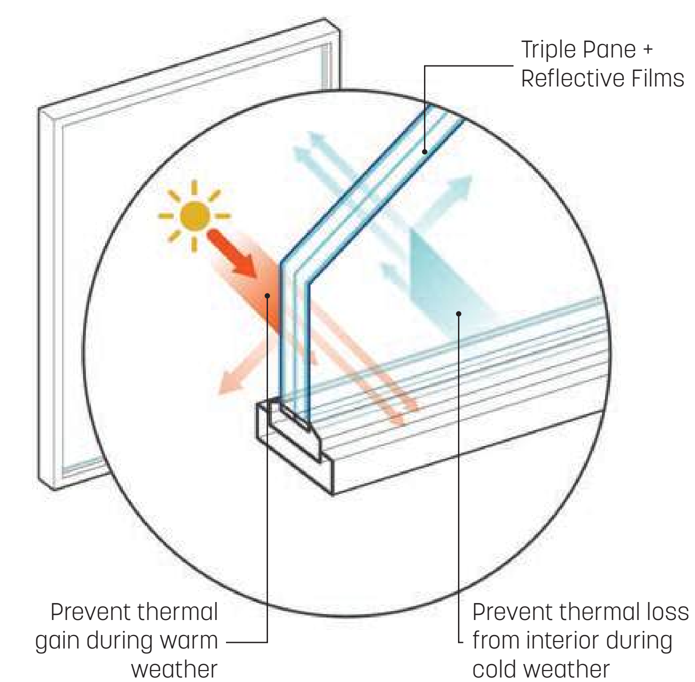
Windows

Reduce thermal conduction, solar gain, and long-wave radiation through windows by installing high-performance, double/triple glazed windows, use exterior and interior shading, or use tinted or reflective films on windows.

Reduce the amount of thermal infiltration by sealing ducts or other areas open to air penetration, and caulking or weatherizing doors and windows.

Older windows tend to allow far greater transfer of thermal energy, especially solar heat gain. New improvements in glazing technology have led to triple-pane windows, low E coating, and films that increase protection from solar gain, and increase overall insulation. Simply replacing older windows can have a major improvement on energy efficiency by reducing thermal conductivity.

Window Triple-pane Cross Section + Reflective Films



3.5.3 Measures for Utility Efficiency

Water Heating Systems

Insulate hot water pipes and water storage tanks.

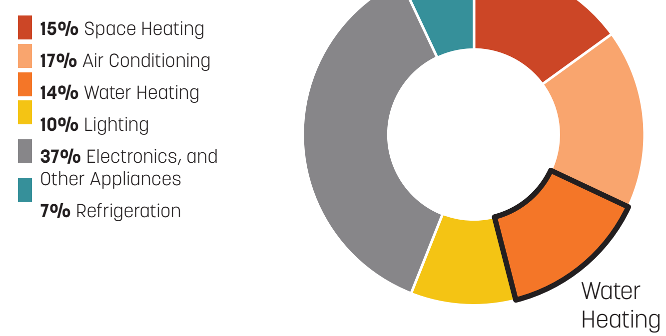
For commercial buildings, lower hot water temperatures, install decentralized water heaters and use smaller water heaters based on seasonal use.

Refer to solar-thermal and water recycling systems to help improve thermal recycling.

Water heating needs are often centralized, even in larger building types. This results in waste heat as water travels over longer distances to reach its destination. Recycling heat through solar-thermal systems, or simply adding insulation to unprotected pipes can improve efficiency. For larger buildings, heating water nearer to the place of consumption can save on the energy lost in transmission.

National Residential Building Energy Consumption

14% of residential building energy use comes from water heating



Source: US Energy Information Administration, 2015 Residential Buildings Energy Consumption Survey

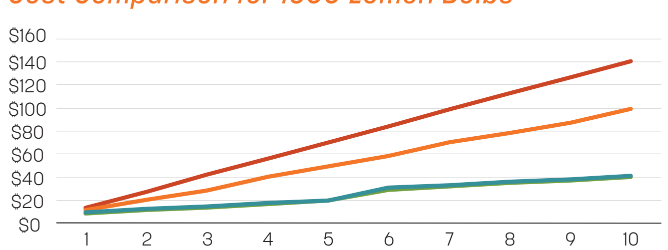
Lighting

Promote the use and habits of daylighting over electrical methods of illumination, and reduce the amount of lighting usage overall. This can also be aided by the use of energy-efficient lights such as LEDs.

For larger buildings and spaces, use occupancy sensors for more efficient usage of light.

Lighting typically makes up a large proportion of energy consumption in both commercial and residential building types. Reducing the amount of electricity used per light unit goes a long way in reducing total costs over time. For larger commercial and warehouse buildings, lighting can be tied to occupancy sensors to reduce overall lighting needs for spaces without a need.

Cost Comparison for 1600 Lumen Bulbs



Conventional Bulbs vs. LED

	Incandescent	Halogen	CFL	LED
450 Lumen	40w **$4.82/yr**	29w **$3.49/yr**	11w **$1.32/yr**	9w **$1.08/yr**
800 Lumen	60w **$7.23/yr**	43w **$5.18/yr**	13w **$1.57/yr**	12w **$1.44/yr**
1100 Lumen	75w **$9.03/yr**	53w **$6.38/yr**	20w **$2.41/yr**	17w **$2.05/yr**
1600 Lumen	100w **$12.05/yr**	72w **$8.67/yr**	23w **$2.77/yr**	20w **$2.41/yr**
Rated Life	1 year	1-3 years	6-10 years	5-20 years
10-yr Cost Ratio*	100%	70%	28%	28%

*Cost ratio is overall bulb cost compared to incandescent over a 10 year period

Building Utility Operations

Right-size heating, ventilation, and air-conditioning (HVAC) systems for the area required

Use Demand-Controlled Ventilation (DCV) systems to increase overall efficiency

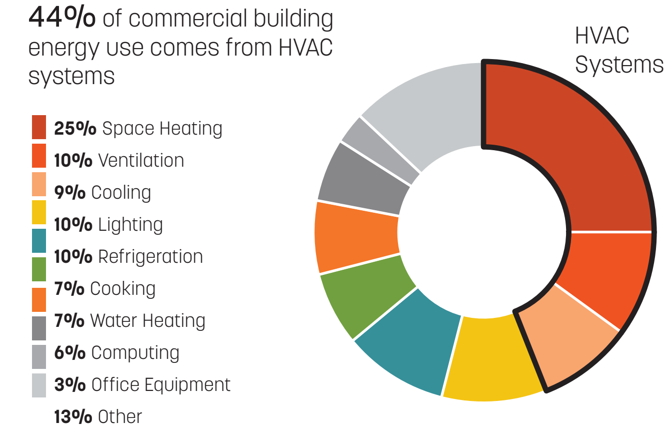
Insulate ducts and HVAC system pipes

Elevate building utility systems above design flood elevation (DFE) to prevent risk damage by flood

Many commercial buildings have been designed with over-engineered utilities and HVAC systems that often do not take into account the potential use of sustainable options and habits, such as opening windows, or promoting cross-ventilation for cooling needs. Both heating and cooling may be done at a floor or building-wide level instead of only heating and cooling where necessary, resulting in much waste. Demand-Controlled Ventilation (DCV) systems can be installed that can direct heating and cooling needs to rooms that require it reducing overall efficiency of the system.

National Commercial Building Energy Consumption

44% of commercial building energy use comes from HVAC systems



Source: US Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey

Efficient Appliances

Replace inefficient and old appliances with more efficient appliances. Many of these come with an ENERGY STAR label.

Like lighting, there are many new technologies available for everyday use that conserve much more energy than older solutions. Helping households and businesses adopt energy-efficient appliances is a simple, non-invasive form of retrofit that can be easily achieved.

Programs and Initiatives

Existing Programs and Resources

MLGW's EcoBUILD

Voluntary green building program by the Memphis Light, Gas, and Water (MLGW) to promote construction standards that meet or exceed the 2009 International Energy Conservation Code (IECC).

MLGW's Share the Pennies Weatherization Assistance Program

In January 2018, the Share the Pennies Program was launched by the MLGW. It is a bill round-up program for all customers of MLGW (that have not opted-out) that helps to reduce the energy bills of vulnerable communities by offering weatherization grants of up to $4,000 for low-income homeowners.

TVA's Green Power Providers Program

Homeowners or businesses can install a solar, wind, biomass, or low-impact hydropower system generating 50 kilowatts or less and TVA will pay for every kilowatt hour generated by that system. Systems must comply with an associate-level certification from the North American Board of Certified Energy Practitioners (NABCEP).

https://www.tva.gov/Energy/Valley-Renewable-Energy/Green-Power-Switch

TVA's Green Power Switch Program

Homeowners or businesses can pay a slightly higher premium that goes towards the installation of renewable energy resources in TVA's energy mix.

https://www.tva.com/Energy/Valley-Renewable-Energy/Green-Power-Providers

Entergy Residential Heating and Cooling Program

A rebate program provided by Entergy Mississippi that offers up to $1,000 on high efficiency systems.

http://www.entergy-mississippi.com/your_home/save_money/EE/heating-cooling.aspx

Tennessee's Sales Tax Credit for Clean Energy Technology

With the installation of a solar power system, the cost of that system is exempt from all sales tax, which can save between 6.25% and 8.25% off the starting cost.

The Weatherization Assistance Program (WAP)

25% to 100% federally funded through a grant (in addition to a guaranteed loan) from the Federal Department of Energy.

The Low Income Home Energy Assistance Program (LIHEAP)

100% federally funded program through a grant from the Federal Department of Health and Human Services. This program helps low-income families manage costs associated with home energy bills, energy crises, weatherization, and energy-related home repairs.

Federal Solar and Wind Tax Credits

Offers 30% credits for residential solar installations until the end of 2019. It then steps down over two years and expires completely at the end of 2021.

Business Energy Investment Tax Credit (ITC)

Offers corporate tax credits on up to 10-30% of expenditures on a variety of renewable energy technologies such as solar, wind, geothermal, etc. for non-Residential sectors.

DSIRE, Business Energy Investment Tax Credit (ITC), http://programs.dsireusa.org/system/program/detail/658.

HomeStyle Energy Program

A mortgage option through Fannie Mae that gives borrowers the ability to finance the implementation of energy efficiency measures for up to 15% of the appraised value of their homes.

https://www.fanniemae.com/singlefamily/homestyle-energy

Federal Energy-Efficient Commercial Building Tax Deduction

The federal government offers a tax deduction of $1.80 per square foot to "owners of new or existing buildings who install interior lighting, building envelope, or heating, cooling, ventilation, or hot water systems that reduce the building's total energy and power cost by 50% or more in comparison to a building meeting minimum requirements set by ASHRAE Standard 90.1-2001." Other deductions are available depending on achievement of energy savings targets.

Rural Energy Savings Program (RESP)

Helps rural families and small businesses with implementing cost-effective energy efficiency measures through a loan program. For more programs and incentives available in Tennessee, see:

Database of State Incentives for Renewables and Efficiency (DSIRE), http://programs.dsireusa.org/system/program?fromSir=0&state=TN.

The CDFI Fund Program

Provides financial and technical assistance. Grants can be issued for a one-to-one match to private, non-federal entities for community development projects such as solar energy installations.

US Department of the Treasury, Community Development Financial Institutions Fund, https://www.cdfifund.gov/Pages/default.aspx

The Bank Enterprise Award Program

Gives out grants to FDIC-insured financial institutions that invest in CDFIs or provide assistance and services to vulnerable communities.

US Department of the Treasury, Community Development Financial Institutions Fund Bank Enterprise Award Program, https://www.cdfifund.gov/programs-training/Programs/bank_enterprise_award/Pages/default.aspx.

Background and Past Recommendations

The Green Building Task Force was employed in 2012[2] to assess the existing green building programs in the Memphis metropolitan area. More recently, the 2018 Climate Action Plan (CAP) for Memphis and Shelby County[3] has made additional recommendations that merit review and are listed below with potential updates for moving forward into 2019 and 2020.

1. Local government lead by example: Adopt the International Energy Conservation Code (IECC 2015), commit to green building for new construction, and continue energy audits of existing buildings. Look to adopting more advanced green building and energy codes that go beyond IECC such as the International Green Construction Code (IGCC).

   Recently, Memphis and Shelby County adopted the 2015 International Building Code, the 2015 International Energy Conservation Code and others for retrofits and new construction. Adopting the IGCC and pursuing other avenues to promote innovative green building standards. See recommendation G.

2. Expand MLGW's EcoBUILD program with a broader set of green measures and adopt a time line for converting it from a voluntary program to a mandatory program.

   This could also be accomplished in combination with a financing program such as MLGW's Share the Pennies Program as well as through facilitation of additional financing options. More work to reduce higher initial costs to a viable level should be done before making certain measures mandatory. See recommendations A, D, F and H.

3. Develop a voluntary green certification program, similar to EcoBUILD, for commercial buildings.

   The EcoBUILD program could be extended to the commercial sector with financing options such as federal tax credits and state sales tax credits to promote retrofit. Additional subsidies can be made available in like manner to help businesses overcome initial costs to obtain shorter-term returns on investment. See recommendations A, B, D, and F.

4. Develop education and outreach programs for local government staff and building industry professionals, in both the residential and commercial sectors, to build capacity for green building and stimulate market demand for measures beyond the minimum requirements.

   This includes making the value proposition of green building retrofits known while making financing options more readily available to interested consumers. See recommendations A, B, C, D, and F.

5. Establish electronic tracking tools that will display, like a flow chart, where customers of Codes, Planning, and other departments are in the application process such that any staff member can report to the customer where they are in the process and the next steps.

   This recommendation goes without saying. Technological tools that centralize information sharing across departments and facilitate coordination are beneficial for reaching collective agency goals.

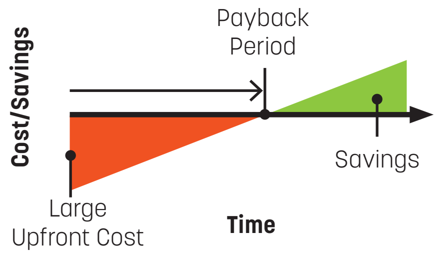
Financing and Implementation

One of the primary benefits of green building retrofits are the cost savings due to the increased energy efficiency achieved through new technologies and better materials used. The charts below illustrate three scenarios of financing and the relative return on investment for green building retrofits.

Typical Green Building Retrofit Financing Methods

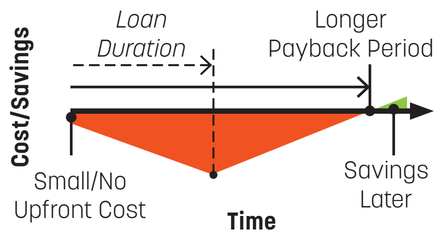
Conceptual Return on Investment Chart | **Description**

Green Retrofit without Financing



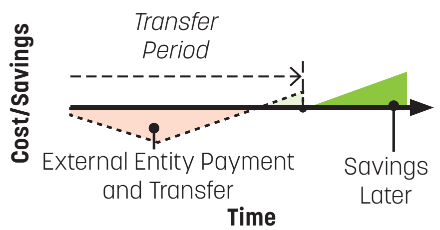
The potential large upfront costs for many technologies and new material assemblies can be steep, but there are eventual cost savings over time. The payback period (where the cost savings on energy consumption is equal to the initial investment) can be several years. This may be adequate for homeowners, but could be too long for the time horizon of a business. However, the initial costs can be prohibitive for both.

Green Retrofit with Loan



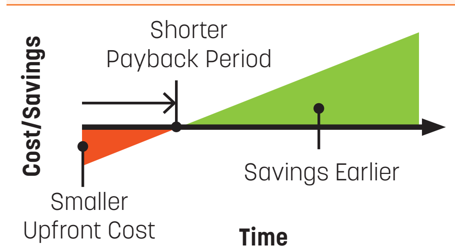
With a loan, green building retrofits have an affordable upfront cost, but spread the costs out over time. This may be more affordable for many consumers, but low-income households may not be able to afford the added costs of the loan. The payback period is also extended under this option.

Green Retrofit with Benefit Transfer



Within this type of contract, an external entity is hired and pays for all implementation and is guaranteed a payment of the difference in energy costs after implementation over a period of time to recoup the expenditure and make some profit. This external entity is usually a special type of energy contractor that has access to financing, tax incentives, and other means that can reduce overall costs of procurement. This may sometimes be more beneficial for owners than other financing options such as a direct loan.

Green Retrofit with Subsidy



With a subsidy, costs may be reduced or transferred from the consumer to a government entity. This reduces the upfront cost while decreasing the payback period resulting in more savings overall and at a quicker rate.

Overview of Potential Financing and Implementation Methods

Type of Technology	Target Beneficiaries	Relevant Organizations	Summary
A Adopt Voluntary Energy Performance Standards	Businesses, Institutions, Public Sector	Counties, Municipalities	Extend MLGW's voluntary EcoBUILD program to the commercial sector to promote higher energy performance standards in buildings.
B Tax Rebates and Exemptions on Value of Retrofits	Homeowners, Businesses	Municipalities, Memphis Housing and Community Development	Incentivize green building retrofits by offering tax rebates on the improvement value after retrofit.
C TIF District funding for Green Building Retrofits	Homeowners, Businesses	EDGE, Community Redevelopment Agency (CRA), Industrial Development Boards	Extend TIF utilization benefits to target green building retrofits in existing and newly established TIF districts.
D Promote Resilience Bonds	Businesses	Municipalities	Promote the use of Resilience bonds to capture the savings from a lowered risk of insurance payout with regard to green building retrofits.
E Promote Energy Savings Performance Contracts (ESPCs)	Businesses, Public Sector	Counties, Municipalities, Energy Service Companies	Utilize ESPCs to implement large energy retrofit projects at low-to-no upfront cost through contracting with an energy services company.
F Finance Microgrids	Homeowners, Businesses, Institutions, Public Sector	State, County, Municipalities, Local Utilities	Utilize a variety of financing mechanisms to promote energy resilience with microgrid implementation in key areas of vulnerability.
G Adopt a Property Assessed Clean Energy (PACE) Program	Homeowners, Businesses	State, Counties, Municipalities	Promote the adoption of enabling legislation that allows local municipalities to promote a savings scheme embedded in liens on property for green energy technologies.
H Promote the Establishment of a Green Bank	Homeowners, Businesses, Institutions, Public Sector	State, Counties, Municipalities	Pursue long-term green energy financing models with the promotion of a green bank to reduce reliance on subsidies and incentives for private-investment in energy efficiency and other green retrofits.

The following recommendations are outlined individually in a list on the following pages but are intended to be mutually-supportive. More than one method of financing is often necessary for successfully funding measures such as green building retrofit, especially across a diverse range of users and stakeholders. For instance, the establishment of a TIF district could incentivize the use of local community-shared microgrids with solar-thermal capacities that can be supported by a program in that district to implement green building retrofits. Coordination of financing programs are valuable in obtaining higher returns on investment, higher efficiencies, and specific targeting of key areas can increase the viability of any one of these methods.

Care should also be taken to include a diverse array of users with regard to which types of technologies and retrofits are more viable to each. Many retrofits for energy efficiency have focused on upgrading insulation and materials for low-income homeowners due to the higher prevalence of low quality housing within this demographic group. For many business owners, solar power and other technologies may not be as effective in reducing costs over a viable length of time given the longer payback periods associated. Incentives should target these key groups and the associated technologies while being diverse in their application. For instance, microgrids are more than just a technological solution—they involve the organization of a diverse array of users with differing degrees of financial viability and distributed risk.

A. Adopt Voluntary Energy Performance Standards

The EcoBUILD program should be extended to commercial properties. The EcoBUILD program has established voluntary guidelines for developers and homeowners for the construction of single- and multi-family homes that use 30% less energy than conventional. According to the Green Building Task Force recommendation: "The statistics indicate, that while the average increase of construction cost associated with building to EcoBUILD standards range from 1.5% to 3%, the average annual energy savings equal to 30%."[2]

In the short-term, education and dissemination programs paired with financial mechanisms can promote voluntary adoption of green building standards in retrofits and new construction. But in the long-term, gradual adoption of green building standards can go a long way.

Maintaining interest and investment in development is important, yet new codes can help correct the market towards more sustainable and affordable options. Gradually adopting mandatory codes based on criteria of affordability is one method that can promote wider adoption of green building standards. Today, energy efficient materials and technologies are becoming more affordable in their upfront costs, and the return on investment period is shorter and shorter. But habits may be difficult to change. An important first step is the education and dissemination of the value proposition green building materials and technologies have. An evaluation of the affordability of 'green' measures against conventional methods should be done in order to determine which codes may be viably adopted and made mandatory.

Target Beneficiaries: Businesses, Institutions, Public Sector

Relevant Organizations: Counties, Municipalities

B. Tax Rebates and Exemptions on Value of Retrofits

Green building retrofits can be incentivized with a 100% tax rebate on the improvement value of a property (the change in value) for a set period of time up to a maximum amount. Sales tax exemptions for green technology use is already in effect in Tennessee but not Mississippi. A tax rebate adds more incentive by including the overall value of a property in its calculation. This also has the added value of illustrating the cost savings and positive effects of green building technologies on real value more generally.

A tax rebate may also require that a certain amount of money be spent on improvements and can outline specific improvements such as solar panel installation, insulation retrofits, etc. Higher incentives could be made by raising the upper limit of the amount of a rebate based on added improvements. There should be an application process for this abatement for homeowners and businesses that requires an inspection of the retrofit improvements for their installation and maintenance before final approval.

Target Beneficiaries: Homeowners, Businesses

Relevant Organizations: Municipalities, Memphis Division of Housing and Community Development, Shelby County Department of Housing

C. TIF District funding for Green Building Retrofits

Tax increment financing (TIF) districts are already employed in the Memphis region. This is a method where local authorities can draw bounded zones for the purposes of directed financing and regulation of each zone for specific purposes—usually for urban renewal and economic development. The local authorities can then sell bonds and use the money to create incentives for targeted actors such as businesses. Future sales or increases in property tax revenue originating from within the TIF district is then used to pay the bonds.

A green building program could be established within a TIF district to incentivize and enable green building retrofits and new construction by directing financing to this activity. The added value of green building retrofits can be a viable means to include in a TIF plan. Leveraging local community organizations in promoting sustainability and resiliency can tie projects with key community goals. Existing districts could also include in their TIF utilization applications green building measures for new and retrofit construction.

Target Beneficiaries: Homeowners, Businesses

Relevant Organizations: EDGE, Community Redevelopment Agency (CRA), Industrial Development Boards

D. Promote Resilience Bonds

Resilience bonds modify the existing catastrophe bond insurance market to capture the savings in insurance premiums due to a lowered risk based on projects that improve building resilience. Resilience bonds use the savings in payments to invest in green building retrofit programs and other resilience infrastructure improvements. This can be used for applications that reduce the risk to buildings in hazard events such as flooding.

Funds can be made available to subsidize cost of flood mitigation measures such as the cost of installing backwater valves and sump pumps on household sewer connections. The City could also create a utility retrofit program that provides incentives for property owners to move mechanical equipment above the DFE.
7.5 Property owners could also upgrade their utilities to smaller more efficient models. See Chapter 7.5 Capital Market Funding.

Target Beneficiaries: Businesses

Relevant Organizations: Municipalities

E. Promote Energy Savings Performance Contracts (ESPCs)

An Energy Savings Performance Contract (ESPC) is a public-private mechanism to fund large-scale energy efficiency retrofits for a variety of users. Owners of properties with large energy usage can hire an Energy Services Company (ESCO) to assist the owner in obtaining financing, installation, operation, and maintenance of building retrofits. ESCOs act as project developers and are federally approved to assume technical and performance risks while implementing retrofits involving on-site energy generation, energy efficiency, and water conservation.

An ESCO can access long-term financing methods such as Tax-Exempt Lease Purchase (TELP) commercial loans or bonds for projects with limited or no up-front costs to the owner. The ESCO enters into an ESPC to implement a green building retrofit. Within this contract, the ESCO pays for most to all of the upfront costs through access to TELP financing and operates under the contractual condition that the cost savings of the new systems will be transferred to the ESCO for a fixed period of time in order to recoup the costs and obtain profit. After this period, the cost savings are fully transferred to the owner. This implementation method is best suited for larger businesses with the capacity to manage larger operations where economies of scale make investing in this form of financing viable.

Target Beneficiaries: Businesses, Public Sector

Relevant Organizations: Counties, Municipalities, Energy Service Companies

F. Finance Microgrids

Microgrids can help shift electricity generation over to more sustainable methods. They are viable systems that can support solar arrays in the event of a grid outage. Microgrids are also much more efficient than conventional transfer stations. This is usually achieved through the use of advanced controllers and software that can monitor and shift energy usage across the system efficiently. It is conventional wisdom that buildings being served by a microgrid also be retrofitted for energy efficiency in support of the entire system.

Energy bonds, tax credits, grants, loans, tax deductions, and credit enhancements from federal and state organizations are all viable financial resources for funding microgrid implementation. Municipalities may also partner with private organizations to supply microgrids.

Investment tax credits (ITCs) and production tax credits (PTCs) are two federal tax credits that may be utilized and cover large-scale energy systems. These tax credits do not offer any direct value to municipalities or tax-exempt organizations but can be utilized in a public-private partnership where a private entity may offer its technical expertise in exchange for the benefits of these tax credits. This arrangement may also include property-tax deductions or exemptions under specific stipulations of the microgrid project. Private financing may also be available in partnerships with public benefit corporations, energy companies, and utilities. For more information on microgrids, see 5.4 Smart Grid. 5.4

Target Beneficiaries: Homeowners, Businesses, Institutions, Public Sector

Relevant Organizations: State, County, Municipalities, Local Utilities

G. Adopt a Property Assessed Clean Energy (PACE) Program

A bill in the Tennessee legislature entitled the "Property Assessed Clean Energy Act" (SB0794)[4] would authorize local governments to establish a property assessed clean energy (PACE) program. Similar bills have been passed by over 35 states throughout the nation. The Tennessee bill enables a local government to implement a Property Assessed Clean Energy (PACE) program:

> "A local government that establishes a program may enter into a written contract with a record owner of real property in a region to impose an assessment to repay the owner's financing of a qualified project on the owner's property. The financing to be repaid through assessments may be provided by a third party or, if authorized by the program, by the local government."[1]

The local government is empowered to identify a local geographical area within their jurisdiction where this program may operate. The PACE program generally works like a "land-secured financing district," which is conventionally referred to as a local improvement district where a local government can issue bonds to fund projects for public benefit. However, this area can also be extended to the entire jurisdiction.

The program is structured to accommodate both residential and commercial property. A PACE program allows a property owner to voluntarily apply for financing for the up-front cost to implement energy efficiency or green improvements on a property. The property owner then pays back the bond over a period of time (between 10 to 20 years) through an assessment of the improved property. These assessments are secured by the property itself and paid as an addition to the owners' property tax bills.

A PACE assessment is a lien that "runs with the land" meaning it is attached to the property as opposed to the property owner, so the obligation is transferred with property ownership over the land. The program will also require dedicated staff and incur administrative expenses. It may not be appropriate for lower-cost investments but is a viable alternative as compared to many private loans.

This sort of financing mechanism can incentivize developers to build with green energy methods in mind as they do not have to incur high up-front costs while foregoing the cost recovery when they sell. It can also provide an incentive for short- and medium-term homeowners by relieving the financial burden that would otherwise take place if they sold the property.

Target Beneficiaries: Homeowners, Businesses

Relevant Organizations: State, Counties, Municipalities

H. Promote the Establishment of a Green Bank in Tennessee

In the long-term, more sustainable financing models should be pursued to reduce reliance on subsidies and incentives for private-investment in energy efficiency and other green retrofits. A Green Bank is a vehicle for funding projects that can reduce overall risk of private investment in support of clean energy and green building retrofits. Green banks can also facilitate market-driven development by providing education to consumers and businesses while connecting a mix of public and private funds to local demand.

Many green banks have been established in the Northeast and West, but an evaluation conducted by researchers at Duke University have concluded that a green bank could help boost clean energy and green investments in the Southeast, including the Memphis metro region.

The essential concept of a green bank is like a local clearinghouse for connecting consumers to financing for energy saving and other green projects. Green banks can also act as an intermediary that can coordinate cross-agency efforts across state and local governments. While the green bank operates at a State level, local support can go a long way in pushing state-level administrators to act. Tennessee has a similar public interest fund that was established by statute called the Tennessee Heritage Conservation Trust Fund. It is tasked to conserve land to promote tourism, protect environmental resources, and provide education to the public.

A green bank can be established by a constitutional amendment, legislative mandate, statute, executive

order, or even by private entities. An example of a fund established by legislature was the Connecticut Clean Energy Fund, established in 2011 by repurposing an existing public fund. In 2016, the legislature created the Connecticut Green Bank that took over operations of the fund and expanded its authority. In some cases a green bank was established through a state agency, such as in New York where the New York Public Service Commission established the New York Green Bank in 2013. This reallocated funding from existing utility-funded programs to the green bank which was established as a division of the New York State Energy Research and Development Authority (NYSERDA). Some funds are established in the private sector. An example of this is The Conservation Fund which was established in 1985 by a group of private individuals that wanted to partner with agencies to acquire land for conservation purposes.

Depending on its method of establishment a green bank can operate as a government-run fund, a quasi-public incorporated entity, or a nonprofit organization. In a government-run fund, the state has the most control over the management of the fund and its objectives. As a quasi-public incorporated entity, a green bank may be subject to a state's requirements and oversight but may operate more independently in terms of its ability to administer financing arrangements, enter into contracts, and assume liability over their own assets. As a nonprofit organization, a green bank must meet federal law and tax requirements, but may be free to access additional funding sources.

There are many funding sources that green banks may draw from. Below are a few key sources:

- *Public Benefit or Infrastructure Fees*
  A surcharge or flat fee on customer energy bills that can be used to fund services and assistance programs. Examples: Connecticut Green Bank, Green Energy Market Securitization (GEMS) program, Energy Trust of Oregon
- *Carbon Tax or Emissions Allowances Sales*
  Utilize carbon pricing or the sales through the Regional Greenhouse Gas Initiative (RGGI) to develop renewable energy capacity. Examples: New York Green Bank, Connecticut Green Bank

Target Beneficiaries: Homeowners, Businesses, Institutions, Public Sector

Relevant Organizations: State, Counties, Municipalities

Case Studies

Mass Save, MA

Mass Save[5] is a collaborative of sponsoring gas and electric utilities and energy efficiency service providers in Massachusetts. The Massachusetts Department of Energy Resources works closely with the sponsors of Mass Save to provide a wide range of services, incentives, training, and information that promotes green energy technologies and energy efficiency for homeowners and businesses.

Mass Save offers energy assessments and a variety of incentives for the adoption of green energy technologies and retrofits in the residential and commercial sector. It offers residential rebates, loans, and incentives for heating and cooling technologies, weatherization methods, energy efficient lighting and appliances, as well as new construction. It also promotes replacement and upgrading of older equipment in the commercial and industrial sectors with rebates and incentives. Funding for these programs is supported from a surcharge on the sponsor's customer energy bills. While MLGW's charter does not allow for customer rebates, many of the other strategies employed by Mass Save could be implemented, and other utilities in the Mid-South may be able to offer customer rebates.

Beth Israel Deaconess Medical Center, a major hospital in the Boston area received a variety of incentives from Mass Save in the upgrading of its HVAC systems. In retrofitting lab spaces to support demand ventilation, it received $321,926 of the total project cost ($644,423) from Mass Save sponsor incentives. This green energy retrofit resulted in around 1.8 million kWh in annual electric savings with a return on investment of 71% (a 1.14 year payback).

(Below and Right) Beth Israel Deaconess Medical Center implemented a green energy retrofit using Mass Save incentives and sponsors

Neighborhood Improvement Program, Chicago, IL

Since 1999, Chicago's Neighborhood Improvement Program (NIP)[6] has been utilizing TIF revenues to reimburse homeowners for repairs and energy efficiency retrofits in certain TIF districts. This program targets homeowners living in single-family residences (1-4 units) earning up to 100% of the area median income (AMI). If a household earns between 100% and 140%, the homeowner must match the grant funding.

The Department of Planning and Development works closely with the Neighborhood Housing Service (NHS) which processes the grant applications and provides additional technical assistance to homeowners in scoping, contracting, and overseeing repair work.

Today, nearly 25 NIPs exist throughout the city. Grants range from around $12,500 for one unit residences to $30,050 for four units. The grants are used for general home repairs but include energy efficiency retrofits such as: providing barriers to air sealing the home, replacing boilers or furnaces with high-efficiency models, and installing roof and wall insulation.

In 2016, over $5 million in home repair grants were approved in six TIF districts.

For more information on local promotions and incentives for energy retrofits in different cities see publications by the American Council for an Energy-Efficient Economy.[7]

Example for Single Family Program (1-4 Units)

	Base Maximum	Allowance for Air Sealing	Allowance for Roof Insulation	Energy Efficient Boiler or Furnace	Maximum Grant Amount
1 Unit	$12,500	$1,850	$1,500	$1,000	$16,850
2 Unit	$17,500	$2,400	$1,500	$1,000	$22,400
3 Unit	$20,000	$3,000	$1,500	$1,000	$25,500
4 Unit	$22,500	$3,550	$3,000	$1,000	$30,050

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1 See a breakdown of energy consumption for Memphis and Tennessee at: *Electricity Local*, Website, last accessed February 8, 2019, https://www.electricitylocal.com/states/tennessee/memphis/.

2 Green Building Task Force, *Final Recommendations Report*, (2012), https://www.sustainableshelby.com/sites/default/files/resources/Green Building Task Force Final 6-12-12.pdf.

3 Memphis-Shelby County Office of Sustainability, *Climate Action Plan for for Memphis and Shelby County* (2018), https://www.memphisclimateaction.com/.

4 "Property Assessed Clean Energy Act," SB794, Amendments to TCA Title 4, Chapter 5; Title 5; Title 6 and Title 68.

5 For more information see: Mass Save Website, https://www.masssave.com/.

6 "Tax Increment Financing-Neighborhood Improvement Program (TIF-NIP)," *City of Chicago*, Website, https://www.cityofchicago.org/city/en/depts/dcd/supp_info/tax_increment_financing-neighborhoodimprovementprogramtif-nip.html.

7 American Council for an Energy-Efficient Economy. "Goals, Incentives, and Requirements for Energy Efficient Buildings." Accessed February 8, 2019. https://database.aceee.org/city/requirements-incentives.

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4

Land Planning

4.1 Resilient Sites

Incorporate Site Resilience Factors into Land Planning Decisions

Key Benefits

1	**Coordinates local planning and regional resilience planning efforts**
2	**Provides a collaborative planning mechanism to guide investment, regulation, and planning generally**

Limitations

1	**Current mechanism for enforcement is limited to discretionary review processes**

Overview

The inherent attributes of a site determine its resilience status. We can, therefore, make zonal distinctions across the entire region based on geographic and biophysical site conditions. Generalized, high-level zonal categorization of land can be useful for broad-based planning coordination for resilience purposes. While large-scale categorizations should not be used for local zoning, they can be a useful for informing local government approvals processes in accordance with regional resilience priorities. For instance, proposing high-level zonal categorization of land assets can help local governments coordinate their efforts for mutual benefit by guiding development.

This recommendation is open-ended. The process by which the proposed zonal categories are constructed is outlined to illustrate how key spatial categories of risk and resilience can inform generalized planning principles according to zonal distinctions. This process should be modified with respect to both local conditions and evolving regional priorities. Government organizations should not use this as a zoning tool, but as a framework to inform larger planning efforts with reference to other recommendations found within this document.

(Right) Aerial photograph of Shelby Farms Park. Source: Shelby Farms Park Master Plan 2008

Resilience Zone Framework

The map to the right categorizes all land within the Mid-South according to its resilience attributes. It is analogous to traditional zoning, but instead of land use categories, the Resilience Zone Framework organizes areas based on their disaster risk and resilience assets.

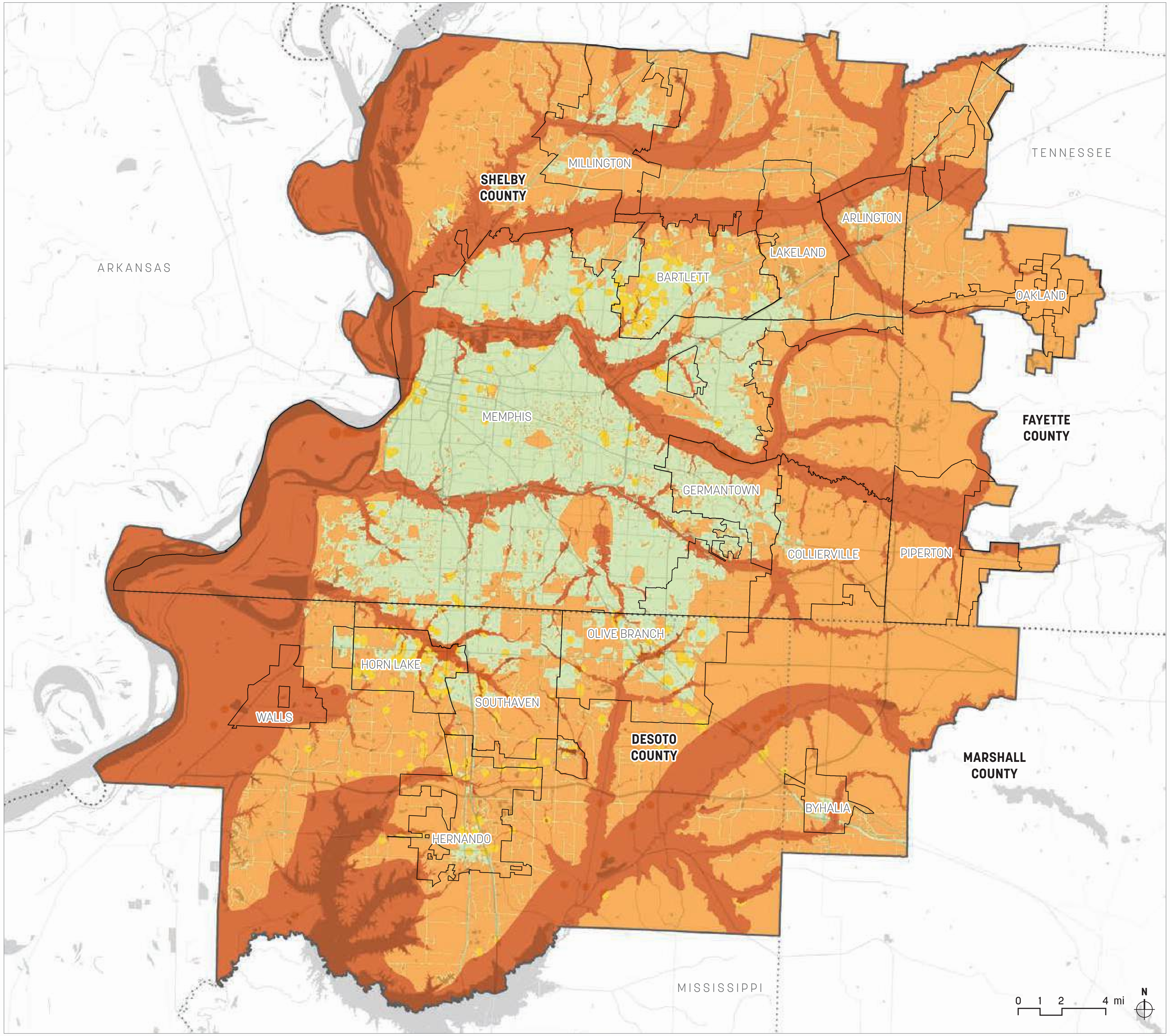
Zone Key

	Zone Details
	Zone 1 areas, in green, have the lowest level of development risk and conflict. These areas avoid high risk disaster zones, such as floodplains, and they also do not conflict with sensitive ecological areas. These areas are the most straightforward for development and would have the lowest impact on regional resilience.
	Zone 2 areas, in yellow, have risks that can be mitigated with enhanced infrastructure. This includes areas with known localized flash flooding and/or insufficient storm drainage. Developing in Zone 2 is risky, but the risk can be mitigated.
	Zone 3 areas, in orange, contain resilience assets that could be compromised by certain kinds of development. These assets include wetlands, forests, meadows, and aquifer recharge areas. The loss of these assets makes the entire region less resilient. Context sensitive development could still occur in these areas to minimize its impact.
	Zone 4 areas, in red, are located in high risk areas, namely riparian corridors and floodplains. Development in these locations is directly at risk for flooding. Although these risks could be mitigated through the construction of major flood control infrastructure, it is generally advisable to avoid these areas for future development whenever possible.

One technical note is that when more than one condition is present, the location receives the highest number zone for which it would qualify. For example, if it has wetlands (Zone 3) and is in the floodplain (Zone 4), it would be designated as Zone 4. Similarly, if it had insufficient storm drainage (Zone 2) and was also in the aquifer recharge zone (Zone 3), it would be designated as Zone 3.

The Framework, as presented, uses the best available data at the time of publication. As more and better data becomes available—for example, additional areas with localized flooding—the spatial model would need to be adjusted. This Framework is therefore meant to be modified and extended, and for it to be used to its fullest benefit, it would need to be updated both as new information becomes available and as planners identify additional threats that are specific to their local communities.

The Resilience Zone Framework is useful for at least two purposes: 1) land planning, and 2) discretionary development review. Future comprehensive land planning efforts could apply the Framework as an additional lens through which to evaluate highest and best use for designating future land use plans. In the development approvals process, a tool such as this could be used to identify potential resilience issues and inform subsequent mitigation requirements and impact off-sets. In both cases, the Framework is meant to be helpful by providing information and organizing spatial data—it is not meant rigidly to restrict or promote development in any specific location. In essence, it answers the question, "what are the resilience considerations present at this location?"



Planning Framework

Development Planning

Zone 1: Low Risk / Impact Expected

Consider existing general development and zoning restrictions with consideration for low-impact site design and compact development typologies.

2.3 4.2

See: 2.3 Low-Impact Development, 4.2 Smart Growth

Zone 2: Potential Impacts to Infrastructure

Consider impact of new and existing development on localized flooding. Consider discretionary review process to mitigate runoff and utilize potential development to mitigate areas of flood risk.

See: 2.3 Low-Impact Development, 3.1 Floodproofing Buildings, 4.2 Smart Growth, 5.2 Drainage Systems

2.3 3.1 4.2 5.2

Zone 3: Moderate and Regional Risks Requiring Mitigation

Areas within Zone 3 are more sensitive to increasing development. Consider strategic investment in ecological assets through revitalization and preservation. Additional development considerations should be made to consider impacts on local and regional hydrology and to mitigate drainage impacts.

See: 2.1 Large-Scale Water Detention, 2.2 Watershed Conservation, 2.3 Low-Impact Development, 2.4 Open Space Strategies, 5.2 Drainage Systems

2.1 2.2 2.3 2.4 5.2

Risk Management

Zone 4: High-risk Hazard Exposure

High risk areas that pose more immediate threats are identified in Zone 4 at present. Consider development restrictions in these zones, as well as measures to mitigate exposure to hazards.

See: 1.1 River and Stream Restoration, 1.2 Flood Barriers, 2.1 Large-Scale Water Detention, 3.1 Floodproofing Buildings, 3.2 Earthquake Resilient Buildings, 4.3 Flood Smart Development

1.1 1.2 2.1 3.1 3.2 4.3

The above decision tree illustrates the levels of increasing risk exposure and potential impacts that new and existing development might have within each zone. Higher-level zones incorporate risk and impact considerations within lower zones in a cumulative manner.

Planning in zones 1 through 3 should incorporate the protection of ecological assets while balancing the promotion of low-impact site design and compact development typologies in appropriate areas.

Higher risk zones, such as Zone 4, consider direct exposure of risks from hazards such as flooding and earthquakes. Thus, considerations for Zone 4 should manage risk much more directly due to the potential impacts on health and safety.

Implementation

This implementation of this form of zoning classification is a function of the scale of jurisdiction and relative power regional organizations have with regard to both policy and economic considerations. Land categorization in terms of resilience at this scale functions as a high-level planning tool. It should, therefore, not be used as a local zoning tool. Its usefulness lies as a method of planning coordination in local government approvals processes in accordance with regional resilience priorities. While the categorization presented on previous pages is constituted by four zones, this four-level configuration could be subject to expansion based on future emerging resilience considerations, priorities, and data. Planning at both the regional scale and at the local level should also begin to refine the parameters of these resilience zones based on local conditions and priorities. Within this framework, there are two major categories of governance and planning elaborated upon below.

Municipal/County Government

Planning should consider promoting LID and compact development typologies in Zone 1 and 2 with consideration to flood mitigation as noted previously. Larger jurisdictions may be more willing to enforce discretionary review processes for sensitive Zones 2 and 3. Areas within Zone 3 might require closer inspection but should prioritize ecological protection and revitalization more broadly. The consideration of strict limitations on development within Zone 4 is also recommended due to the risk exposure to health and safety.

Small Town and Rural Governments

These categorizations should be used as a guide for mitigation of risk where new development is pursued in Zones 1 through 3 with increasing diligence. Efforts should be made to protect and further prevent development within Zone 4 for the purposes of mitigating risk exposure to health and safety.

Update and Management Process

7.1

A process should be put in place for regular coordination between regional entities and local governments involved with resilience planning. Local and regional planners should also take care to adjust zones according to new data available. For instance, Zone 2 includes local flooding data but is incomplete. See 7.1 Resilience Database for more information on this.

Resources

"Resilient Zoning." Wetlands Watch online. Last accessed February 4, 2019. http://wetlandswatch.org/resilient-zoning/.

National Oceanic and Atmospheric Administration, US Climate Resilience Toolkit: https://toolkit.climate.gov/topics/built-environment/planning-and-land-use. (Accessed February 4, 2019)

"Land Use Solutions for Colorado." *Planning for Hazards* online. (Last accessed February 4, 2019). https://planningforhazards.com/resilience-planning.

Green, Shelby D., "Zoning Neighborhoods for Resilience: Drivers, Tools and Impacts," 28 Fordham Envtl. L. Rev. 41 (2016), http://digitalcommons.pace.edu/lawfaculty/1080/.

4.2 Smart Growth

Encourage Compact and Infill Development

Key Benefits

1	Reduces impervious surfaces by limiting sprawl
2	Protects critical ecological land cover
3	Diversifies choice in housing stock and physical environment
4	Reduces energy consumption

Limitations

1	Current market may not support affordable building typologies
2	Higher density may mean higher reliance on transit access

Overview

Land use and development patterns have a major impact on regional resilience. This dynamic is somewhat under-discussed but is closely linked with issues such as flooding.

The encouragement of compact and infill development through smaller block sizes and transit-supportive density can redirect growth within key urban areas and limit expansion of sprawl and impervious cover. This can reduce the potential over-extension of resources across larger areas and help to prevent encroachment onto sensitive or hazard-prone areas, such as areas in the floodplain. This should also be accomplished by protecting natural flood protection features such as wetlands and stream buffers.

New typologies should be encouraged in areas that are not prone to flooding and are otherwise less physically vulnerable. This includes the promotion of a mix of uses, the improvement of public spaces to promote walkability, and the expansion of transit options, all while prioritizing infill development, cluster subdivision, and other mid- to high-density patterns. Effective policy tools can be used to regulate and encourage new development of this kind.

(Right) Sprawling neighborhoods increase the amount of impervious cover which may intensify the damage of flooding. Houston, TX, in 2017 after Hurricane Harvey.

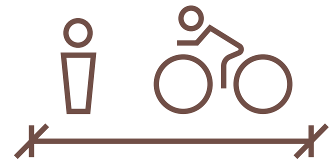
Principles of Compact Development

1 Promote Mixed-use Zones and Diversity in Choice

Identify key central areas and nodes to promote mixed-use development to support the growth of amenities and commerce

Develop new standards for mixed-use districts in key areas of development away from vulnerable areas such as those prone to flooding.

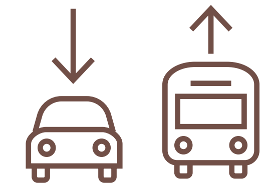
A mix of uses can help build resilience capacity and social cohesion by concentrating amenities and uses that can be mutually beneficial in the adaptation to the many stressors faced by communities as well
7.4 as promote resilience in times of recovery (See 7.4 Prioritize Investment in Vulnerable Communities). Mixed-use areas can also cultivate diversity in choice for residents. These may improve the potential social cohesion in a neighborhood through the networks made between residents, tenants, and business owners—improving the social (and material) resources available in times of need.



2 Update Dimensional Codes to Promote Walkability

Update street and building dimensional codes in key areas to make them more attractive for pedestrian and commercial activity

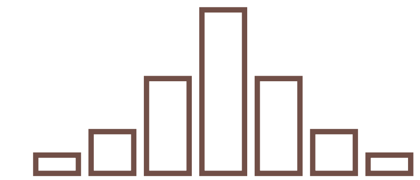
The dimensions of streets, sidewalks, setbacks, and other open spaces are important in fostering a sense of safety, recreation, aesthetics, and in accommodating important uses such as commercial frontage. In areas where improved walkability is desired, wide streets should be made thinner where viable, with more pedestrian space, more frequent cross walks, bike lanes, and areas for building frontage can help to activate an area in support of compact development types. This can make an area more attractive for both living, working, and retail that is mutually supportive of transit and higher-density development.



3 Strategically Reduce Parking Requirements and Promote Transit

Improve transit use by concentrating development in key areas with reduced parking requirements and promoting connection to walkability and transit

Outside of accommodating those without cars, transit ridership and walkability are related to the allocation of parking. High parking requirements can limit the amount of space that can be dedicated to other uses, such as for residential and commercial. It can also be nonviable where no direct revenue can be made from its inclusion. Strategically consolidating parking areas to the periphery of areas of densification can allow for more compactness in the type of urban development within a target area. Within this, transit use and walkability standards can be promoted, improving the overall viability of a transit system which, in turn, can encourage more compact development and commercial activity.



4 Increase Density in Central and Key Areas

Promote higher-density development types in key areas while preserving open space in sensitive or otherwise hazard-prone areas

Increasing the allowable density in areas that are less risk-prone can redirect development pressure away from peripheral areas that encroach upon open space or natural flood protection features such as wetlands and stream buffers. This also helps to cultivate a diversity of choices for residential living. Areas that might benefit from further densification include key transit/transportation intersections to support growth, a diverse mix of uses, and already existing density—particularly in town or city centers.

A common misconception is that higher density development means more impervious cover, less greenspace, and therefore worse flooding. On a site scale, this can be effectively mitigated through water capture, filtration, storage, and flood mitigation strategies (see Chapter 2.3 on Low Impact Development). At the regional scale, higher densities result in less impervious area per person and more protected large tracts of undeveloped open space, all of which benefit regional hydrology and make the region more resilient.

Existing Development Typologies

Below are several selected typologies that reveal certain patterns or potential for compact development for resilience capacities. In many existing development typologies, surface parking is a consistent factor. While it is difficult to reduce parking space, assessments should be made to understand the utilization of surface parking lots. In areas where density may be desirable, this area could be targeted for compact development policies while strategically relocating parking to other sites.

Commercial Corridor

1-3 story, Building

Many commercial buildings along major corridors have high requirements for parking on each site. This takes up a lot of area for impervious cover along important routes.

Downtown Patchwork

1-3 story, Office/Retail

Large areas of surface parking make up Downtown and Midtown Memphis where a patchwork of commercial buildings punctuate the concrete.

Light-industrial Town

1-2 story, Logistics/Storage Facilities

Many smaller towns in Shelby and DeSoto counties have a loose urban framework but have several major intersections with a sparse mix of industrial and commercial uses.

Single-Family House

1-2 story, Single Homes

The predominant development typology in the Memphis metropolitan area is the single-family house.

Multifamilty Low-rise

1-2 story, Planned Unit Development

Many large-scale developments such as the planned unit development type incorporate buildings with a series of attached units with some common open space.

Multi-family Mid-rise

3-6 story, Development Block/Infill

In recent years, this type of development has been preferred for its compactness and its complimentarity with standards of walkability and relatively mixed-use neighborhoods. Built in more compact neighborhoods, this type may also reduce overall need for parking.

Multi-family High-rise

7+ story, Tower

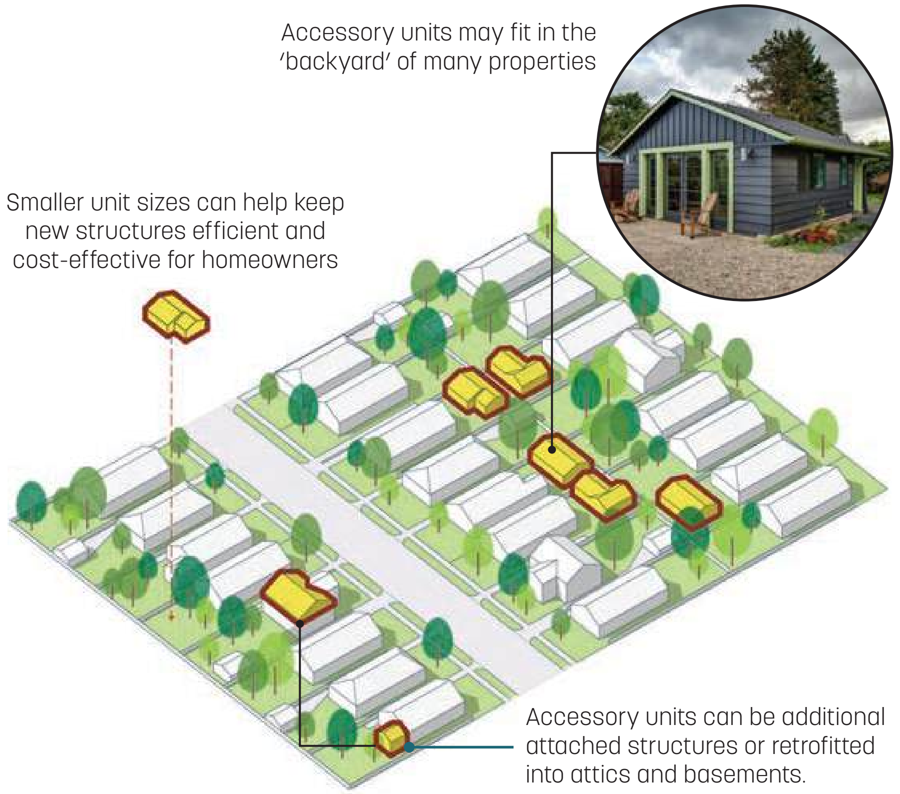
High-rise types are effective in supporting higher density living but are less desirable outside of the city center, and many models have failed to integrate into nearby neighborhoods effectively. However, if built in more compact neighborhoods, this type may also reduce overall need for parking.

Compact Development Typologies

Accessory Units

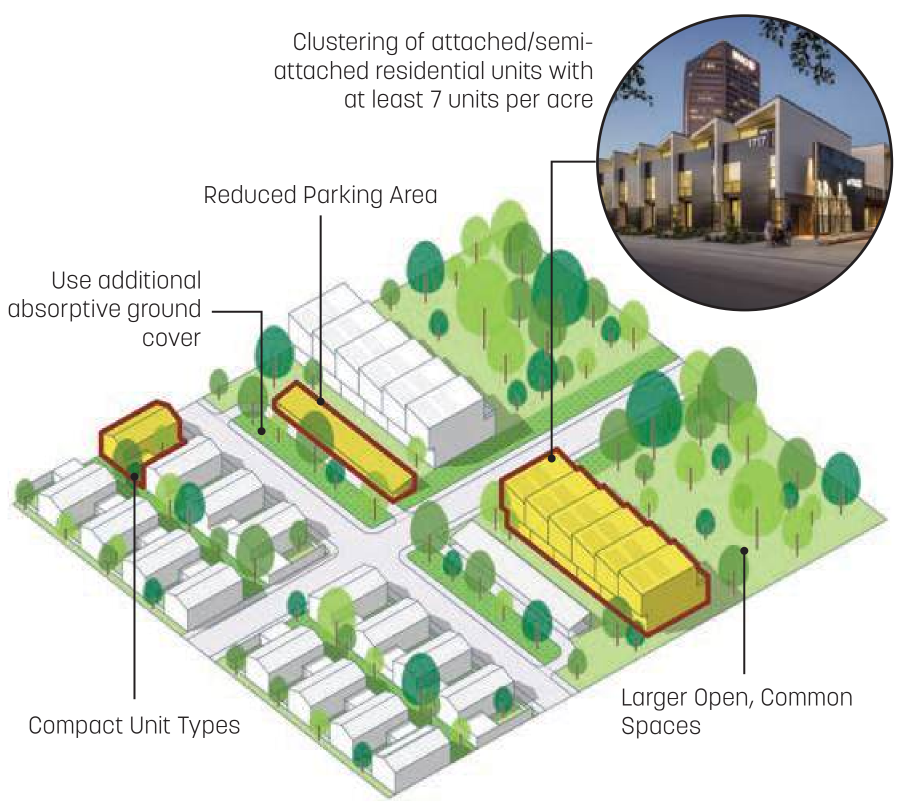
Accessory Units can be enabled by code and built by property owners themselves. This should be promoted in key areas of reduced risk and built with standards of minimal impact to ground conditions. These are currently allowed subject to certain conditions in the Memphis and Shelby County Unified Development Code.[1] This typology can help improve resilience in a few ways:

- Creates units in areas that are already built out, reducing expansion of impervious areas at the periphery
- Supplies homeowners with additional income from rent
- Enables renters to 'plug-in' to a neighborhood's network in the event of emergencies



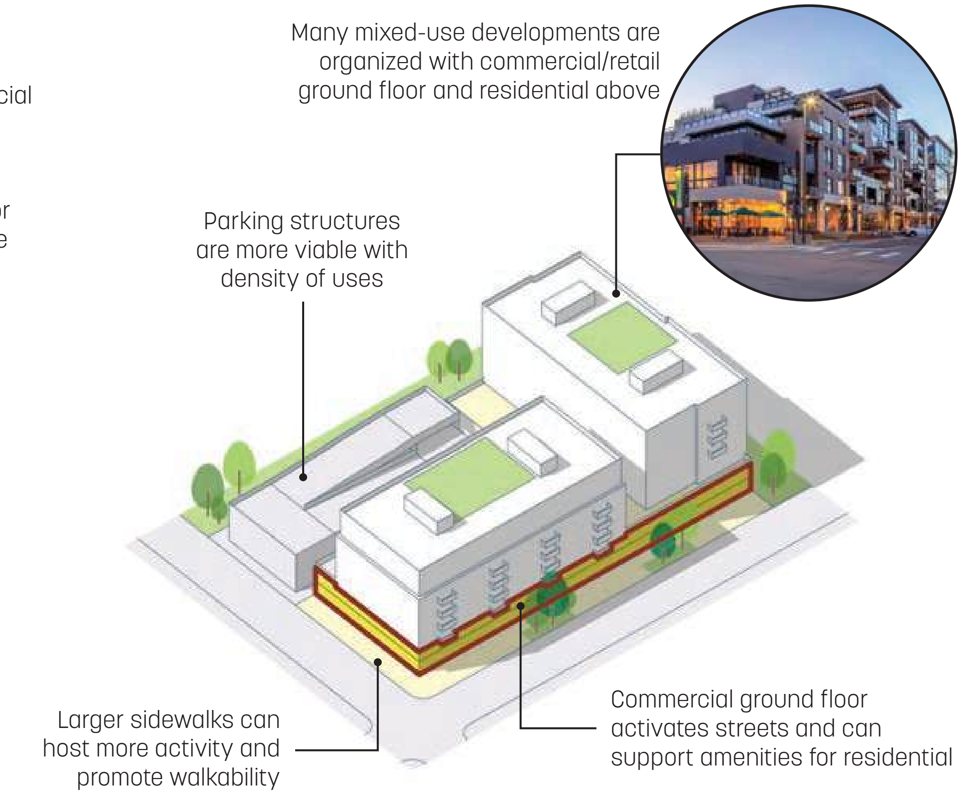
Cluster (PD) Development

Revise Planned Development (PD)[2] standards to emphasize attached development typologies to maximize compactness and open space preservation. This should include higher floor/height limits in addition to increasing the amount of shared open space and permeability. Limit or prevent PUDs on ecologically sensitive or risk-prone areas.



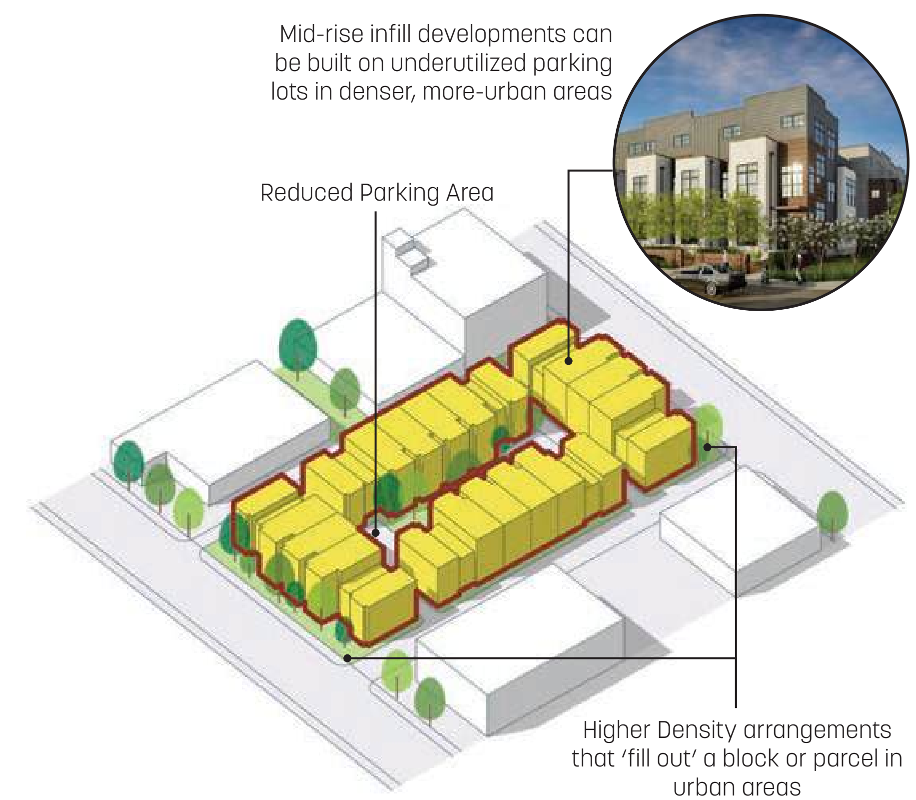
Mixed-use

Mixed-use usually contains a mix of multi-family residential with commercial uses and amenities. Mixing uses can be achieved within one building vertically – with commercial/retail ground floor and residential above, or horizontally with a mix of uses on the same parcel or in close proximity.



Multifamily Infill

Promote the continued development of mid-rise multifamily typologies in key areas near central places like Downtown and Midtown. Lower parking ratios can be achieved where transit infrastructure is provided, significantly lowering the amount of impervious coverage not utilized by residential uses.



Programs and Initiatives

Existing Initiatives

EDGE, Residential Payment-in-Lieu-of Tax Program Tax (PILOT)

Economic Development Growth Engine (EDGE) may grant payment-in-lieu-of-tax (PILOT) incentives for new residential developments built with 25 units or over. The PILOT program also includes provisions for low and moderate-income accommodations.

Economic Development Growth Engine (EDGE), Project Database, http://database.growth-engine.org/.

Memphis 3.0

Built on public input, Memphis 3.0 planning focuses on "anchoring growth around the City's core and areas of high activity" to promote neighborhood connection and compact growth. Through its outreach it has developed Community Character plans, and a Comprehensive Plan for implementation in 2019.

Memphis 3.0, Website, http://www.memphis3point0.com/.

Metrics for Compact Development

LEED for Neighborhood Development

Neighborhood Pattern and Design Prerequisites

LEED compact development encourages residential components at a density of at least seven dwelling units per acre and nonresidential components at a density of 0.50 or higher floor-area ratio (FAR) for the available land, with higher densities within walking distance of transit service.

STAR Community Rating Program

Built Environment Objective 3: Compact & Complete Communities

The community should achieve thresholds for residential and nonresidential density, diverse uses, public transit availability, and walkability. Demonstrate that plans and policies support compact, mixed-use development. Identify areas appropriate for compact, mixed-use development on the future land use map. At the time of writing, STAR is merging with the US Green Building Council (USGBC) resulting in the replacement of the STAR Community Rating Program with LEED for Cities and Communities in 2019.[3]

Implementation Methods

Policy tools are the most effective ways of encouraging compact and infill development. These tools may range from modification to city-wide ordinances to zoning overlays within existing codes. These policies should target key areas for compactness, while preserving areas with important natural landscape functions.

Policy Method	Relevant Organizations	Pros	Cons
4.3.1 Unified Development Code	Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities	• Comprehensive • Unifies regulatory approval	• Requires significant organizational change
4.3.2 Form-Based Code or SmartCode	Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities	• Targets building typology and density • Promotes mixed-use	• Additional regulatory considerations
4.3.3 Transit-Oriented Development (TOD)	Memphis EDGE, Memphis Area Transit Authority (MATA), Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities	• Multiple, compounding benefits for transit and commerce • Promotes mixed-use	• Less viable in areas without light rail • May require additional investment to implement
4.3.4 Design Guidelines	Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities	• Easier to implement piecemeal	• May need additional regulatory enforcement or incentives
4.3.5 Zoning Overlay	Memphis EDGE, Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities	• Flexible • Fits within existing regulatory framework	• May not significantly promote mixed-use

4.3.1 Unified Development Code

A unified development code consolidates all regulations, including zoning, subdivision regulations, design and development standards, and review procedures. It is generally more comprehensive than separate codes or ordinances but may eliminate overlap or inconsistency in requirements by keeping all review and approval procedures in one place.

Memphis and Shelby County's Unified Development Code may be a good reference for other governments in the region.[4] This code should also serve as the foundation for further regulatory mechanisms to promote smart growth strategies.

Relevant Organizations

Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities

Other Examples

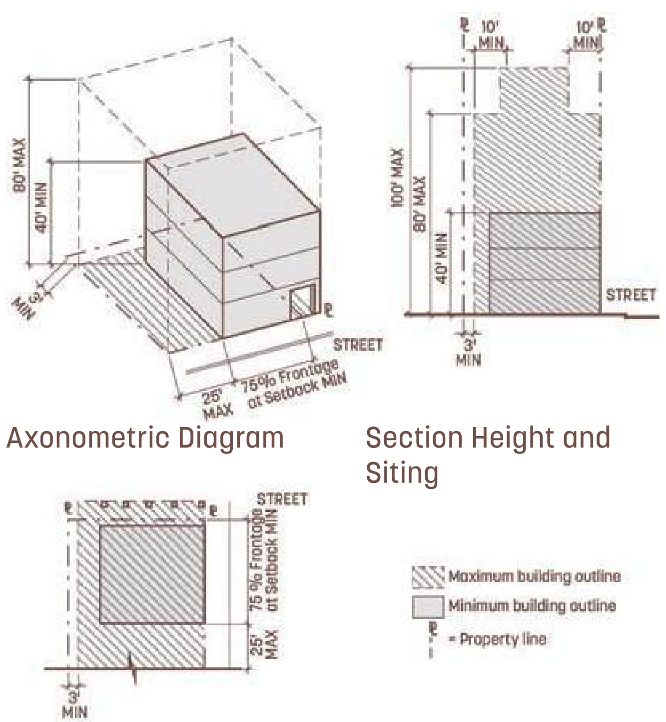
Durham, North Carolina, Unified Development Ordinance, (2006), http://durhamnc.gov/414/Unified-Development-Ordinance-UDO.

San Antonio, Texas, Unified Development Code Chapter 35 City Code, https://library.municode.com/tx/san_antonio/codes/unified_development_code

4.3.2 Form-Based Code or SmartCode

A form-based code differs from conventional zoning by outlining specific urban and building formal characteristics rather than focusing on use. Form-based code can encourage a more integrated approach to development rather than by separating land uses. Formal characteristics may be comprised of: height, bulk, setbacks, built-to lines, frontage, and typologies, including those that apply to both public spaces and buildings. This type of code can be applied through specific area plans or a city-wide code.

Form-based Code Example



Axonometric Diagram

Section Height and Siting

Plan Width and Siting

Key

Adapted from Knoxville, Tennessee, Form Based Development Code: Regulations for Designing the South Waterfront, (2007)

Area Plans

Area form-based plans set dimensional and form-based regulations within a designated zone—regulating development only within the designated zone, allowing development outside to continue to refer to the broader ordinance.

Relevant Organizations

Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities

Examples

Arlington County, Virginia, Columbia Pike, (2003), http://www.ferrell-madden.com/Columbia_Pike.php.

Knoxville, Tennessee, Form Based Development Code: Regulations for Designing the South Waterfront, (2007), https://archive.knoxmpc.org/zoning/swaterfront/fb_code.pdf.

Peoria, Illinois, Form-Based Code, Phase II of Heart of Peoria Plan, (2007), https://library.municode.com/il/peoria/codes/code_of_ordinances?nodeId=CO_APXAUNDECO_6.0FODI_6.5WADI

City-Wide Code

A city-wide form-based code applies to the entire jurisdiction and may require modification to the existing regulatory codes. A more comprehensive type of development code, the SmartCode, can provide further regulatory guidance to encourage a diversity of uses and building types by using a zoning procedure that breaks up zones according to the urban transect, or by use intensity. The SmartCode addresses the physical forms of the buildings and public spaces while offering a dynamic way to promote mixed-use development typologies of various densities while coordinating across transportation needs and environmental performance.

Relevant Organizations

Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities

Examples

Gulfport, Mississippi, SmartCode, (2007), http://www.mississippirenewal.com/documents/Post_Gulfport_SmartCode.pdf.

Leander, Texas, SmartCode, (2005), http://www.growsmartri.org/training/Municipal%20Examples%20for%20Form-Based%20Zoning/Leander%20TX%20SmartCode%208-02-05.pdf.

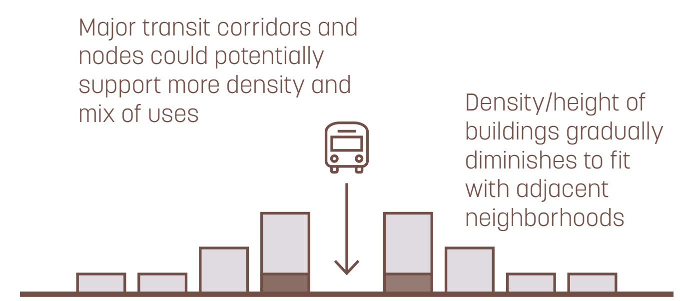
Montgomery, Alabama, Traditional Neighborhood Development Overlay SmartCode (2006), http://www.montgomeryal.gov/home/showdocument?id=129.

St. Lucie County, Florida, Form-Based Code, (2006), http://formbasedcodes.org/codes/st-lucie-county-towns-villages-countryside.

4.3.3 Transit-Oriented Development (TOD)

Many higher-density developments benefit from access to transit. To sustain compactness, this may also mean a reduction in area for parking. In the case of Transit-Oriented Development (TOD), higher-density mixed-use typologies are promoted where transit options exist or are planned. This type of development promotes walkability, a rich mixture of land uses, and can accommodate a range of demographics reflecting a general opportunity to support affordable housing. This type of development does not prohibit the use of cars—but reduces the amount of space available for

TOD Concept



cars to promote access to public transit. Reduction in area for parking is one of the major ecological benefits of a TOD project.

Promotion of TODs is usually confined to specific geographic areas where transit 'hubs' may be established. It extends a certain distance (usually within a 5 to 10-minute walk) where the density promoted decreases gradually away from a key intersection or transit 'node.' High- to Mid-rise developments are usually promoted that incorporate a variety of uses so that it can support additional residential units as well as draw in the population of neighboring areas with retail and office.

By concentrating development along transit nodes and away from sprawling areas, measures for resilience can also be more economically distributed and transit infrastructure can be utilized more effectively when needed. Compact building types and decreased reliance on the automobile also reduce the total energy consumption of a community, resulting in lower cost burdens. Higher-density structures and increased access to transit may also support a potentially higher degree of social cohesion—an improved capacity of a community to withstand shocks and stressors due to the shared nature of dwelling.

Relevant Organizations

Memphis EDGE, Memphis Area Transit Authority (MATA), Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities

Examples

Atlanta, GA, MARTA Transit Oriented Development, (2010), https://www.itsmarta.com/uploadedFiles/More/Transit_Oriented_Development/TOD%20Guidelines%202010-11.pdf.

4.3.4 Design Guidelines

Design guidelines are a set of standards addressing certain aspects of building and public-space such as building facades, preservation of historic character, landscaping standards, lighting, crosswalks, accessibility standards, on-street parking, bicycle lanes, etc. These are guidelines that establish how streets, pedestrian ways, and open spaces work together with development to promote walkability and integration of neighborhoods. Sections of the UDC include design guidelines[5] for streetscapes but can be expanded to accommodate compact development standards across a larger territory. Design guidelines may also be paired with TOD development by helping to promote transit use through the improvement of walkability in areas of reduced parking demand.

Relevant Organizations

Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities

Examples

Memphis and Shelby County Unified Development Code, (2010), http://www.shelbycountytn.gov/DocumentCenter/View/13413/ZTA-13-002-Complete-UDC-as-approved.

Mountainview, CA, Residential Guidelines, Rowhouse Design Guidelines and R4 Multifamily Standards, (2005), https://www.mountainview.gov/depts/comdev/planning/regulations/zoning/zoning.asp.

4.3.5 Zoning Overlay

The promotion of compact development can be done by utilizing existing tools such as zoning overlays that alter some of the regulations. Much of the newer zoning codes may relate to suburban development patterns, resulting in larger setbacks and the promotion of lower-density development types. A zoning overlay can address key areas where more compact urban fabric is desired.

Relevant Organizations

Memphis EDGE, Shelby County Division of Planning and Development, DeSoto County Planning Commission, Municipalities

Examples

Nashville, Tennessee, Metro Zoning Code, Urban Zoning Overlay, (2006), https://www.municode.com/library/tn/metro_government_of_nashville_and_davidson_county/codes/

Case Studies

Sustainable Design and Energy Efficient Development (SEED), Keene, NH

The Sustainable Design and Energy Efficient Development (SEED) overlay zone in Keene, NH, promotes compact development and energy efficiency.[6] It is the product of much planning to improve the resilience of Keene in the face of climate change and persistent dangers of flooding.

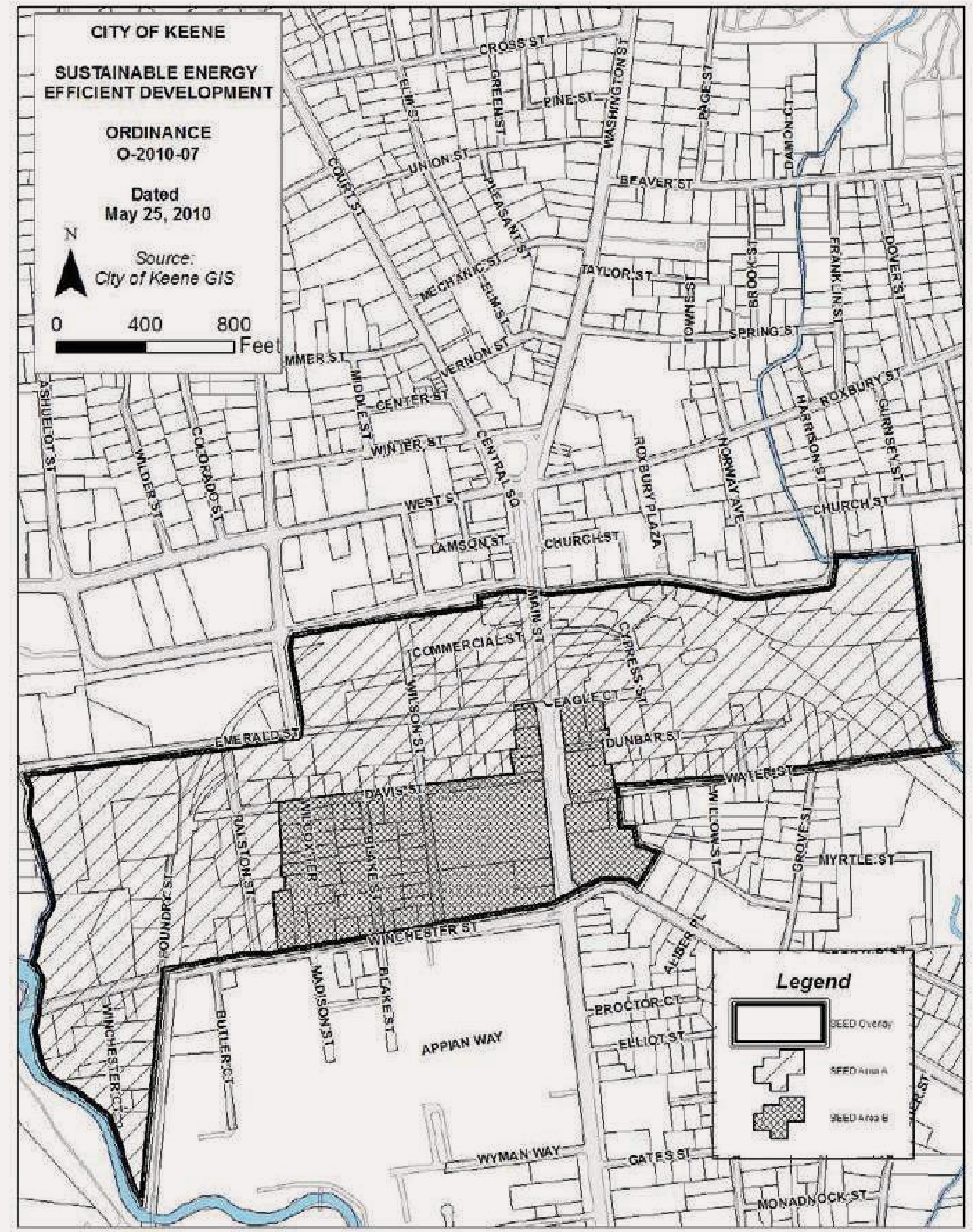
In 2005, Keene, NH, received more than 11.5 inches of rain in less than 48 hours. The rain caused Keene's streams to overflow, leaving some homes flooded under seven feet of water.

In response to the floods and other observed climate change effects, Keene, working with ICLEI–Local Governments for Sustainability to develop a Climate Adaptation Action Plan, which was approved in 2007.[7] The plan presented land use planning and design recommendations to reduce the city's vulnerability to extreme weather events. The city then began to institutionalize adaptation efforts throughout all departments' operations.

In 2009, the city adopted an ordinance for low-impact development (LID) site plan regulations to lessen stormwater impacts. Following this, in 2010, Keene incorporated climate change issues in its comprehensive master plan.[8] It encourages infill development to bring more amenities downtown and protect open space for flood mitigation.

The same year, the city created the Sustainable Design and Energy Efficient Development (SEED) overlay zone to promote downtown redevelopment. The SEED zone covers an area around the city's core. Within this area, new construction is incentivized to meet certain national green building standards with reduced parking requirements, more height, and higher density. Overarching goals were adopted within the SEED plan to reduce sprawl and promote infill development / redevelopment. This includes:

- Developing areas that have infill or redevelopment potential
- Adopting smart growth principles
- Revising conservation subdivision regulations
- Incentivizing infill development in areas within the City that have been identified as being at low risk for flooding



Transit-Oriented Development, Atlanta, GA

With the Atlanta region population expected to grow by 2.5 million by 2040, it is investing in existing infrastructure in order to curb sprawl and promote regional resilience through compact development. TOD projects center on providing additional housing choice including affordable options with higher transit accessibility. Since 2014, the Metropolitan Atlanta Rapid Transit Authority (MARTA) has been planning and constructing TOD projects at key transit hubs.[9] It is seen as a way to generate more revenue for MARTA while supporting local community development and regional economic development.

In 2016 Atlanta passed two referenda to expand the MARTA bus and rail lines and a sales tax increase to improve Atlanta's transit and network of parks while promoting transit-oriented development projects. This effort is supported by the TransFormation Alliance (TFA), a partnership of 17 government agencies, businesses, and nonprofits that includes MARTA.[10] This strategic partnership ensures that the various organizations' combined efforts are managed cohesively to promote regional development.

(Below) Edgewood/Candler Park Station TOD by MARTA.

(Above) Planned TOD development led by MARTA near the Avondale station in Decatur.

(Right) Planned TOD development led by MARTA near the King Memorial station.

Endnotes

1 See *The Memphis and Shelby County Unified Development Code, 2.7.3 Accessory Dwelling Units*, (2010): 46, http://www.shelbycountytn.gov/DocumentCenter/View/13413/ZTA-13-002-Complete-UDC-as-approved.

2 Ibid., *4.10 Planned Development:* 230.

3 STAR Communities, "STAR's Merger with USGBC," accessed May 30, 2019, http://www.starcommunities.org/star-updates/faqs-star-leed-for-cities/.

4 *The Memphis and Shelby County Unified Development Code*, (2010): 68-232, http://www.shelbycountytn.gov/DocumentCenter/View/13413/ZTA-13-002-Complete-UDC-as-approved.

5 See *The Memphis and Shelby County Unified Development Code, Articles 3 and 4*, (2010): 68-232.

6 City of Keene, New Hampshire, "Energy and Climate Committee," https://ci.keene.nh.us/energy-and-climate-committee.

7 City of Keene, New Hampshire, *Climate Adaptation Action Plan*, (2007), https://ci.keene.nh.us/sites/default/files/Boards/CCP/Keene%20Summary%20Report_ICLEI_FINAL.pdf.

8 City of Keene, *Code of Ordinances, Chapter 102, Article XIII*, (2010), https://library.municode.com/nh/keene/codes/code_of_ordinances?nodeId=PTIICOOR_CH102ZO_ARTXIIISUENEFDEOV.

9 MARTA, "TOD Overview," https://www.itsmarta.com/tod-overview.aspx.

10 Kim, Michael, "Throughout Atlanta, an array of transit-connected MARTA development is rolling," Curbed, (January 30, 2018), https://atlanta.curbed.com/2018/1/30/16945328/marta-transit-oriented-developments-status-check.

Resources

General

Smart Growth online. http://smartgrowth.org/

Smart Growth Fixes for Climate Adaptation and Resilience. Document number EPA 231-R-17-001. U.S. Environmental Protection Agency, 2017. https://www.epa.gov/sites/production/files/2017-01/documents/smart_growth_fixes_climate_adaptation_resilience.pdf.

Essential Smart Growth Fixes for Urban and Suburban Zoning Codes. U.S. Environmental Protection Agency, 2009. https://www.epa.gov/smartgrowth/essential-smart-growth-fixes-communities.

"Project Database." *Economic Development Growth Engine* (EDGE) online. http://database.growth-engine.org/.

Unified Development Code

Durham, North Carolina. *Unified Development Ordinance*. 2006. http://durhamnc.gov/414/Unified-Development-Ordinance-UDO.

San Antonio, Texas. *Unified Development Code Chapter 35 City Code*. https://library.municode.com/tx/san_antonio/codes/unified_development_code.

Form-based Code and SmartCode

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Knoxville, Tennessee. *Form Based Development Code: Regulations for Designing the South Waterfront*. 2007. https://archive.knoxmpc.org/zoning/swaterfront/fb_code.pdf.

Peoria, Illinois. *Form-Based Code, Phase II of Heart of Peoria Plan*. 2007. https://library.municode.com/il/peoria/codes/code_of_ordinances?nodeId=CO_APXAUNDECO_6.0FODI_6.5WADI

Gulfport, Mississippi. *SmartCode*. 2007. http://www.mississippirenewal.com/documents/Post_Gulfport_SmartCode.pdf.

Leander, Texas. *SmartCode.* 2005. http://www.growsmartri.org/training/Municipal%20Examples%20for%20Form-Based%20Zoning/Leander%20TX%20SmartCode%208-02-05.pdf.

Montgomery, Alabama. *Traditional Neighborhood Development Overlay SmartCode*. 2006. http://www.montgomeryal.gov/home/showdocument?id=129.

St. Lucie County, Florida. *Form-Based Code.* 2006. http://formbasedcodes.org/codes/st-lucie-county-towns-villages-countryside.

Design Guidelines

Mountainview, CA. R*esidential Guidelines, Rowhouse Design Guidelines and R4 Multifamily Standards*. 2005. https://www.mountainview.gov/depts/comdev/planning/regulations/zoning/zoning.asp.

Zoning Overlay

Nashville, Tennessee. *Metro Zoning Code, Urban Zoning Overlay*. 2006. https://www.municode.com/library/tn/metro_government_of_nashville_and_davidson_county/codes/code_of_ordinances?nodeId=CD_TIT17ZO_CH17.36OVDI_ARTXIIURZOOVDI.

4.3 Flood Smart Development

Exceed the minimum requirements of the National Flood Insurance Program

Key Benefits

1	**Reduces flood damage**
2	**Preserves high functioning open space**
3	**Protects life and safety**

Limitations

1	**Increases cost of development**
2	**Reduces land available for development**
3	**Raises cost of enforcing development regulations**

Overview

All of the communities in the Mid-South participate in the National Flood Insurance Program (NFIP). The NFIP offers federally-subsidized flood insurance to individuals in a participating community, helping to protect families from major financial loss due to flooding. To participate in the NFIP, a community must adopt minimum building and zoning ordinances that reduce future flood risks to new construction within the Special Flood Hazard Area (SFHA).

Communities can opt to enact additional flood-protection measures that exceed the minimum requirements of the NFIP. The benefits of exceeding NFIP's minimum requirements are twofold. First, more stringent flood risk reduction measures reduce the risk to health and safety and the loss of personal effects and property. Second, the additional flood risk reduction activities can help flood insurance policy-holders in the community lower the cost of their premiums through participation in the Community Ratings System (CRS). This section provides recommendations for activities that exceed the NFIP minimum requirements, which may be implemented together or in isolation.

(Right) The City of Fort Collins restricted floodplain development along the Poudre River after a series of devastating floods.

Background

Exceeding the minimum requirements of the NFIP will offer significant additional financial protection for a community. The NFIP allows for a maximum coverage of $250,000 for a single family home, covering both building and contents. This is rarely enough to compensate homeowners in the event of a total loss, encouraging owners in the riskiest areas to rent their properties to tenants. A tenant's personal property is not covered by an owners' policy, and a tenant may not know to buy flood insurance or may not be able to afford to do so.

Additionally, after a flood that leads to a substantial loss, owners must rebuild to current building codes, which often require more expensive construction than was previously in place and would not be covered by the NFIP claim (supplemental insurance exists for these instances, but it is not mandated).

Finally, while meeting the minimum requirements of the NFIP is mandated, national compliance varies region to region. The Midwest has the lowest compliance rate in the country at 43%.[1] The most frequently cited reason for non-compliance is the high cost of the flood insurance premiums. Exceeding the minimum requirements of the NFIP enables a community to participate in the CRS program, effectively lowering flood insurance premiums for residents which may increase compliance (though this would not change the $250,000 maximum flood insurance coverage offered by the NFIP). Today, the City of Hernando in Mississippi is the only Mid-South community that participates in the CRS.

To join the CRS program, a community must complete an application, adopt a resolution of intent to participate and cooperate with FEMA, and adopt a floodplain management ordinance that meets or exceeds the minimum NFIP criteria:

1. Require permits for development in the SFHA.
2. Require elevation of the lowest floor of all new residential buildings or substantially improved buildings in the SFHA to, or above, base flood elevation.
3. Restrict development in the regulatory floodway to prevent increasing the risk of flooding.
4. Require certain construction materials and methods that minimize future flood damage.

Tennessee's State NFIP Coordinator provides model ordinances for communities that meet the minimum NFIP criteria, shared on the Tennessee Association for Floodplain Management website. The Mississippi Emergency Management Agency Floodplain Management Bureau provides the same.

Many recommendations on the following pages would provide additional physical protection regardless of participation in the CRS.

Community Rating System

The Community Rating System (CRS)[2] is a program sponsored by the National Flood Insurance Program (NFIP). Communities that participate in the National Flood Insurance Program can elect to participate in the CRS. Participating communities earn credits for additional flood prevention or hazard mitigation activities that exceed the requirements of the NFIP. At certain credit thresholds, residents of participating communities are entitled to discounts on their flood insurance premiums. The CRS program has two main benefits: it reduces flood insurance premiums for individual residents and it encourages implementation of flood risk mitigation activities.

In 2017, 4,662 residents in the region paid over $3 million for flood insurance premiums. This yielded over $1.3 billion in insurance coverage. Shelby County residents paid nearly two thirds of the premium costs, and Memphis residents were responsible for approximately half of that, or just over $1 million. Full participation in the CRS as a Class 1 community could reduce flood insurance premiums for residents in the region by 45%, saving over $1 million annually, though this level of participation is atypical for most participating communities.

Requirements

A participating community must have authority from the state to adopt and enforce regulations for that area. For example, Shelby County could apply to participate, but reductions in flood insurance premiums would only apply to policy holders in unincorporated Shelby County, not policy holders in the City of Memphis. Smaller municipalities which may be unable to undertake the CRS process on their own, due to administrative or cost burdens, can sign a Memorandum of Understanding with one or more neighboring municipalities to consolidate the administration of the program.

To participate in the Community Rating System, a community must first designate someone as the official CRS Coordinator. In an area with low population and little growth, this role can usually be assumed by a current employee. In larger population areas or areas that are growing quickly, FEMA recommends hiring or appointing a designated CRS Coordinator. The designated CRS Coordinator would then commence the CRS application process.

Flood Insurance Discounts for Property Owners in CRS Communities

Rate Class	SFHA Discount	Non-SFHA Discount	Credit Points Required
1	45%	10%	4,500+
2	40%	10%	4,000 - 4,499
3	35%	10%	3,500 - 3,999
4	30%	10%	3,000 - 3,499
5	25%	10%	2,500 - 2,999
6	20%	10%	2,000 - 2,499
7	15%	5%	1,500 - 1,999
8	10%	5%	1,000 - 1,499
9	5%	5%	500 - 999
10	0%	0%	0 - 499

Application Process

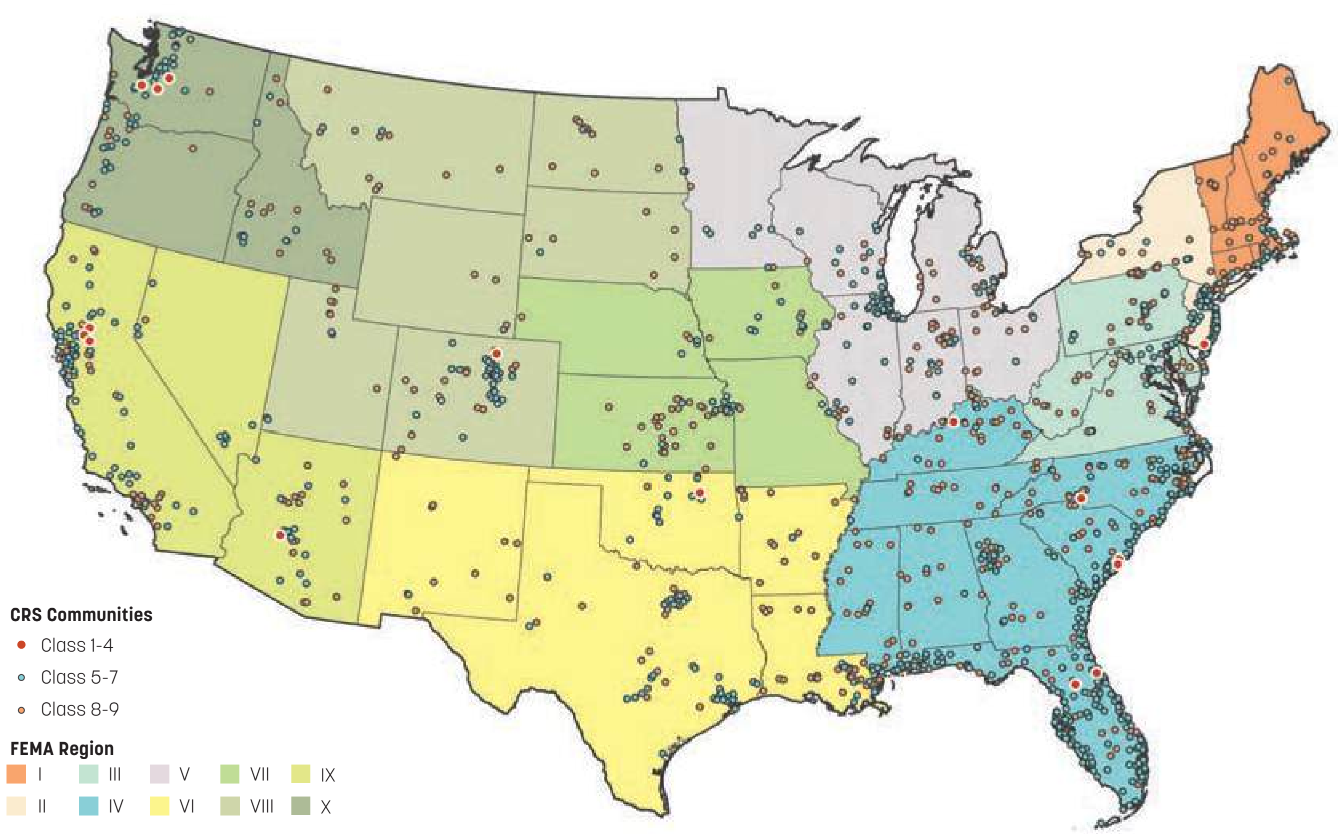
Flood risk mitigation activities that count toward credits for the CRS program are identified within the National Flood Insurance Program Community Rating System Coordinator's Manual. They largely fall within four categories: Public Information, Mapping and Regulation, Flood Damage Reduction, and Warning and Response. Individual activities range in capital cost from relatively low (advertising the availability of Floor Insurance Rate Maps) to capital intensive (elevating or relocating buildings in the floodplain). Activities are designed to protect insurable properties, and thus credit is not given for flood risk mitigation projects that protect infrastructure or land.

The CRS "Quick Check" tool can help a community evaluate existing regulations and ordinances that are eligible for CRS credits. So long as a community is in full compliance with NFIP rules and regulations, the community can apply to participate in the CRS.

The application process entails several steps:

1. Community submits letter of interest showing implementation of activities earning at least 500 credits. Communities with less than 500 credits would be eligible only for Class 10, which offers no flood insurance premium discounts and is the default designation for communities that participate in NFIP but do not participate in CRS.
2. The application must be approved by FEMA's regional office, confirming that the community is in full compliance of NFIP regulations.
3. An ISO CRS Specialist schedules a verification visit to review all community activities that could deserve credit, beyond the activities identified in a community's original submittal. After the visit, the ISO specialist submits the findings to FEMA, and FEMA sets the CRS credit to be granted. This establishes the community's classification (and effective flood insurance premium discount rate).

National Flood Insurance Program (NFIP) Community Rating System (CRS) October 2018



Adapted from "Community Rating System" FEMA online

Potential Credits Available for Existing Activities

Existing state regulations in Mississippi and Tennessee would automatically provide 20 and 25 credits, respectively, for participating communities. The CRS has also identified possible additional credits that may be in effect for communities within the region (100 for Mississippi and 91 for Tennessee). Model ordinances have been developed in order to minimize the legislative burden for smaller communities; adoption of these ordinances would also automatically provide communities with CRS credits (between 338-447 credits in Mississippi). If participating communities in Mississippi were eligible for all of the possible additional credits identified by the CRS and adopted the state-drafted model ordinance, residents could achieve a Class 5 rating and receive discounts on flood insurance premiums of up to 25%.[34]

	Activity	Summary	Tennessee	Mississippi
Uniform Minimum Credit	Activity 340	Other Disclosure Requirements	15	10
	Activity 450	Erosion & Sedimentation Control	10	10
		Total	25	20
Possible Additional Credit	Activity 340	Disclosure of Other Hazards	33	33
	Activity 450	Water Quality	20	20
	Activity 630	State Dam Safety	0-38	0-37
	Activity 410	Cooperating Technical Partnership Agreement		10
		Total	**53-91**	**63-100**

4.3.1 Avoidance

Avoidance describes flood mitigation strategies that prevent flood damage by preventing risky situations from happening altogether. This is typically done through a combination of regulatory control (prohibiting risky behavior) and education (helping people understand risky behavior).

Preserve Open Space in the Floodplain

Guarantee that currently vacant parcels in the floodplain will be kept free from development by prohibiting the construction of occupiable structures in the SFHA. This will avoid risking additional property damage, the health and safety of occupants and rescue workers, and infrastructure and utilities.[5]

Require Development Permits in the Floodplain

Prevent cut, fill, grading, storage of materials, stream crossings, and building activities from taking place in the floodplain without a permit, including by government agencies not typically subject to building permits.[6]

Make Flood Protection Information Public and Accessible

Increase public awareness through outreach projects and hazard disclosures. Provide flood protection information through public library and community websites, including insurance information and physical interventions. Provide flood protection assistance by giving inquiring property owners technical advice on how to protect their buildings from flooding, and publicize this service.[7] See 7.2 Outreach for more information. 7.2

Create a Community Flood Database

Keep flood and property data on computer records, using high quality basemaps, and maintain elevation reference marks.[8] See 7.1 Resilience Database for more detailed information. 7.1

Construct Critical Facilities Outside the Floodplain

Critical facilities and access to critical facilities should be constructed or established outside of the SFHA and Community Flood Hazard Area (CFHA), or elevated and protected to or above the 0.2% chance flood level.

4.3.2 Managed Retreat

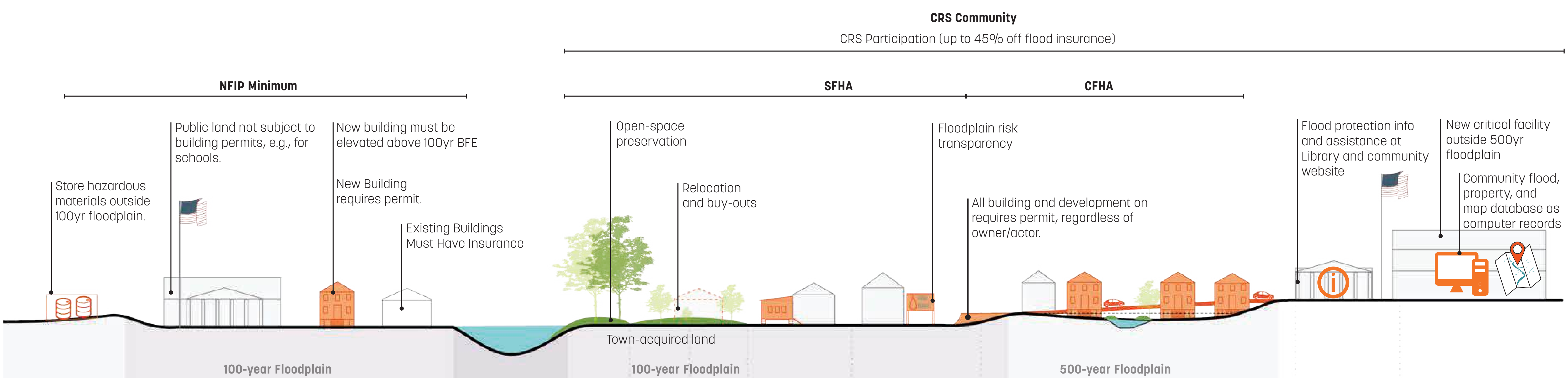
Managed Retreat describes a flood adaptation strategy that involves moving at-risk assets out of harm's way in a controlled manner. Through management, it is possible to avoid individuals from experiencing windfalls (at the expense of someone else), or wipeouts (for situations that may have been beyond their knowledge or control).

Buyouts and Relocations

Acquire buildings located in the SFHA from voluntary sellers and demolish the buildings to restore the parcel to open space. Alternatively, relocate buildings sited
6.1 in the SFHA to locations outside of the SFHA.[9] See 6.1 Voluntary Buyouts for more detailed information.

Establish a Community Flood Hazard Area (CFHA)

Designate areas determined by the community to be subject to periodic inundation by floodwaters, but are not part of the SFHA on the community's Flood Insurance Rate Maps (FIRMs), to be designated as CFHAs and held to the same standards as SFHAs.[10]



4.3.3 Accommodation

Accommodation refers to strategies that allow at-risk assets to remain in place in a safer manner through minor interventions, but do not include attempts to stop flooding or inundation.

Require Substantially Damaged Properties to Mitigate

Require substantially damaged properties to mitigate (elevate or relocate) after a flood. Elevation mitigation must be accompanied by a deed restriction that prohibits subsequent conversion of enclosed areas subject to flooding. If property owners choose not to mitigate, they must sign a Memorandum of Understanding (MOU) that they will not receive additional financial assistance after the next storm and that infrastructure and utility service will not be maintained in the area. Substantial damage shall be aggregated and tracked by percent damaged for a minimum of 10 years.[11]

Elevate Additions Above Base Flood Elevation

Require additions to an existing structure in the SFHA be elevated above base flood elevation, even if it isn't considered a substantial improvement.[12] See 3.1 Floodproofing Buildings for more information.

3.1

New Development Must Not Impact Stormwater Flows

All new proposed development, including all subdivisions (no exceptions for size), must submit an engineering study to show that post-development runoff is no worse than pre-development runoff.[13]

Require Dry Egress From All Floodplain Sites

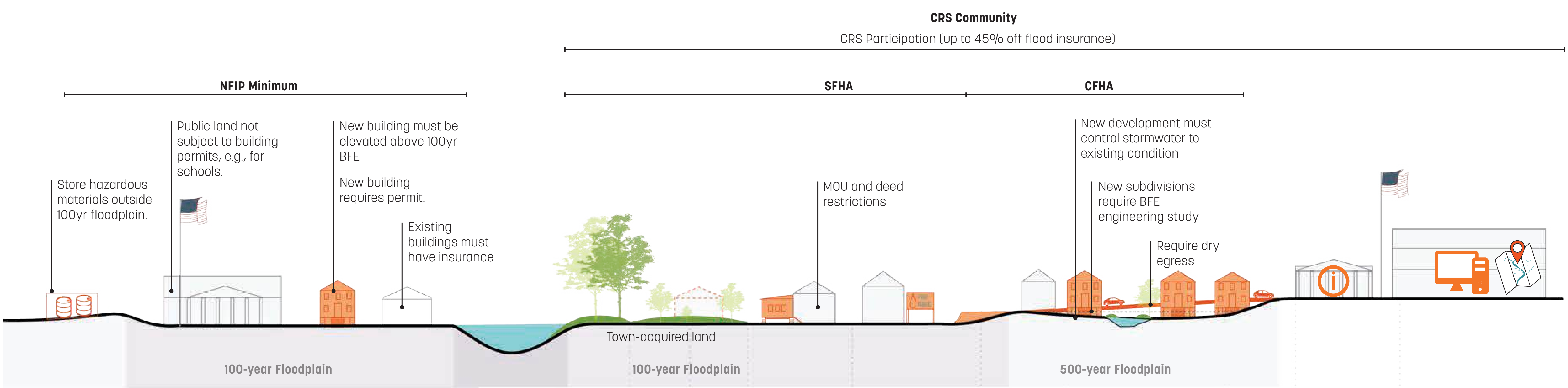
Require new development located in the SFHA or CFHA, to the maximum extent practical, to have walkways and driveways on land at an elevation greater than the base flood elevation.[14]

New Development Must Not Be Below Base Flood Elevation

All new proposed development, including all subdivisions (no exceptions for size), must submit engineering study to show finished floor elevations above the Base Flood Elevation (BFE) of a 1% annual chance event.[15]

List of Acronyms Used

Acronym	Definition
BFE	Base Flood Elevation
CFHA	Community Flood Hazard Areas
CRS	Community Ratings System
FIRM	Flood Insurance Rate Map
MOU	Memorandum of Understanding
NFIP	National Flood Insurance Program
SFHA	Special Flood Hazard Area



Implementation

Most of the methods described in this section would be implemented through changes to local zoning codes, building or development codes, or stormwater management policies. The specific amendment process will vary across individual communities, but would follow the same process as other amendments to the relevant documents in each community. Some of the recommendations appear in more detail in other chapters of the report; please see referenced sections for more information on implementation. For other recommendations, some key considerations, potential partners, or additional resources that may be useful have been identified.

Preserve Open Space in the Floodplain

A key consideration in the preservation of open space in the SFHA is the identification of allowed uses for existing undeveloped parcels in the floodplain that are presently zoned for more intense uses. Potential uses for these parcels include agricultural uses that do not affect stormwater flows, open space recreation areas, timber production, or hunting. These may offer opportunities for private revenue-generation and tax collection, and would help mitigate the loss of value for privately held, undeveloped land in the SFHA. Potential partners include conservancies, local, state, or the federal government, farmers, and timber companies.

Make Flood Protection Information Public and Accessible

7.2 See 7.2 Outreach for more detailed information.

Create a Community Flood Database

7.1 See 7.1 Resilience Database for more detailed information.

Construct Critical Facilities Outside the Floodplain

A change to the local zoning code, creating a floodplain overlay district that aligns with the 500-year floodplain and prohibits critical facilities, could deter the development of privately-owned critical facilities such as hospitals and some utilities in the 500-year floodplain. Publicly-owned critical facilities, such as police stations, fire stations, or state and federal facilities, are generally not required to comply with local zoning ordinances. However, it is in the public interest to site critical facilities outside the floodplain in order to ensure continuity of services in the event of a flood.

In the instances where critical facilities must be constructed within the floodplain, because of a water-dependent use or inability to provide adequate service coverage from a location outside the floodplain, all needed utilities and buildings should be constructed in a resilient manner. See 3.1 Floodproofing Buildings for more detailed information. 3.1

Buyouts and Relocations

See 6.1 Voluntary Buyouts for more information. 6.1

Require Development Permits in the Floodplain

An amendment to the local building code would extend permitted activities to include all development: cut, fill, grading, storage of materials, stream crossings, and building activities. These activities would require a permit, including by government agencies and for activities not typically subject to building permits. Permit issuance could be contingent upon proof that the development activities will have no impact on flood levels beyond the parcel in question.

Establish a Community Flood Hazard Area (CFHA)

Implementation of this recommendation would be initiated by a Floodplain Administrator or other qualified official. The designated person would use technical studies, historical information, or other existing or commissioned information to officially define the CFHA boundaries in order to protect the community in that area from flooding.

The process for establishing the CFHA should include a public engagement process in order to allow the community to provide input into areas of frequent flooding.

See 5.1 Critical Facilities and 6.1 Voluntary Buyouts for more information on local flood prone sites. 5.1 6.1

Require Substantially Damaged Properties to Mitigate

A key consideration in requiring substantially damaged properties to mitigate after a flood is the existence of complementary programs that provide options for property owners. Successful implementation of this recommendation will avoid windfalls (where building owners receive insurance payouts that exceed the value of their property over time), or wipeouts (where building owners are divested of the financial equity they held in their property prior to the flood).

A complementary buyout or relocation program offers property owners the chance to relocate from a property in the floodplain to a comparable property outside the floodplain. More information about the implementation of a buyout program can be found
6.1 in 6.1 Voluntary Buyouts. If non-financial reasons tie a property owner to the floodplain parcel, they are permitted to stay at their own financial cost, transferring the financial risk of future flooding from the public to the private owner. More information about this can be found in the Vicksburg, Mississippi Memorandum of Understanding Case Study on the next page.

Elevate Additions Above Base Flood Elevation (BFE)

Implementation of this recommendation would follow the local process for amendments to the local building
3.1 code. See 3.1 Floodproofing Buildings for more detailed information.

New Development Must Not Impact Stormwater Flows

Implementation of this recommendation would follow the local process for amendments to the local
2.3 building code. Please refer to 2.3 for more detailed information.

Require Dry Egress From All Floodplain Sites

Implementation of this recommendation would follow the local process for amendments to the local building code. Model language for this requirement is available in the 2013 Guide for Higher Standards in Floodplain Management.

New Development Must Not Be Below Base Flood Elevation

Implementation of this recommendation would follow the local process for amendments to the local building code.

Case Study

Memorandum of Understanding, Vicksburg, MS

The City of Vicksburg, Mississippi has been implementing a voluntary home buyout program as part of its flood resilience program. Between 1990 and 1993, the city orchestrated the buyouts of over 75 homes in an established neighborhood.

More recently, it has been challenging for the City to conduct home buyouts following a flood. This is in part due to changes to federal buyout programs which take longer to finalize. Many families are able to repair their homes before a buyout can be arranged, making the return to their home a more appealing short term option that leaves them vulnerable to future flooding in the long term. Many families also occupy homes that have been in their families for generations, so have emotional connections to the property that supersede their perceived risk.

To address this issue, the City enacted a Flood Plain Damage Prevention Ordinance. After a flood event, City staff work with individual homeowners to determine if substantial damage has been done, also considering the 10-year damage history of the home. Once a property has been considered substantially damaged, the ordinance requires the homeowner mitigate through demolition, relocation, or elevation before a Certificate of Occupancy is issued. This means that homeowners cannot occupy their homes until the mitigation has occurred without risking their homeowners insurance or incurring fines or other penalties imposted by the local jurisdiction.

If a homeowner is unwilling or unable to mitigate, they may sign a Memorandum of Understanding acknowledging that they are in violation of the ordinance and article 1316 of the National Flood Protection Act. This means they are ineligible for flood insurance or other assistance following a flood. At this point, homeowners are then issued a Certificate of Occupancy. This allows families to stay in their homes, while transferring the financial risk of flooding from the City to the individual homeowners.

For this effort, the City is receiving credit towards the Community Ratings System program, lowering flood insurance rates city-wide.

For further information about the Vicksburg, Mississippi case study, see the Association of State Floodplain Managers' Flood Science Center website.

(Below) Satellite image of Vicksburg before program in 1994.

(Below) Satellite image of Vicksburg after program in 2018.

MEMORANDUM OF UNDERSTANDING BETWEEN _______ AND THE MAYOR AND ALDERMEN OF THE CITY OF VICKSBURG

THIS Memorandum of Understanding (AMOU@) is intended to document the intention of the Mayor and Aldermen of the City of Vicksburg (ACity@) to authorize the release of the electricity, water and gas utilities to the undersigned property owner(s) ("Owner(s)") at _________________, Vicksburg, Warren County, Mississippi, subject to the following understanding:

WHEREAS, Owner(s) herein acknowledge(s) and confirm(s) that the undersigned is/are all Owner(s) of fee simple title in the real property located at ________________, Vicksburg, Warren County, Mississippi, and bearing PPIN ____________, and;

WHEREAS, in the __________ of 20___ there occurred in Warren County, Mississippi, a riverine flood within the Mississippi River watershed which encompassed the property located at ______________, Vicksburg, Warren County, Mississippi, and;

WHEREAS, as a result of the _________ of 20____ flood, the City performed a damage analysis on the above described property and determined that substantial damages of fifty percent

(50%) or greater had occurred at the residence in the riverine flood event of 20____ wherein Owner(s) was/were eligible for benefits pursuant to the National Flood Insurance Act and in accordance with the City ordinance, Owner(s) would have to comply with the ordinance by elevating the structure or removing the structure, and;

WHEREAS, it is the intention of the City pursuant to Chapter 1 of the International Building Code to release the electrical, water and gas utilities to Owner(s) at the above described structure for the sole and only purpose of performing repairs that do not require a building permit, also referred to as Anon permitted repairs@ as said term is defined in Chapter 1 of the International Building Code, and;

WHEREAS, pursuant to the City Flood Plain Damage Prevention Ordinance, it is agreed by the parties herein that Owner(s), upon release of the utilities as set forth above, can enter upon the property to perform non permitted repairs but Owner(s) cannot, and is/are not authorized by this Memorandum to occupy or allow any other person or persons to occupy the structure described above unless and until the flood hazard at the above described address is mitigated by one of the following events:

1. Participation in a flood buyout program.
2. Elevate the structure to the required height.
3. Remove or relocate the structure to comply with required height.

WHEREAS, in the event Owner(s), before mitigation, shall or does/do occupy or allow others to occupy the structure described above, there will be a citation filed against Owner(s) by the City in Municipal Court pursuant to the City Flood Plain Ordinance and thereafter a request by the City to MEMA/FEMA for a denial of flood insurance for the structure located at ____________, Vicksburg, Mississippi, pursuant to the National Flood Insurance Act, Section 1316, and;

WHEREAS, in the event Section 1316 of the National Flood Insurance Act is invoked as to Owner(s) and the property described above, it is acknowledged, understood and agreed that one or more of the following may occur:

1. The property may be difficult or impossible to sell.
2. The market value of the property may fall.
3. The cost of suffering flood damage without insurance may be too great a risk for the property owner(s).
4. Lending institutions holding the property=s mortgage may threaten to foreclose.
5. Any permanent reconstruction will be denied disaster relief.
6. The Owner(s) will be ineligible for any insurance claim or disaster relief.

WHEREAS, if the Owner(s) does/do not occupy the property but allows others to occupy the structure, Owner(s) hereby agree(s) and is/are required to disclose to the person(s) occupying the structure that said structure is in the Flood Plain and susceptible to flooding.

WHEREAS, the Owner(s) herein is/are required and does/do agree to give immediate notice of this MOU to any current or future tenant and to the Director of Inspection.

WHEREAS, this MOU incorporates the entire understanding and agreement between the City and Owner(s) and supersedes all prior understandings and agreements between the parties, whether oral or written, with respect to the subject matter hereof and is not binding on any future City Administration as it relates to the Flood Plain Management Ordinance.

SO ENTERED, UNDERSTOOD and AGREED this, the _____day of______ 20____.

CITY OF VICKSBURG	**OWNERS:**
______________________________	______________________________
BY: name of attorney	
	______________________________

Endnotes

1 *National Flood Insurance Program (NFIP), Community Rating System (CRS): A Local Official's Guide to Saving Lives, Preventing Property Damage, and Reducing the Cost of Flood Insurance*. Document number FEMA B-573. (Federal Emergency Management Agency: 2015).

2 Horn, Diane p. and Brown, Jared T. *Introduction to the National Flood Insurance Program (NFIP)*." Document number CRS Report for Congress, R44593. (Congressional Research Service: 2018), 12.

3 CRS Resources, "CRS Uniform Minimum Credit Mississippi" (2014), http://crsresources.org/files/200/umc/mississippi.pdf.

4 CRS Resources, "CRS Uniform Minimum Credit Tennessee" (2014), http://crsresources.org/files/200/umc/tennessee.pdf.

5 National Flood Insurance Program Community Rating System Coordinator's Manual, 420.

6 Ibid, 510.

7 Ibid, 330.

8 Ibid, 320.

9 National Flood Insurance Program Community Rating System Coordinator's Manual, 520.

10 Mississippi Emergency Management Agency, Floodplain Management Bureau. "Model 'B' - 'E' Flood Damage Prevention Ordinance." (2011).

11 Mississippi Emergency Management Agency, Floodplain Management Bureau. "Model 'B' - 'E' Flood Damage Prevention Ordinance." (2011).

12 Ibid.

13 National Flood Insurance Program Community Rating System Coordinator's Manual, 500.

14 A Guide for Higher Standards in Floodplain Management (2013).

15 Mississippi Emergency Management Agency, Floodplain Management Bureau. "Model 'B' - 'E' Flood Damage Prevention Ordinance." (2011).

Resources

"Memorandum of Understanding Helps Vicksburg Facilitate Buy-outs of Repetitive Loss Properties." *Association of State Floodplain Managers Flood Science Center* online. Last accessed Dec 10, 2018. https://www.floodsciencecenter.org/products/crs-community-resilience/success-stories/vicksburg-mississippi/.

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"CRS Uniform Minimum Credit Tennessee." National Flood Insurance Program Community Rating System (NFIP/CRS), January 2014. Available at http://crsresources.org/files/200/umc/tennessee.pdf.

"Community Rating System." *Federal Emergency Management Agency* online. Last modified December 11, 2018. https://www.fema.gov/community-rating-system.

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National Flood Insurance Program Community Rating System Coordinator's Manual. Document number OMB 1660-0022 and FIA-15/2017. Federal Emergency Management Agency, 2017.

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5 Infrastructure

5.1 Critical Infrastructure Planning

Create Critical Facilities Protection Plans

Key Benefits

1. **Mitigates hazard risk by protecting vulnerable systems**
2. **Enhances post-disaster response capacity**
3. **Improves baseline infrastructure functions**

Limitations

1. **Cannot mitigate underlying development patterns that are challenging to service and maintain**

Overview

'Critical facilities' include buildings and other infrastructure that provide vital functions before, during, and after a natural disaster. These can include infrastructural services, such as parts of the electrical grid, waste management facilities, and other facilities that support emergency operations such as police stations, fire stations, and hospitals, among many others. This section provides an overview of critical infrastructural services and provides mapping of these facilities using available data. It is recommended that local governments create a Critical Facilities Protection Plan (CFPP) in order to (1) identify key needs, service gaps, and issues with existing facilities, (2) take inventory of critical assets, assess vulnerability, and explore the viability of possible hazard mitigation measures, and (3) set guidelines and priorities for future infrastructure upgrades based on resilience and capital investment priorities.

(Right) An MLGW substation in Memphis, TN. Substations are critical to the supply of electricity throughout the region.

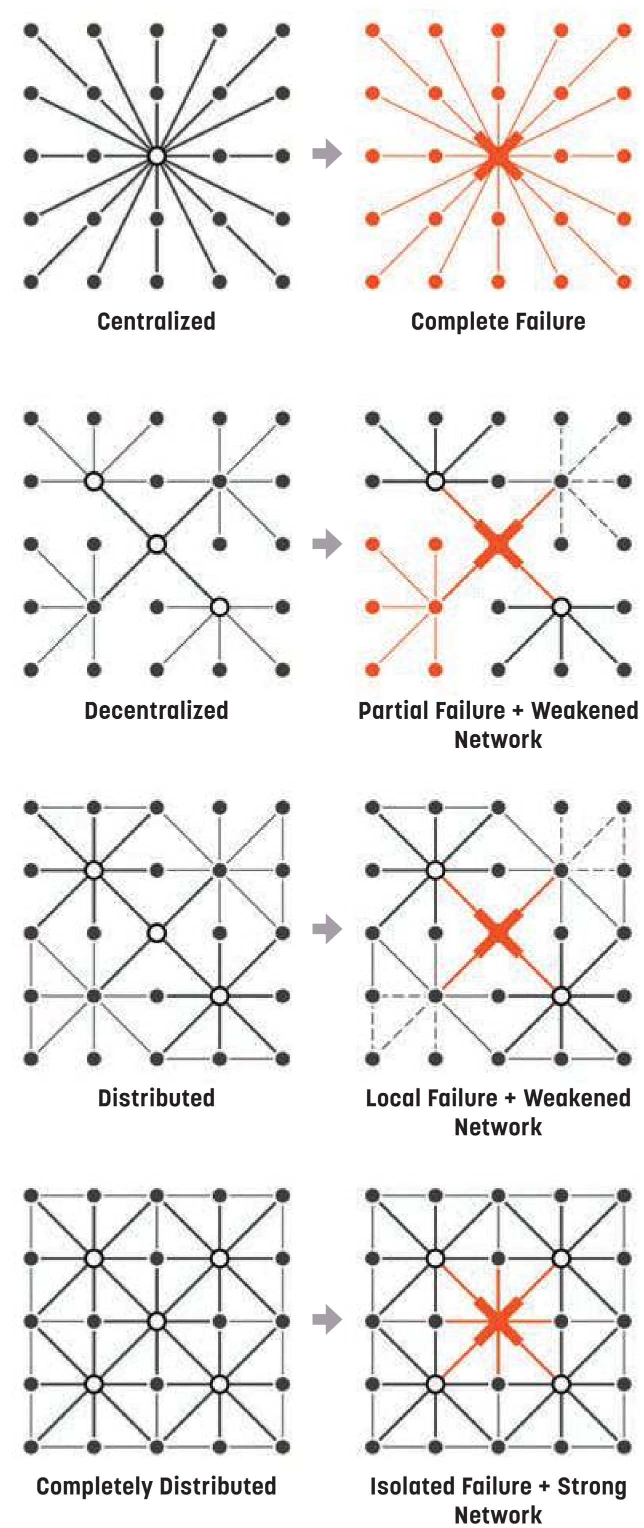
What Makes Something a Critical Facility?

Critical facilities are defined by their critical role within a larger network of emergency operations involved in the health and safety of a community. For instance, power facilities are critical because of the role they play in a network of operations: they power healthcare facilities, transportation infrastructure, and communications systems. The failure of one component may impair other critical functions within a larger network.

Before discussing the varied approaches for critical facility identification, it is important to understand the role of network typologies in infrastructural systems. The diagrams on the right illustrate several network typologies and their associated failure patterns. The network typologies range from centralized to completely distributed, with various node types. At a basic level, decentralized and distributed networks are much more resilient compared to centralized networks with bottlenecks and single points of failure.

Each network typology is related to a type of infrastructure that includes factors that may limit decentralization in various ways such as: ownership structures, physical limitations in landscape, cost considerations in implementation and maintenance, lack of manpower or effective organization, limitations in a related network (such as with energy production by fossil plants), as well as others. Not all centralized networks can easily be transformed into decentralized or distributed networks due to the issues named above—it may even be difficult for a decentralized network to further distribute its operations for the same reasons. To mitigate a potential failure of a node, protection measures can be taken to prevent systemic failure. This is where the identification and reinforcement of critical facilities plays a role.

Network Typologies and Scope of Failure



What are Critical Facilities?

Critical facilities are important to the operation of a community, as well as those needed for emergency response, encompassing services such as power, water, transportation, EMS, and healthcare infrastructure, among others. These may also include key installations in the economic sector that support post-disaster rebuilding. Because of their important role in the functioning of a community, it is essential to identify critical infrastructural elements in hazard planning.

More generally, critical facilities includes all man-made structures or network linkages that pose a risk in the event that they are destroyed, damaged, or impaired by the impacts of a natural hazard. This includes the following:

- Facilities vital to the effective response and recovery activities during and after a disaster (i.e. police stations, healthcare facilities, fire stations).
- Facilities vital to a range of emergencies that cannot be made redundant given their special characteristics (i.e. emergency, medical, and healthcare facilities).
- Importance in supplying resources or access to other critical facilities (i.e. power and communications facilities).
- Having the capacity or service areas affecting a large number of people if impaired (i.e. water facilities, schools, libraries, and shelters).

The 2012 International Building Code (IBC),[1] and 2010 American Society Of Civil Engineers (ASCE) 7-10,[2] both classify facilities in term of Risk Category:

- *Risk Category I:* structures that typically include agricultural facilities, temporary facilities, and minor storage facilities that pose a low hazard to human life if they fail.
- *Risk Category II:* structures other than those in Risk Category I, III, or IV.

Critical Facilities fall under III- and IV-type facilities:

- *Risk Category III:* structures that can house a large number of people in one place, or contain occupants with limited mobility or without the ability to move without incurring harm. This may include theaters, lecture halls, schools, prisons, and community centers. It may also include utility infrastructure that is required to protect the health and safety of a community such as power generating stations, telecommunication centers, and water and sewage treatment plants.[3]
- *Risk Category IV*: police stations, fire stations, emergency communication centers and similar emergency facilities, hospitals, infrastructural facilities required to maintain the operations of these facilities during an emergency, and facilities containing hazardous materials that could threaten the public if released into the environment.[4]

A more complete list can be found in FEMA's documentation[5] where defined critical facilities list includes:

- *Emergency Response:* Police stations, fire stations, critical vehicle and equipment storage facilities, and emergency operations centers needed for emergency response activities before, during, and after a natural hazard.
- *Medical Care:* Hospitals, nursing homes, clinics, blood banks, and other health care facilities likely to have occupants who may not be sufficiently mobile to avoid injury or death during or after a natural hazard.
- *Shelter Facilities:* Shelters, evacuation centers, schools, day care centers, community centers, or other structures with large occupancy capacity.
- *Critical Energy:* Power generating stations and other public and private utility facilities vital to maintaining or restoring normal services to areas before, during, and after a natural hazard.
- *Critical Sanitation:* Drinking water and wastewater treatment plants.
- *Hazardous Facilities:* Structures or facilities that produce, use, or store hazardous materials and waste that can be dangerous to human contact.

Additional definition and guidance is also given in the Community Rating System Manual.[6] See 4.3 Flood Smart Development for more information related to this. 4.3

The 'critical' aspect of a facility is also related to key factors such as its location relative to a potential hazard, or its central location relative to a community. The capacity of a facility to provide services or its potential impact if affected by a hazard are also important considerations. Key factors and aspects of critical facilities are detailed in the following section: Creating a Critical Facilities Protection Plan.

Creating a Critical Facilities Protection Plan (CFPP)

Many towns and cities across the US are creating CFPPs as part of their hazard planning and investment strategies through the reinforcement of critical facilities and proactive planning for potential natural hazards. The speed at which a community is able to resist and recover from a natural hazard is closely linked to the resilience of its critical infrastructure and its ability to continue to function in the face of a disaster.

Preparing a CFPP allows local governments to take coordinated, actionable steps to improve overall infrastructural resilience. A CFPP identifies critical infrastructure and facilities and plans for the targeted improvements and protection of these critical facilities. Mapping and planning can identify shortfalls in emergency preparedness of the structural or infrastructural properties in order to take measures to mitigate these deficiencies. Proactive planning can help identify safe sites to implement new critical facilities through updates to hazard information and maps used by city departments.

The objective is to mitigate the potential damage done to larger systems by preventing or dampening the "ripple effect" due to cascading issues that may come with systemic failure. This can save money for local, state, and federal governments. A CFPP should also be integrated into long-term planning functions providing organizational linkages between various departments and emergency planners. This builds organizational capacity across multiple departments in managing and implementing emergency response plans.

Key Considerations

- A CFPP should be integrated into local Hazard Mitigation Plans as well as local Comprehensive Plans (including the Capital Investment Plan) that may steer growth and future investment.
- The CFPP process should include community outreach to determine shelter locations and integrate into other outreach measures. See 7.2 Outreach for more information.
- Site investigations and facility evaluations should be made by architects, engineers, and other specialists.

7.2

1 Identify

The first step in creating a CFPP is to identify critical facilities (see previous page) and begin to develop a strategy to collect key attributes for each facility that is not known at a high level. These should be:

- *Location of Facility*: The locations of facilities are important to note and should be coordinated with relevant GIS and mapping management processes and mapped accordingly.
- *Hazard Risks*: Facilities should also be evaluated on the potential risks posed by various hazard types such as earthquakes, flooding, etc. Inferences should also be made based on building or infrastructure type to assess the affect of other hazards such as wind, cold, heat, etc.
- *Organizational Use*: The array of critical facilities may be managed and operated by a variety of organizations from government to private sector. These organizations should be listed with facility data to facilitate coordination.

This initial identification process will likely inform an outreach strategy to obtain more information through engagement with a managing organization and the local community.

2 Inventory and Assess

Further assessment of the vulnerability of each facility is needed to inform an investment or action plan to mitigate risk. Engagement with managing organizations and the local community is necessary in assessing key criteria:

- *Facility Importance or Capacity*: The 'importance' of a facility involves both subjective and data-driven assessments that may involve community or organizational engagement to determine the critical nature of a facility, such as its community or security functions, or a facility's potential danger, such as with facilities that manage hazardous material. This should be conducted in consultation with relevant engineers and specialists.
- *Service Gaps*: Gaps in service coverage should be assessed in order to evaluate additional strategies to mitigate a potential issue, such as with electricity infrastructure that may be either reinforced or made more resilient through the addition of distributed systems.
- *Structural Issues*: Facilities should be assessed for their structural resilience and the potential investment cost to reinforce or rebuild. This should be conducted in consultation with relevant engineers and specialists.
- *Possible Hazard Mitigation Measures*: This should be conducted in consultation with relevant engineers and specialists. See other hazard mitigation measures throughout this report for reference.

3 Integrate Plan

Set guidelines and priorities for future infrastructure planning within broader hazard mitigation and capital investment goals. This should include prioritization of investment based on the critical needs of facilities identified. High-risk facilities, including those that are at risk to cause larger systemic issues, should be prioritized early.

A CFPP should be integrated into other existing plans. This may involve coordination with a facility's management organization to explore options for hazard mitigation measures. The integration of a facility into a larger planning structure can also facilitate communication and coordination in times of emergency.

Mapping Critical Transportation Assets

The Memphis metropolitan region has done extensive work to address its transportation issues. There has been comprehensive planning focused on the critical nature of the transportation system at the regional level by TDOT.[7] These reports also parallel the efforts of the region's largest businesses such as FedEx and their efforts to improve the functioning of the transportation system.

Livability 2040 Regional Transportation Plan

The Livability 2040 Regional Transportation Plan was established by the Memphis Metropolitan Planning Organization (MPO) in 2016. It will serve as a guide for transportation planning for the next 25 years. The plan addresses many aspects of resilience through its performance-based planning and emergency considerations, including identified improvements to safety and security.

Memphis Metropolitan Planning Organization (MPO), Livability 2040 Regional Transportation Plan (2016), http://memphismpo.org/sites/default/files/public/livability-2040-all-chapters.pdf.

FY 2017-2020 Transportation Improvement Program (TIP)

The Transportation Improvement Program for the Mid-South illustrates how transportation revenues will be invested over a period of four years between FY 2017-2020. It is coordinated with the Statewide Transportation Improvement Program (STIP) and approved by the MPO and the Governors of Mississippi and Tennessee.

Memphis Metropolitan Planning Organization (MPO), FY 2017-2020 Transportation Improvement Program (TIP), (2017), http://www.memphismpo.org/plans/fy-2017-20-transportation-improvement-program.

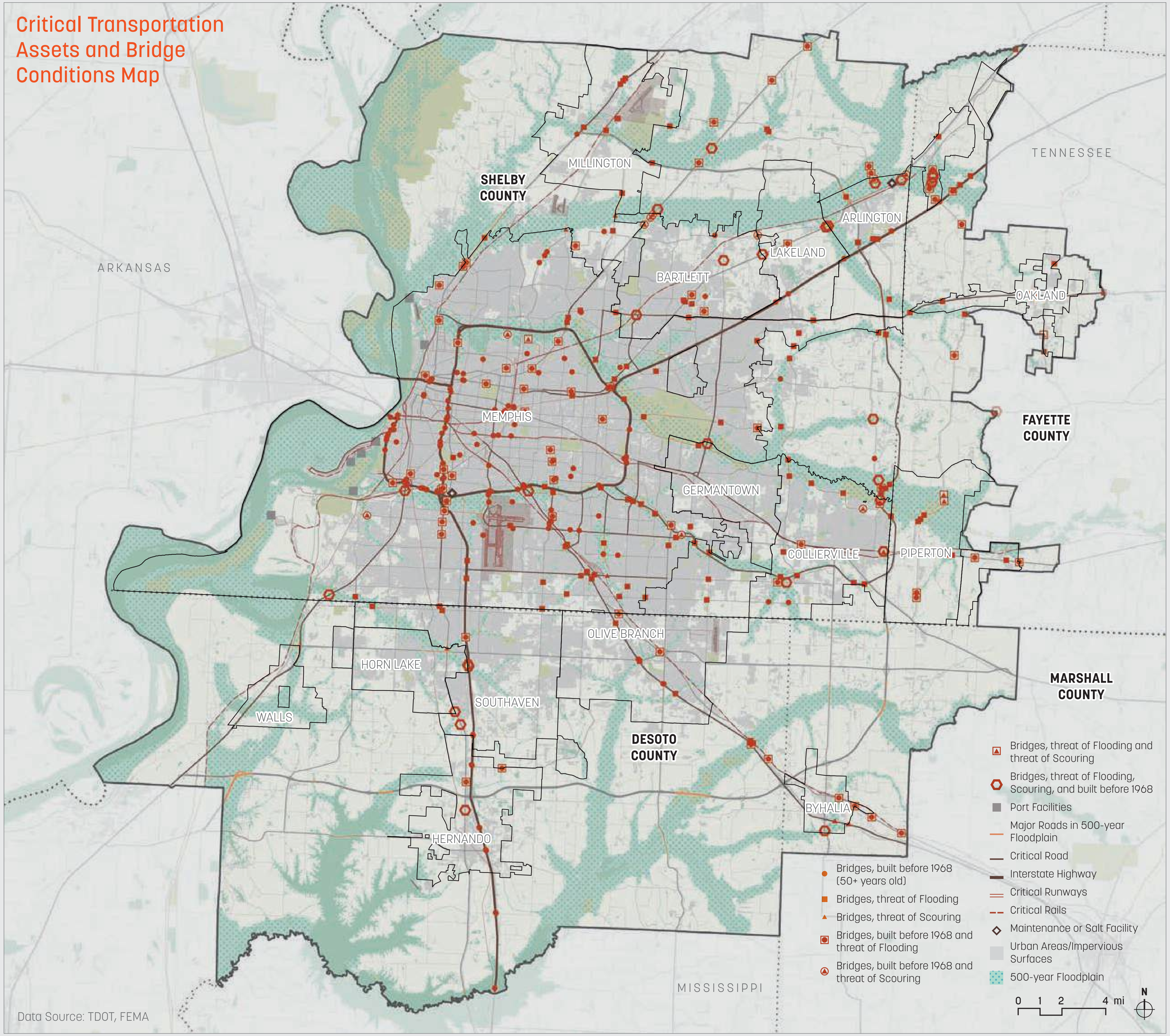
Bridge Conditions

Within infrastructure networks, some of the most critical points of failure are usually areas of bottlenecks, or areas that lack redundancy. Failure or damage done to areas like these can prevent the sufficient functioning of a system resulting in major consequences. In times of disaster or emergency, the functioning of systems is a high priority. For many transportation systems, bridges can be a critical point of failure. Flooding and earthquakes may pose serious risk to bridges that are not properly maintained.

The Federal Highway Administration keeps detailed data on bridge conditions in the National Bridge Inventory. The map to the right is illustrated with bridges on major roads within the Mid-South that:

- Were built before 1968 (are 50+ years old) and have not been rebuilt
- Have at least a minimal threat of flooding (water over-topping)
- Are under threat of damage by scouring (eroding of the foundations)

Combinations of these attributes are illustrated with different icons. Also illustrated are segments of major roadways that are located in the 500-year floodplain.



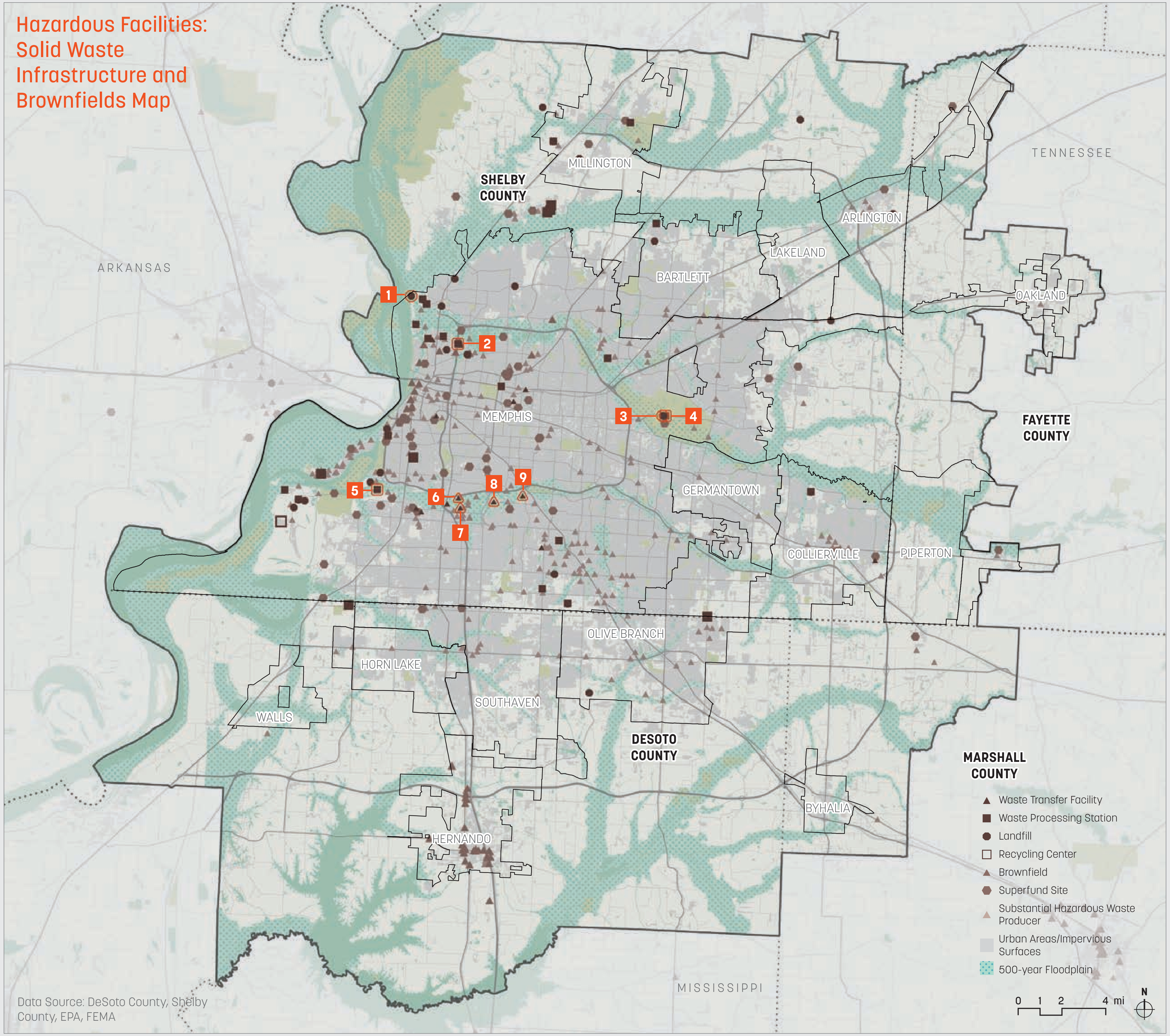
Mapping Hazardous Facilities

The map to the right utilizes data from the Environmental Protection Agency's (EPA) public datasets and Shelby County's database. Key solid waste infrastructure facilities located within the floodplain are identified as potential candidates for further assessment. When it comes to hazardous sites and facilities, consideration should be given to preventing the release of toxic material into the community and watershed. Landfills, brownfields, and superfund sites are also listed on the map.

Facilities Located in Floodplain

1. North Memphis Landfill
2. Bellevue Facility
3. Shelby County Penal Farm Landfill (Inactive)
4. Extrusion Technologies Processing Facility
5. Stericycle, Inc.
6. Switch Medical Waste Transfer Station
7. Inservco Corporation Transfer Station
8. Democrat Road Transfer Station
9. Memphis Farrisview Transfer Station

Hazardous Facilities: Solid Waste Infrastructure and Brownfields Map



Data Source: DeSoto County, Shelby County, EPA, FEMA

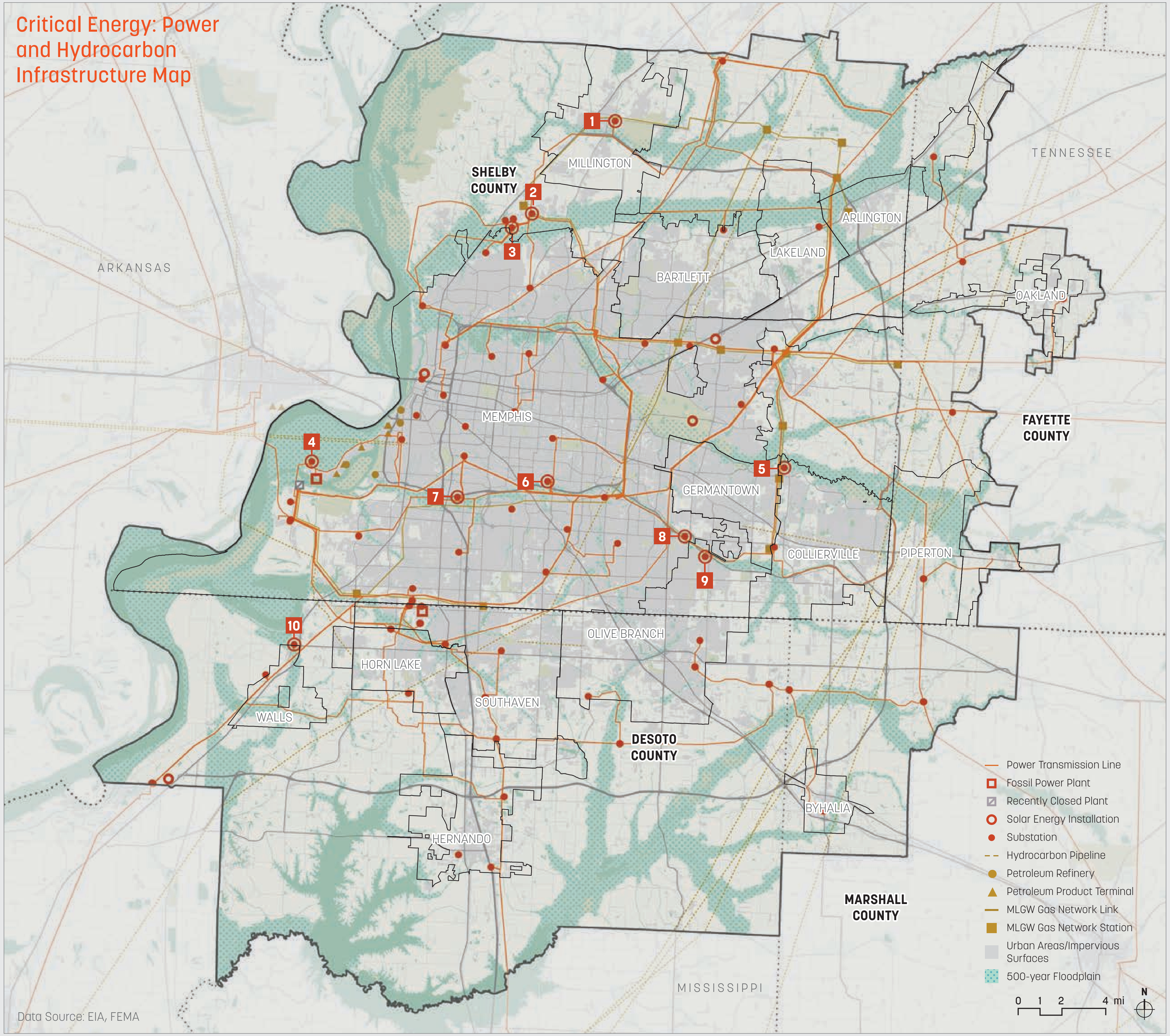
Mapping Critical Energy

Energy infrastructure is critical to many functions and is essential to a region's resilience. These systems can be complex, involving an overlapping array of ownership and delivery infrastructure. Mapping these facilities can help to identify key sites of engagement between local governments and utility organizations. For instance, most of the substations identified in the floodplain here are managed by MLGW, but may have implications for local power resilience.

5.3 5.5 See 5.3 Power Lines and 5.5 Community Energy for more information on the electric grid and on the overlay of ownership of energy delivery systems.

Facilities Located in Floodplain

1. Substation 15
2. 3065 Fite Road Substation
3. 5184 Millington Road Substation 13
4. Substation 67
5. Old Houston Levee Road Substation
6. 1703 Getwell Road Substation
7. Longate Drive Substation
8. 744 Winchester Road Substation
9. 4071 Stansell Court Substation
10. MS-161 Substation

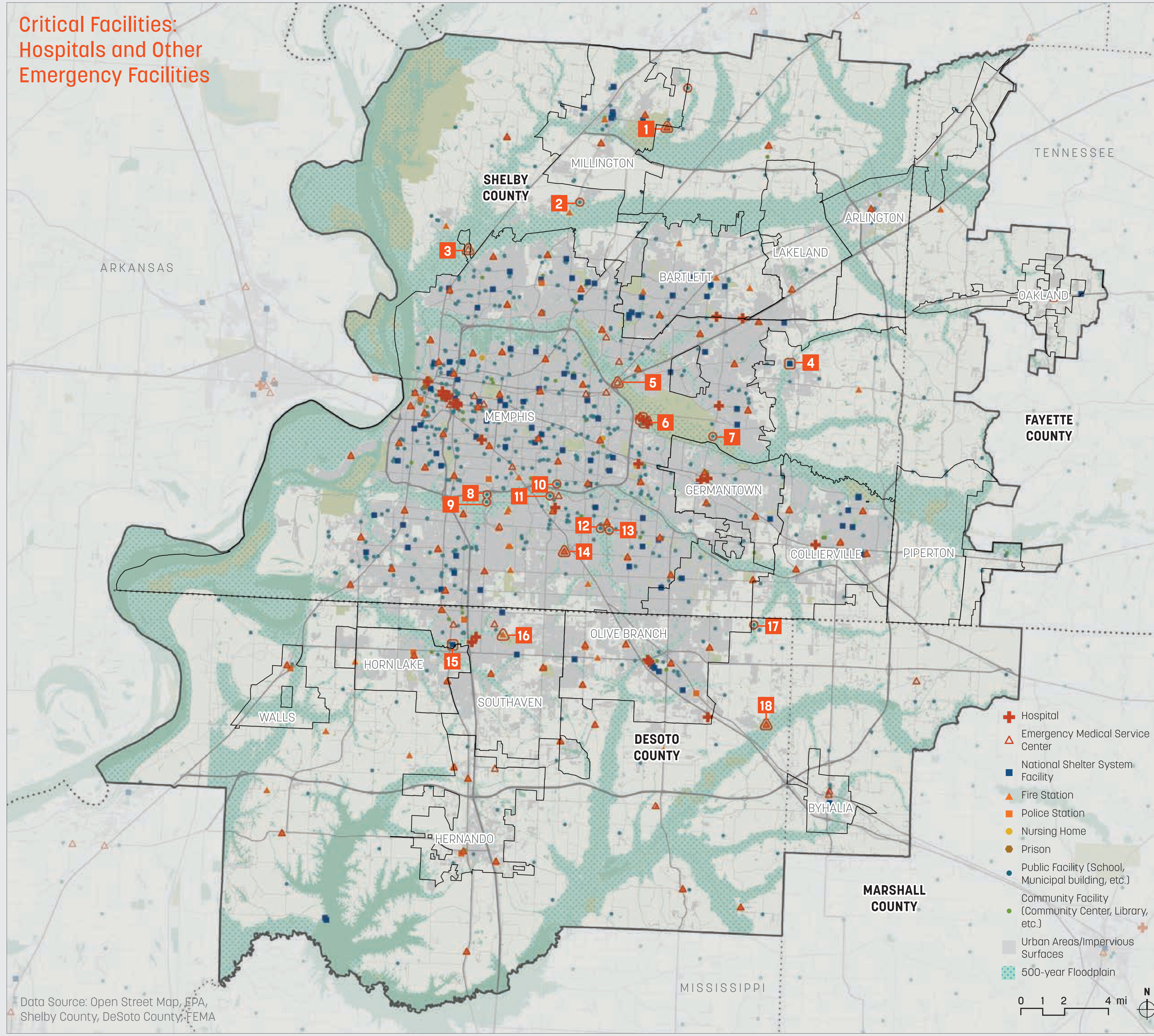


Mapping Hospitals and Other Emergency Facilities

Physical infrastructure sustains social networks. The map to the right illustrates a variety of important facilities involved in emergency preparedness, response, and recovery based on available data. Facilities in the floodplain have been identified, but may need to be assessed for specific site factors that affect a facility's flood vulnerability, such as ground floor elevation.

Facilities Located in Floodplain

1. Millington Fire Station 4
2. Faith Heritage Christian Academy
3. Memphis Fire Emergency Medical Service
4. Calvary Church of the Nazarene
5. Rural/Metro Corporation Mid-South
6. Baptist Memorial Hospital Memphis Complex
7. La Petite Academy
8. Green Tree Child Care Center
9. Remington College
10. South Park Elementary School
11. American Way Middle School
12. Wooddale Junior High School
13. Power Center Academy High School
14. Memphis Fire Station 50
15. Southaven Multi-Purpose Shelter
16. Southaven Fire Station 2
17. Center Hill Middle School
18. Fairhaven Fire Station



Case Study

Critical Facility Vulnerability Assessment, Hazard Mitigation Plan, Holderness, NH

New Hampshire's state and local hazard mitigation planning includes an assessment of critical facilities.[8] Its integration gives the state and local governments concrete plans to invest in systemic resilience. An example of a CFPP assessment for the Town of Holderness is shown here for reference. It illustrates key facilities, their location, classification, and structural value. Each facility has been mapped and assessed for its vulnerability along multiple dimensions.

Table 12: Impact of Hazard on Holderness Critical Facilities Note: The darker shades of blue indicate greater probability of occurrence (Table 9).

NAME	Severe Wind (Tornado/ Down-burst/ Thunderstorm)	Lightning	Recreational Activities	Flood	Ice Jam	Ice Storm	Radon	Blizzard/ Snow Storm	Nor'easter	Drought	Extreme Heat	Wildfire	Hurricane	Hail	MV Accident involving HazMat	Oil Spills	Earthquake	Landslide	Avalanche	Mil. Aircraft Accident	Pandemic	Rabies	TOTAL
Town Hall	3	3	1	1	1	1	1	1	1	1	1	1	3	1	2	2	3	1	1	1	1	1	32
Holderness Safety Building	3	3	1	1	1	1	1	1	1	1	1	1	3	1	2	2	3	1	1	1	1	1	32
Holderness Elementary K-8	3	3	1	1	1	1	1	3	3	1	1	1	3	1	2	2	3	1	1	1	3	1	38
Highway Dept.	2	2	1	1	1	1	1	1	1	1	1	2	2	1	2	2	3	1	1	1	1	1	30
Holderness Public Library	2	2	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1	1	1	1	27
Holderness School (Prep)	2	2	1	1	1	2	1	1	1	1	1	1	2	1	3	3	1	1	1	1	3	1	32
Holderness Post Office	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	24
Town Center Bridge	2	2	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1	1	1	1	27
Ace Afterschool Program	2	2	1	1	1	1	1	1	1	1	1	1	2	1	2	2	3	1	1	1	1	1	29
Holderness School Ice Rink	2	2	2	1	1	1	1	1	1	1	1	1	2	1	3	3	1	1	1	1	1	1	30
PSU Fieldhouse	3	3	2	3	3	1	1	1	1	1	1	1	3	1	3	3	3	1	1	1	3	1	41
PSU Ice Arena	1	3	2	3	3	1	1	1	1	1	1	1	3	1	3	3	3	1	1	1	3	1	39
Holderness Schl. chem.. lab	2	2	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1	1	1	1	27
Holderness School fieldhse	2	2	2	1	1	1	1	1	1	1	1	1	2	1	3	3	3	1	1	1	1	1	32
Rockywold/Deephaven	2	2	2	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	2	28
Historical Society Bldg.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22
Squam Science Center	2	2	2	1	1	1	1	1	1	1	1	2	2	1	1	1	1	2	1	1	1	2	29
Asquam Marina	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	23
Squam Boats Livery	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	23
cell tower/communication	3	3	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1	28
HUB at PSU	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	24
NH Route 3	3	3	1	3	1	1	1	1	1	1	1	1	3	1	3	3	1	1	1	1	1	1	34
NH Route 175A	1	1	1	3	3	1	1	1	1	1	1	1	1	1	3	3	1	1	1	1	1	1	30
NH Route 113	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	1	1	1	1	1	1	26
Montesorri School A	2	2	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	25
Montesorri School B	2	2	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	25
Camp Deerwood	2	2	2	1	1	1	1	1	1	1	1	2	2	1	2	2	1	1	1	1	1	2	30
Electrical substation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	24
Total	**53**	**55**	**37**	**36**	**34**	**29**	**28**	**30**	**30**	**28**	**28**	**32**	**55**	**28**	**56**	**56**	**44**	**29**	**28**	**28**	**36**	**31**	

(Above) Critical Facility Assessment including potential impact of hazards, Holderness, NH Hazard Mitigation Plan, 2015

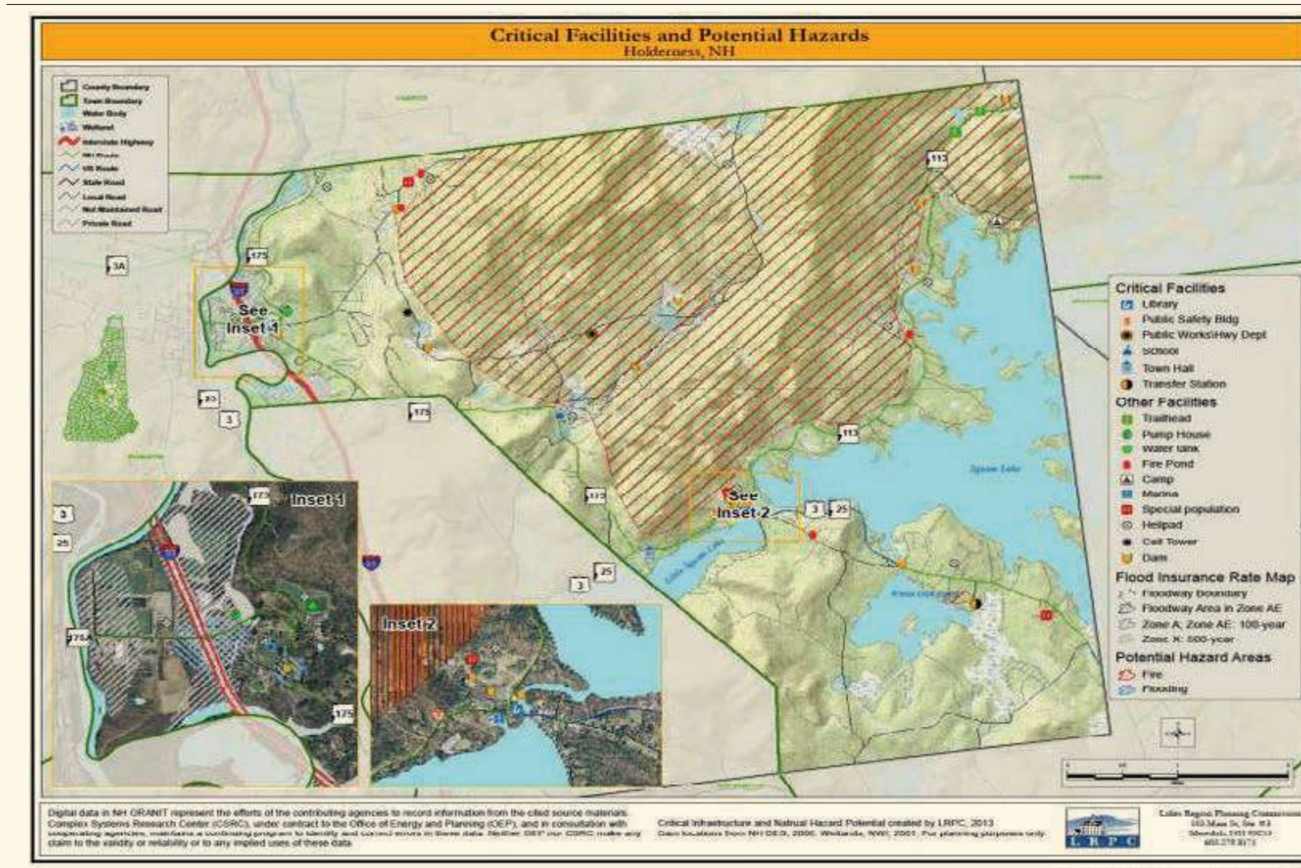
(Right, Top) Critical Facility Assessment, Holderness, NH Hazard Mitigation Plan, 2015. Indicates several aspects including location, classification, generation capacity, occupancy, and structural value.

(Right, Bottom) Map of Critical Facilities and Potential Hazards, Holderness, NH Hazard Mitigation Plan, 2015

Table 11: Critical Facilities

TYPE	NAME	ADDRESS	CLASSIFICATION	Generator?	Shelter Capacity	Structural Value
Public Information	Town Hall	1089 NH Route 3	Essential Services	In process	50	$322,200
EOC	Holderness Safety Building	922 NH Rte. 3	Emergency Shelter	Yes		$796,400
School and Primary Shelter	Holderness Elementary K-8	19 School St.	Populations to Protect/ Structures and Services	Yes	125	$3,979,000
Public Works	Highway Dept.	62 Beede Rd.	Essential Services	Portable		$293,800
Library	Holderness Public Library	866 NH Rte. 3	Structures and Services	In process		$198,200
School	Holderness School (Prep HS)	33 Chapel Ln.	Populations to Protect	yes		$15,426,800
Post Office	Holderness Post Office	846 NH Rte. 3	Structures and Services			$89,700
Infrastructure - Bridge	Town Center Bridge	NH Rte. 3	Structures and Services			
Daycare	Ace Program	19 School St.	Populations to Protect	Yes		Value included in Holderness Elementary
Haz Materials	Holderness School Ice Rink	NH Rte. 175	Structures and Services			$492,770
Haz Materials	PSU Fieldhouse	(Rm 134) 27 Fieldhouse Rd.	Structures and Services			$2,912,800
Haz Materials	Holderness School chemistry lab	Chapel Ln.	Structures and Services			$65,870
Haz Materials	Holderness School field house	Mt. Prospect Road	Structures and Services			$1,497,280

APPENDIX F: CRITICAL FACILITIES & POTENTIAL HAZARDS MAP



Endnotes

1 International Code Council, *International Building Code* (2012), Section 1604, General Design Requirements, Table 1604.5,

2 *ASCE 7-10,* (American Society Of Civil Engineers, 2010), Section 1.2, Definitions and Notations, Table 1.5-1 (2010).

3 Ibid; International Code Council, *International Building Code* (2012)

4 Ibid.

5 *Fact Sheet: Critical Facilities and Higher Standards*, (Federal Emergency Management Authority), last accessed February 5, 2019, https://www.fema.gov/media-library-data/1436818953164-4f8f6fc191d26a924f67911c5eaa6848/FPM_1_Page_CriticalFacilities.pdf.

6 Federal Emergency Management Agency (FEMA), National Flood Insurance Program Community Rating System Coordinator's Manual, (2017), https://www.fema.gov/media-library-data/1493905477815-d794671adeed5beab6a6304d8ba0b207/633300_2017_CRS_Coordinators_Manual_508.pdf

7 Abkowitz, Mark, Janey Camp and Leah Dundon, Assessing the Vulnerability of Tennessee Transportation Assets to Extreme Weather, Final Report for TDOT, (University of Tennessee, 2015)

8 Town of Holderness, Hazard Mitigation Plan, (2015), http://www.holderness-nh.gov/Public_Documents/HoldernessNH_WebDocs/Hold_HMP15_FinalApproval.pdf; New Hampshire Department of Safety Homeland Security and Emergency Management, State of New Hampshire Multi-Hazard Mitigation Plan, (2013), https://www.nh.gov/safety/divisions/hsem/HazardMitigation/documents/hazard-mitigation-plan.pdf

Resources

Critical Facilities and Flood Risk. (Association of State Floodplain Managers, Inc., 2011). https://www.floods.org/ace-files/documentlibrary/Whitepapers/ASFPM_Critical_Facilties_and_Flood_Risk_Final_Feb_2011.pdf

US EPA. *Inland Port Community Resilience Roadmap*. (2018). https://nepis.epa.gov/EPA/html/DLwait.htm?url=/Exe/ZyPDF.cgi/P100UA4W.PDF?Dockey=P100UA4W.PDF.

5.2 Drainage Systems

Enhance the Capacity of Waste and Stormwater Systems

Key Benefits

1. **Reduces flash flooding and sewer overflows**
2. **Reduces the burden on stormwater outflows**
3. **Collects stormwater for irrigation, reducing potable-water use**

Limitations

1. **Construction can cause traffic disruptions and delays**
2. **Water service may be interrupted during servicing**
3. **Extensive cost and time of implementation**

Overview

Storm and wastewater infrastructure is a necessary component of modern life. Cities and neighborhoods rely on underground pipes, storage tanks, and treatment facilities to carry away everything flowing down drains and sewers. The Memphis drainage system is a century old and facing capacity challenges. In rain events, sewers that surpass their capacity can result in flooded streets, backflows into homes, and untreated discharge to rivers. Fortunately, there are several strategies to improve a sewer system's ability to handle local demand. The two major strategy types are commonly referred to as "green" and "grey" infrastructure. Green-infrastructure techniques use vegetated areas to reduce the amount of stormwater flowing into storm-drains while also improving water quality. This report addresses multiple types of green infrastructure in chapters 1 and 2. The focus of this section is on grey infrastructure strategies, which involve expanding pre-sewer storage capacity, expanding wastewater treatment capacity, and expanding the sewer system itself.

1
2

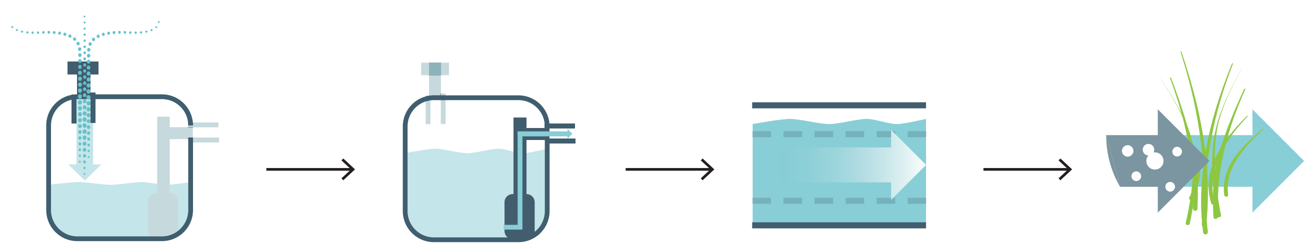
(Right) Pipe replacement in Malden, Missouri by R.L. Persons

Stormwater System Expansion

Expanding greywater systems requires extensive research, planning, and financial commitment, but Memphis and the Mid-South are well positioned compared to other cities. Unlike many other historic cities, the sewer system was designed to keep stormwater and sanitary wastewater separate from each other. This means that stormwater projects do not necessarily involve sanitary sewers. In the event of heavy rains, overflowing stormwater is less likely to contain sanitary wastewater. While many other cities struggle to find space to expand storage and treatment facilities, the Mid-South also has land available for the expansion of storage and treatment facilities.

Currently, the City of Memphis has an initiative called the Sewer Assessment and Rehabilitation Program, or SARP10.[1] This program is bringing wide-ranging improvements to the City's sanitary sewer system. The greater Mid-South also has room to expand funding for infrastructure. Water costs in Memphis are low compared to other US metropolitan areas. The average household in Memphis paid $55 per month in 2015, while households in most other major cities paid between $100 and $200 per month.[2] Stormwater fees are a small portion of this: a typical household pays $4.65 and the fees are being raised over the next five years by $8 to $10 per month.[3] By raising wastewater rates, funds would be available for the renovation, maintenance, and expansion of the system. Given the devastating effect floods have on the Mid-South, funding infrastructure projects is an investment to protect against future damage.

Wastewater System Expansion Opportunities



On-site Storage

- Pipes
- Chambers
- Vaults

Infiltration

Managed Release

- Staggered Release
- Pumps
- Remote management

Increased System Capacity

- Culverts
- Drains and Inlets
- Pipes
- Pumps
- Outflows

Sewer Overflow Mitigation

- Biofiltration in Wetland Catchment Basins
- Distributed Treatment Facilities

Challenges of Overflows

Storm sewer overflows result in water backing up into streets during storms, causing flash flooding.

Heavy discharge may be released into rivers.

Intense rains can cause the sanitary and storm sewers to combine and overflow together.

Combined sewer overflows result in unsanitary conditions that shut down entire areas.

5.2.1 Increase Stormwater Storage

Sewers overflow when the amount of water entering the system exceeds system capacity. This is occurring much more frequently in modern cities because the prevalence of impermeable surfaces has increased the rate and volume of stormwater runoff. Diverting some of this runoff to storage areas reduces the burden on the sewer system during and immediately after a storm. The diverted water is released slowly over the next few days or weeks, as the sewer system is able to handle it. Alternatively, the water is infiltrated on site.

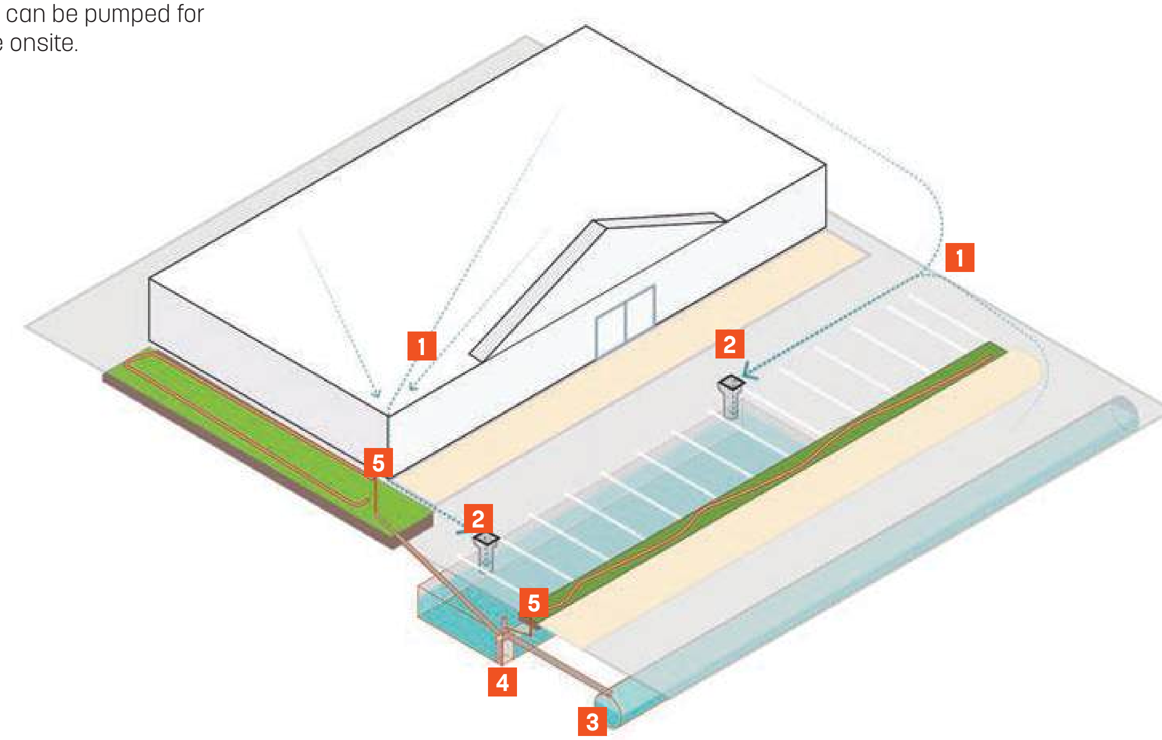
Underground chambers, pipes, and vaults are the most common storage systems. Usually, development projects incorporate these systems under surface developments such as fields, courts, parking lots, and roads.

Including examples of grey infrastructure in the Memphis Shelby Country Drainage Manual would facilitate broader use. On-site storage is currently required of new development in cases where the sewer system cannot handle the new development. Phase in requirements for on-site water storage for when existing businesses and large organizations, such as condominiums, apartments, and institutions, apply for new building and renovation permits.

See 2.4 Open Space Strategies for more information. 2.4

Underground Storage

1. Runoff is directed towards underground water storage.
2. Runoff flows into the underground storage.
3. Water overflows into sewer if sewer water level is low enough.
4. Stored water can be pumped into the sewer.
5. Stored water can be pumped for irrigation use onsite.



Methods

Precast Concrete Chambers

Concrete chambers tend to be strongest and have the highest capacity, but are also expensive.

1. Above-ground Building Project
2. Concrete Vault
3. Concrete Base
4. Impermeable Base

Pipes

Pipes usually are the least expensive and store a moderate capacity of water. The water must be drained out of the system.

1. Surface-level Project
2. Pipes
3. Connecting Pipe
4. Gravel Bed

Vaults

Vaults have an impermeable top and an open bottom. The bottom can be made of permeable gravel bottom, meaning that water can slowly infiltrate into the ground below.

1. Vault
2. Gravel Infiltration Bed

5.2.2 Create a GIS-Based Digital Sewer Map

Having a digital map of the sewer system with accurate geo-locations is a critical tool in smart management. Digital maps have the power to combine all of the different jurisdictions and data sets into one, sharable resource. They combine plans, GPS data, maps, institutional knowledge, and in-the-field measurements.

Digital maps can store information about each piece of the sewer system, including:

- Overflow reports
- Maintenance log
- Scheduled maintenance and maintenance requests
- Customer information (for connection points)
- Pipe and drain capacity, diameter, material, age, and condition
- Operations and maintenance personnel
- Jurisdiction and Regulations
- Photography and sketches
- Anecdotal notes from the field

Such a database should also include a citizen-scientist component, where the public is engaged to photograph and report the conditions and overflows of local sewers.

Having all of this information in one place makes it easier for planners to decide when, where, and how to expand. For example, it would be easier to discern patterns in overflows if local residents could contribute information from across the system.

Digital maps also make it easier to respond to on-the-ground conditions in real time. When overflows do occur, emergency personnel have immediate access to the information they need. When meteorologists predict heavy rain, sewer system managers can strategically change operations to prevent overflows (by opening storage areas, increasing flow rates, etc.).

Digital maps usually operate on Geographic Information Systems (GIS) software. Consultants who specialize in wastewater engineering, management, and mapping are qualified to begin the digitization process. Increased efficiency, management, and planning should offset the cost of digitization.

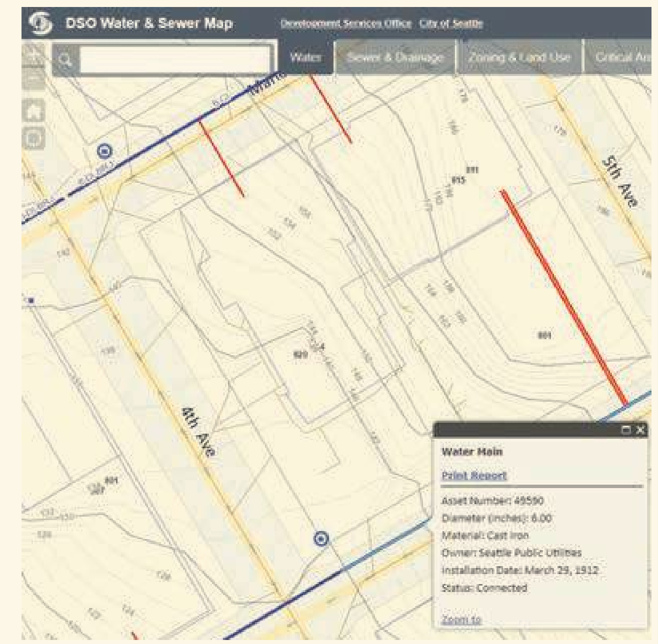
The USEPA has developed some online tools that help map and predict stormwater, which may be of use. The Storm Water Management Model (SWMM) evaluates how much runoff will occur for different storm events based on a given system. SWMM incorporates hydraulic modeling, hydrologic processes, pollution load estimation, as well as the effectiveness of different LID system additions.[4]

GIS-Based Digital Mapping

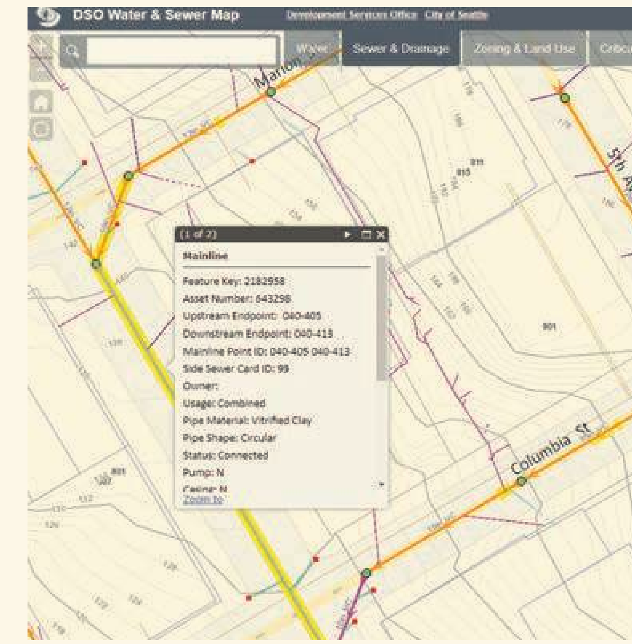
Effective mapping systems combine relevant information layers into an easy to use interface. In addition to water and sewer system component characteristics, useful information includes special topographic features, zoning, and maintenance / construction in the area. A sample digital map service is illustrated on the page to the right. See 7.1 Resilience Database for more information on resilience data management practices. 7.1

Sample Digital Map

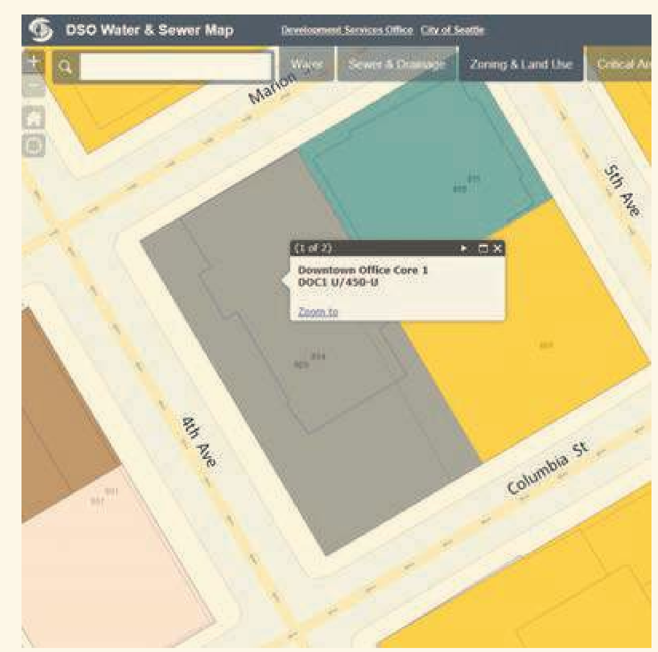
Operated by the City of Seattle Development Services Office, these Water and Sewer maps are publicly accessible through an easy-to-use online viewer.



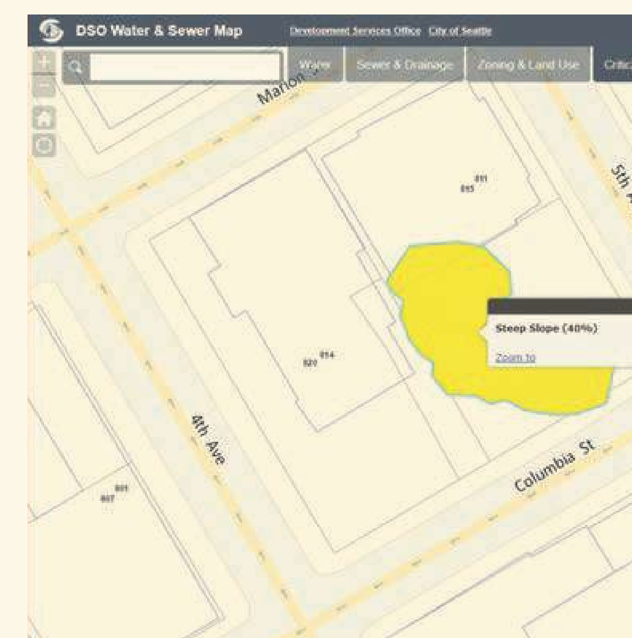
Water Mains



Sewer System



Zoning and Land Use



Critical Areas by Ordinance

5.2.3 Expand Capacity of Existing System

(Left) Sewer overflow.

(Left) Gutter clogged with debris, causing local flooding. Source:

(Left) Tree roots can clog pipes, causing drainage problems and local flooding.

(Left) Old pipes corrode and break, causing system disruptions and local flooding.

The third major option to manage excess stormwater and flash flooding is to increase the capacity of the sewer infrastructure. This includes increasing the size and/or numbers of drains, culverts, sewer pipes, outflows, and any associated treatment facilities. Increasing sewer capacity requires substantial investments and is disruptive to city streets.

The first phase of sewer infrastructure replacement is careful study. Extensive data collection must occur during and after various rain events, in order to identify problem areas. Working with hydraulics and hydrology requires specialized engineers and sophisticated computer modeling. The outcome of any study ideally includes identification of problem areas, discussion of solution options, and an estimated timeline and budget for each solution option. It is then up to the local government and water and sewer utility to decide which option to pursue.

Modifying wastewater infrastructure is invariably an expensive endeavor. Once the full cost of increasing the system is understood, some cities (such as the City of Philadelphia) have chosen to make alternative multi-purpose investments in green-infrastructure and LIDs. If the local government and water and sewer utility decide to go ahead with the replacement, funds need to be raised. Funds typically come from three major sources: increased wastewater fees, public funds, and bonds.

Replacing infrastructure is a slow process, proceeding block-by-block throughout a neighborhood. Costs typically range from $50 to $250 per linear foot, and vary based on the groundcover and depth of pipe. The traditional method of replacement is to tear up the surface directly above a pipe and take it out for replacement. A newer technology, the "trenchless sewer line replacement," has the potential to cost less and leaves most of the surface intact. This procedure uses one excavation point, pushes the old pipe out of the way, and inserts the new pipe. However, this procedure is most suitable for small pipes, such as those connecting a private home or business to the main line.

Other Common Issues

An overflowing sewer drain is not necessarily a sign that the entire system needs to be upgraded. Sewers can begin to overflow to a variety of reasons. The images on

the left show common issues that arise over the life of normal sewers. First, drains and pipes are often clogged with trash and vegetal debris, particularly falling leaves. Second, tree roots are attracted to water that leaks or condenses on the surface of underground pipes. It is common to find masses of roots clogging old pipes. Third, clay, concrete, and metal pipes decay over time, filling with their own corrosion and the surrounding fill.

Methods

Traditional Sewer Repair

Traditional wastewater system upgrades require excavation of the entire system and replacement with larger pipes and infrastructure.

(Right) Photos showing a traditional sewer repair process.

Trenchless Sewer Repair

Old pipes are replaced in-situ without excavation by pushing in a new flexible plastic pipe while breaking the old one. The new pipe is then inflated and hardened, creating a solid new pipe.

1. Beginning of pipe repair
2. End of pipe repair
3. Expanded old pipe
4. New plastic pipe

(Right) Pipe repair process and a sample pipe section.

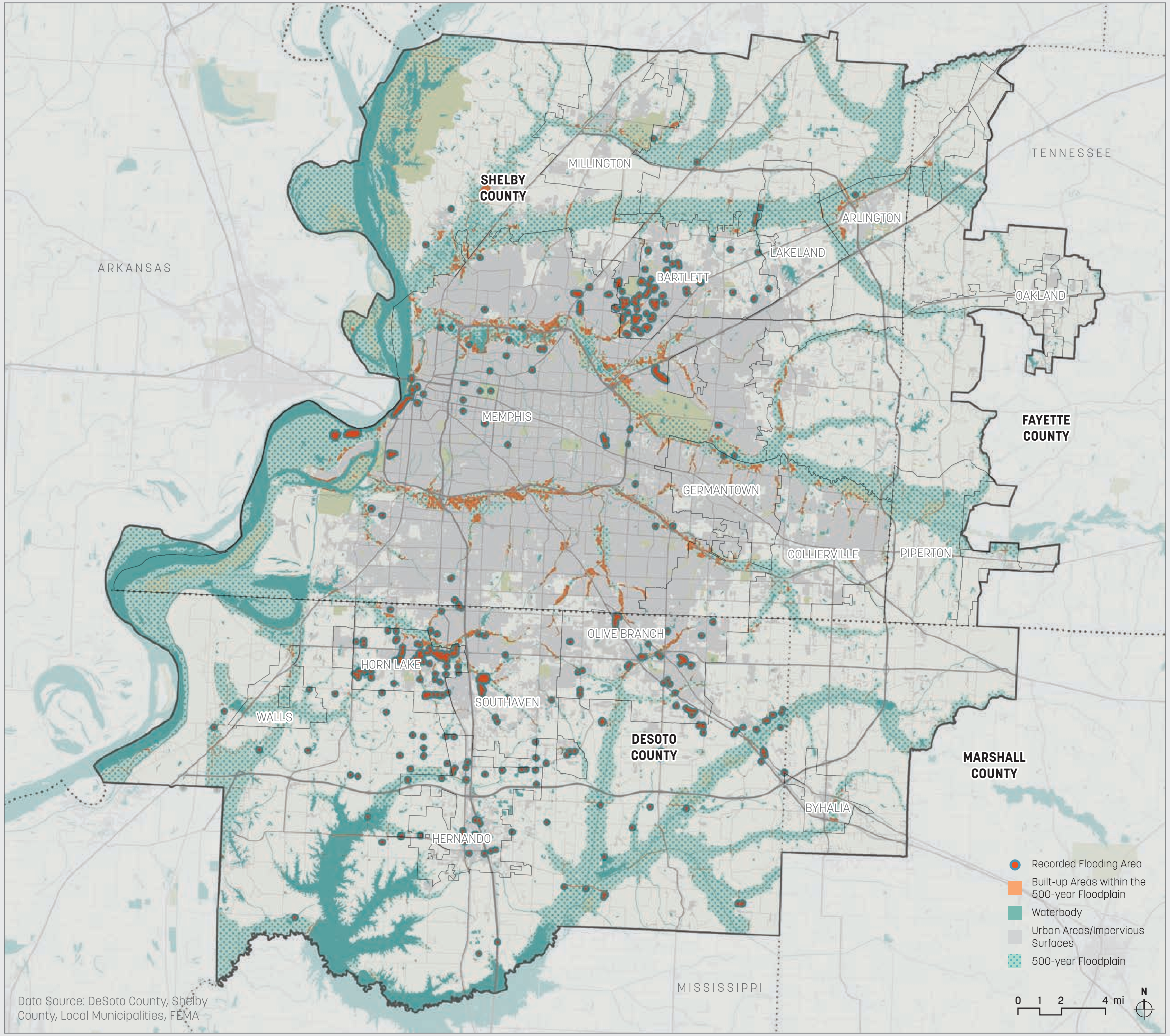
Local Flood Locations

There are two types of local flooding within developed areas. The first type occurs when inlet drains are not large enough or plentiful enough to accommodate all of the stormwater flowing in. The second type is caused by sewer backflows when the catchment system is filled to over-capacity. These locations are the most effective places to start for grey infrastructure expansion. They are usually also ideal places for increasing Green Infrastructure, as discussed in 2.3 Low-Impact Development.

2.3

The overflows shown in this map are based on existing reports, databases, anecdotal information, and interactive flood mapping with citizens engaged in the planning process. While this is not a comprehensive data set, it indicates problem areas within some parts of the Mid-South. These are areas where local planners and engineers may want to check first to start identifying areas for future capacity expansion and applying the techniques found in this section.

The severity, frequency, and causes of the flooding shown in these locations is only known if that information was provided when the data was compiled. Given the varied causes of localized flooding, each site must be evaluated individually and systematically before developing an improvement plan.



Implementation

Multi-disciplinary Teams and Long-term Plans

The complex nature of water management requires that project participants work across jurisdictions, professions, and time scales. Sewer expansion projects involve local public works and planners, the regional utility, civil and hydraulic engineers, contracted construction teams, the state environmental department, and likely federal and corporate funding partners.

At the street level, individual projects may only take a few weeks or months to implement. However, at the system level, projects routinely take decades to fully research, plan, and implement across the service area. Proactive and comprehensive planning is the key to coordinating future projects that may be designed and implemented years apart from each other.

Process

1 Initiation	Identify problem sites on the ground and work with local residents and public works to gauge extent of the problem.
2 Research	Engage engineers and scientists to formally research system capacity and potential solutions.
3 Planning	Form multidisciplinary teams with engineers, planners, and public works. Decide on a design scheme and preferred solution. Draw project plans for expanding sewer capacity.
4 Funding	Apply for funding from grants, lenders, annual municipal and state budgets, as well as capital funds.
5 Building	Engage a specialized contractor to implement project.
6 Monitoring and Maintenance	Collect hourly or daily in and outflow volumes and flow rates to interpret system function and best management practices.

1 Initiation

Problems with wastewater systems are usually apparent on the ground in the form of flash flooding, sewer overflows, or ponding water. System wide problems are reported to the local government by residents, treatment plant workers, and public works employees. Once a pattern of issues is established for an area, the local public works department, or similar entity, could reach out to the county to conduct a study.

2 Research

Municipalities engage city or contracted engineers and scientists to study the existing characteristics of the system and the degree to which it is under-performing.

Green to Gray Infrastructure Spectrum

Gray	Green/Gray	Green
Roads, Sewer/Water Pipelines Centralized treatment Collects and channels runoff High impact	**Detention Ponds and Holding Tanks** Slow release into sewer system Volume peak rate reduction	**Networks of Wetlands/Floodplain Restoration** Allows infiltration Evaporation Transpiration Enhanced air quality Reduced erosion/sedimentation Restoration Minimal impact

(Above) Adapted from PlanPhilly, Philadelphia Water Department Green City Clean Waters project, WHYY.

3 Planning

Engineers and designers, working with public works and the planning department, develop a plan to bring the system up to current and future needs. Typically, engineers design the system to handle a 100- or 500-year storm capacity and the system needs to operate on a 24-hour basis. They should also take into account the increasing intensity of storms, population growth, and anticipated development.

4 Funding

With a project in mind, towns and cities can apply for grant funding, financing, or technical assistance from the federal or state government. Money may also be allocated from stormwater funds, capital improvement budgets, or annual budgets.

5 Building

Hire a qualified engineering firm to draft plans. Bid and build the project. Build monitoring tools into the system.

5 Monitoring and Maintenance

Regularly collect data on inflow volumes, flow rates, outflow volumes. Use this data to inform maintenance and future projects.

Cost Considerations

Underground Storage

Underground storage systems can be a cost-effective way to increase sewer capacity without rebuilding the sewer system. They are most cost-effective when built into new development because design, mobilization, excavation, and construction costs can be shared with the main project. The same principle applies to renovations and maintenance of surface-based projects such as parking lots, roads, and fields. Funding for these projects may come from the developer, the city stormwater fund, or wastewater grants and low-interest financing.

Pre-cast concrete vaults cost $10-$15 per cubic foot of stormwater storage. Chamber systems, which include an infiltration component, cost $5-$9 per cubic foot of storage. Pipe systems cost $5-$7 per cubic foot of storage.[5]

Digital Mapping

Digitizing all records related to wastewater is a serious undertaking requiring specialized technicians or consultants. The overall cost for an area like the Mid-South would be several million dollars, primarily due to the labor involved in data finding and entry. Additional costs come from proprietary software, additional computers, and staff training. However, the benefits from digitizing will provide cost savings in the form of more efficient operations, better communication, easier record keeping, and more effective management. 7.1 See 7.1 Resilience Database for more information.

System Expansion

Increasing the capacity of the drains, pipes, and outflows can be expensive and time-consuming. A substantial amount of time, money, and effort goes into developing a plan with a specialized engineer. Then, since the pipes are typically under the roadway, the entire road network is dug up, street by street, over several years. The cost of the materials and labor may be less than LIDs and expanded storage. However, disruptions in service, constant construction, and long implementation timeframes may make replacing a sewer system undesirable.

Potential Partners

Potential partners for wastewater system upgrades are diverse and widespread.

On the private-sector side, **developers** should continue to implement on-site storage. This includes all types of development: commercial, residential, factories, parking lots, entertainment venues, etc. As developers renovate and add to existing properties, they can and should be called upon to upgrade existing facilities to accommodate on-site storage.

Local residents have the most knowledge about the day-to-day function of the sewer system in their area. They can be partners for information collection, monitoring, and planning. The citizen-scientist or crowd-source are examples of how to operate a program. In each case, the organization seeking information creates a website where residents can make geo-referenced notes and upload photos. As an example, volunteer residents could report how quickly an overflow recedes, providing photos of the drain at hourly intervals. For a citizen-scientist system to provide reliable data, volunteers should be recruited and trained.

MLGW is an existing partner based on its collection of the stormwater management fee. MLGW is not involved in setting rates. As noted previously, Memphis sewer rates are very low compared to the rest of the country. Given the need for investment in flood prevention, there is room to increase the stormwater fees. This is particularly true for businesses and institutions that are not currently managing their stormwater on-site. An increase of a few dollars per month would generate tens of millions of dollars for stormwater improvements. The City of Philadelphia is an example of this strategy, and was profiled as a case study in 2.3 Low-Impact Development. 2.3

MLGW is also a primary partner in implementing projects. As the three-service utility provider, MLGW has necessary information on the system, maintenance, and users. MLGW can also coordinate sewer upgrades with other underground utility projects.

The **public works departments** of all of the municipalities in the Mid-South are critical partners who should be engaged in leading stormwater improvement projects.

Likewise, **local municipal planners** can provide insight on land development trends. Once plans are established, planners can codify the design in zoning and building regulations.

Funding

Utilities that provide public water and wastewater services are eligible for **Community Development Block Grants (CDBG)**[6] operated by the Department of Housing and Urban Development (HUD). CDBG applies to a wide range of projects that contribute to the long-term development and infrastructure of a community. Example activities include planning, acquiring property, construction of public works projects, funding towards non-profits, and funding for businesses that promote community economic development. CDBGs may match FEMA grants, making them a viable option for funding of flood mitigation and recovery projects. Both Memphis and Shelby County are CDBG Entitlement Communities, meaning they can apply directly to HUD rather than through state-based programs. At the state level, the Tennessee Department of Economic and Community Development oversee the CDBG program.

The Clean Water State Revolving Fund (CWSRF) provides low cost financing for infrastructure projects related to water. Sewer and stormwater projects that may qualify for the CWSRF include constructing a publicly owned treatment works. In addition, measures to reduce the amount of water flowing into sub-surface drainage may qualify, such as stormwater recapture and reuse or conservation and efficiency.

The USDA Water and Environmental Program focuses on the water and wastewater needs of small, rural communities with up to 10,000 people. WEP is most applicable to communities in unincorporated areas and small towns outside of Shelby County. The program operates at the federal level, with the assistance of field staff across the country. Two of the three types of WEP funding are relevant for wastewater projects. The first, the Water and Waste Disposal Loan and Grant Program, provides funding in cases where commercial credit is not a viable option. Funding may be used for constructing and improving home and business infrastructure for drinking, stormwater, and wastewater management. The second, the Water and Waste Disposal Pre-development Planning Grant, provides communities with planning assistance for water infrastructure projects. The goal for grantees is to prepare an application for other USDA grants, which will then fund the project. Other Water and Wastewater Disposal funding can come in the form of loan guarantees, revolving loan funds, and technical assistance and training grants.

Also at the federal level, programs related to economic revitalization may be sources of funding, if the proposed project will enable development and job creation. **The US Economic Development Administration Public Works Program is** dedicated to improving and expanding physical infrastructure where it is needed for economic growth. For example, the PWP may provide funding for sewer system expansion on a site if the expansion will enable new commercial development there. In addition, the USEDA if offering $587 million (FY2018) in supplemental grants for economic recovery from natural disasters in 2017.[7]

In cases where wastewater infrastructure would prevent flood damage to a critical facility, the **FEMA Hazard Mitigation Grant Program** may be an applicable funding source. For example, a hospital may qualify for a grant when adding drainage and storage capacity to protect from a known flooding issue. In these cases, the cost of the damage prevented must exceed the cost of implementing the project. Applications are made at the state level.

Case Study

Toronto Sewer Upgrades,[8] Canada

The City of Toronto is proactively changing out sewer pipes in anticipation of more frequent flooding. While most cities are working on upgrading corroded pipes from the 19th and early 20th century, the Toronto project is replacing pipes that are from the 1980s and 1990s. This unusual project was prompted by two storms in the 2000s that caused over $500 million (Canadian dollars) in damage.

The frequency of intense storms prompted officials to re-evaluate how storm-design standards are applied to stormwater systems. The pipes that were installed in the 1980s and 1990s were designed to handle up what was then the five-year storm event. From 1986 - 2011 there were eight so-called 25-year storms. In other words, the 25-year storm occurred every three years. Given the frequency of 25-year storms by the 2000s, the City of Toronto increased the design storm event to the 100-year storm. In all, 32 neighborhoods will be upgraded to the new 100-year storm design standard.

In the world of stormwater management, designing for a 100-year storm is very aggressive. However, the City reasoned that over the life of the infrastructure, the 100-year storm would become the 2 to 5 year storm due to the changing climate. In other words, the City decided to design with future rain patterns to extend the useful life-span of the pipes as long as possible.

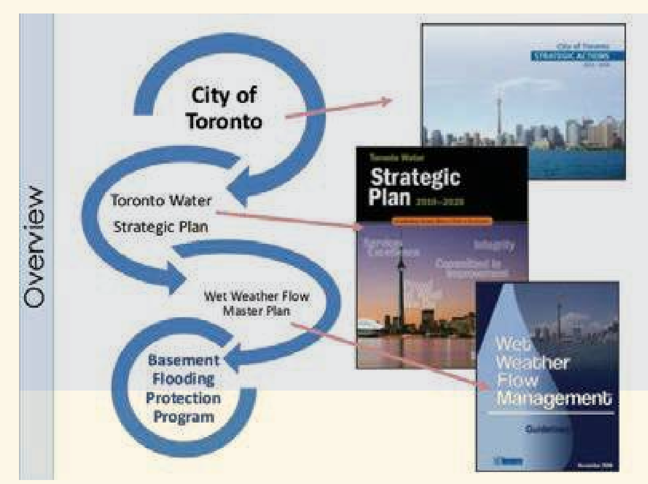
Planning stormwater infrastructure around climate predictions is not an exact science, given the variability in climate models and ever-changing scenarios. However, all evidence points towards more heavy rain events in Southeast Canada, and the Midwestern and Northeast United States. As noted in Toronto, this trend is already well underway.

The grey infrastructure pipe-replacements are part of the larger multi-billion dollar Wet Weather Flow Master Plan. The Plan addresses city-wide water quality issues associated with combined sewer overflows, rivers, and beaches as well as the general maintenance backlog. Being part of a system-wide master plan has made it easier to fund the pipe-replacement project.

(Below) The Finch Ave. culvert collapsed during a 2005 storm. Source: The Toronto Star

(Below) New infrastructure is built to higher design storm standards Source: AIL Industries

(Left) 2005 Flooding in Toronto (Frank Gunn/The Canadian Press)



(Above Left) Management Chart for the Wet Weather Flow Management Plan (City of Toronto)

(Right) The Wet Weather Flow Management Plan also addresses large scale land use changes (Waterfront Toronto)

Endnotes

1 See "Sewer Assessment and Rehabilitation Program (SARP10)," http://www.sarp10.com/.

2 LaFond, Kaye, "Water News Infographic: 2015 Price of U.S. Water, Sewer, and Stormwater," *Circle of Blue* online, April 24, 2015, last accessed March 28, 2019, https://www.circleofblue.org/2015/world/infographic-2015-price-of-u-s-water-sewer-and-stormwater/.

3 Arthur, Shea, "Director of Public Works explains stormwater, sewage fee increases," (News Channel 3 WREG Memphis online, July 17, 2017), last accessed February 5, 2018, https://wreg.com/2017/07/17/director-of-public-works-explains-storm-water-sewage-fee-increases/.

4 More information about the modeling system is available through US EPA Research at the National Risk Management Research Laboratory in Cincinnati, Ohio.

5 W R Toole Engineers, INC. and Georgia Regents University Augusta, *Underground Stormwater Detention Systems*, (Presentation at Georgia Chapter of APPA Annual Meeting, 2015).

6 "Housing and Urban Development Community Grants Available to Water and Wastewater Utilities," *U.S. Environmental Protection Agency* online, last updated January 31, 2018, https://www.epa.gov/fedfunds/housing-and-urban-development-community-grants-available-water-and-wastewater-utilities.

7 "EDA's Disaster Supplemental Funding," *U.S. Department of Commerce Economic Development Administration* online, last accessed March 28, 2019, https://www.eda.gov/programs/disaster-recovery/2018-supplemental/.

8 Kessler, Rebecca, "Stormwater Strategies: Cities Prepare Aging Infrastructure for Climate Change," *Environmental Health Perspectives*, December 2011; 119(12): a514-1519.

Resources

USEPA Stormwater Management Model

"Storm Water Management Model (SWMM)." *U.S. Environmental Protection Agency* online. Last updated October 30, 2018. https://www.epa.gov/water-research/storm-water-management-model-swmm.

USDA Water and Environmental Program

"Water and Environmental Programs." *U.S. Department of Agriculture* online. Last accessed February 5, 2019. https://www.rd.usda.gov/programs-services/all-programs/water-environmental-programs.

Clean Water State Revolving Fund

"Clean Water State Revolving Fund (CWSRF)." *U.S. Environmental Protection Agency* online. Last updated February 4, 2019. https://www.epa.gov/cwsrf.

Community Development Block Grants and Entitlement Cities

"CDBG Contacts: Tennessee." *U.S. Department of Housing and Urban Development* online. https://www.hud.gov/states/tennessee/community/cdbg.

"Housing and Urban Development Community Grants Available to Water and Wastewater Utilities." *U.S. Environmental Protection Agency* online. Last updated on January 31, 2018. https://www.epa.gov/fedfunds/housing-and-urban-development-community-grants-available-water-and-wastewater-utilities#cdbg.

US Economic Development Public Works Program

"Funding Opportunities." U.*S. Economic Development Administration* online. https://www.eda.gov/funding-opportunities/

Kessler, Rebecca. "Stormwater Strategies: Cities Prepare Aging Infrastructure for Climate Change," *Environmental Health Perspectives*, 119(12) (December 2011), a514-a519. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3262001/.

5.3 Power Lines

Selectively Bury Overhead Electrical Lines

Key Benefits

1. **Reduces power outage frequency and duration for customers**
2. **Removes unsightly overhead wires from the public realm**

Limitations

1. **High cost per mile of electrical lines**
2. **May require disruptive road work**

Overview

Power outages are a major stressor for residents of the Mid-South Region. The frequency of outages as well as duration of outages present challenges for business continuity, daily living, and health and safety. Burying power lines under the road in public rights-of-way would significantly reduce the frequency of outages for customers served by electric lines that are entirely underground between the distribution station and their residence or business. For other customers, the duration of power outages may decrease as repair workers can concentrate their efforts on the remaining above-ground power distribution lines. Burying the power lines is an expensive proposition; Memphis Light Gas and Water (MLGW) conducted a study and determined that putting all of the utilities in Shelby County underground would cost $3.6 billion. Since 1994, MLGW has spent $93 million responding to eight major storms. Based on this analysis, it would be most efficient to selectively bury overhead electrical lines across the region, rather than comprehensively bury overhead electrical lines.

5.4 5.5 Selectively burying overhead lines may only be part of a more comprehensive and appropriate solution. See 5.4 Smart Grids and 5.5 Community Energy for more information on improving systemic resilience in the electric grid.

(Left) During storms, winds may bring trees down onto power lines disrupting service across the grid. Source: Red's Complete Tree Service

Regional and Local Resilience in Power Transmission

Nearly 1,000 miles of linear transmission lines cross the Mid-South Region. The majority of these lines are overhead lines, susceptible to damage from extreme weather events and falling trees. Over 83% of these lines are owned by the Tennessee Valley Authority (TVA) and outside the purview of utility organizations in the Mid-South. 5.5 See 5.5 Community Energy for more information on energy distribution territories.

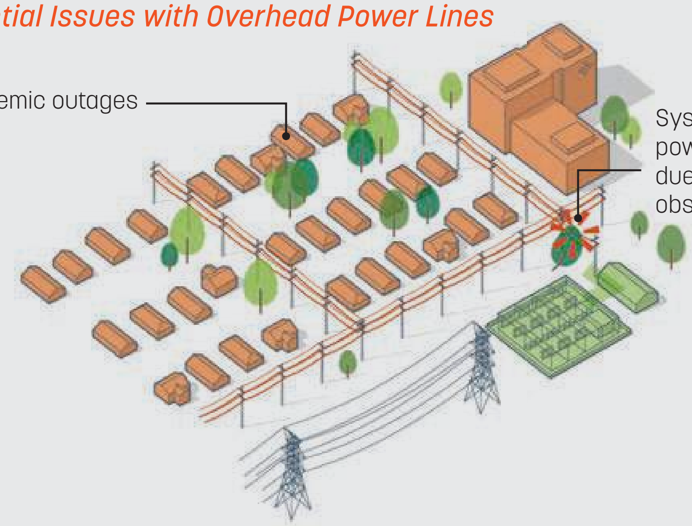
While regional transmission lines may be costly to bury, local overhead power distribution lines offer more opportunities for interventions that enhance power resilience across the region. The following pages describe three strategies to support this goal:

5.2.1 Bury Hard-to-Access Overhead Lines

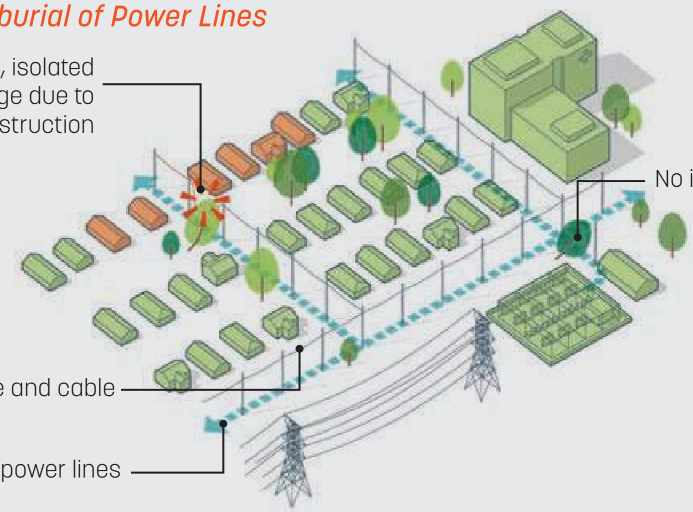
5.2.2 Bury Power Lines on Major Tree-Lined Corridors

5.2.3 Require New PDs to Bury Power Lines

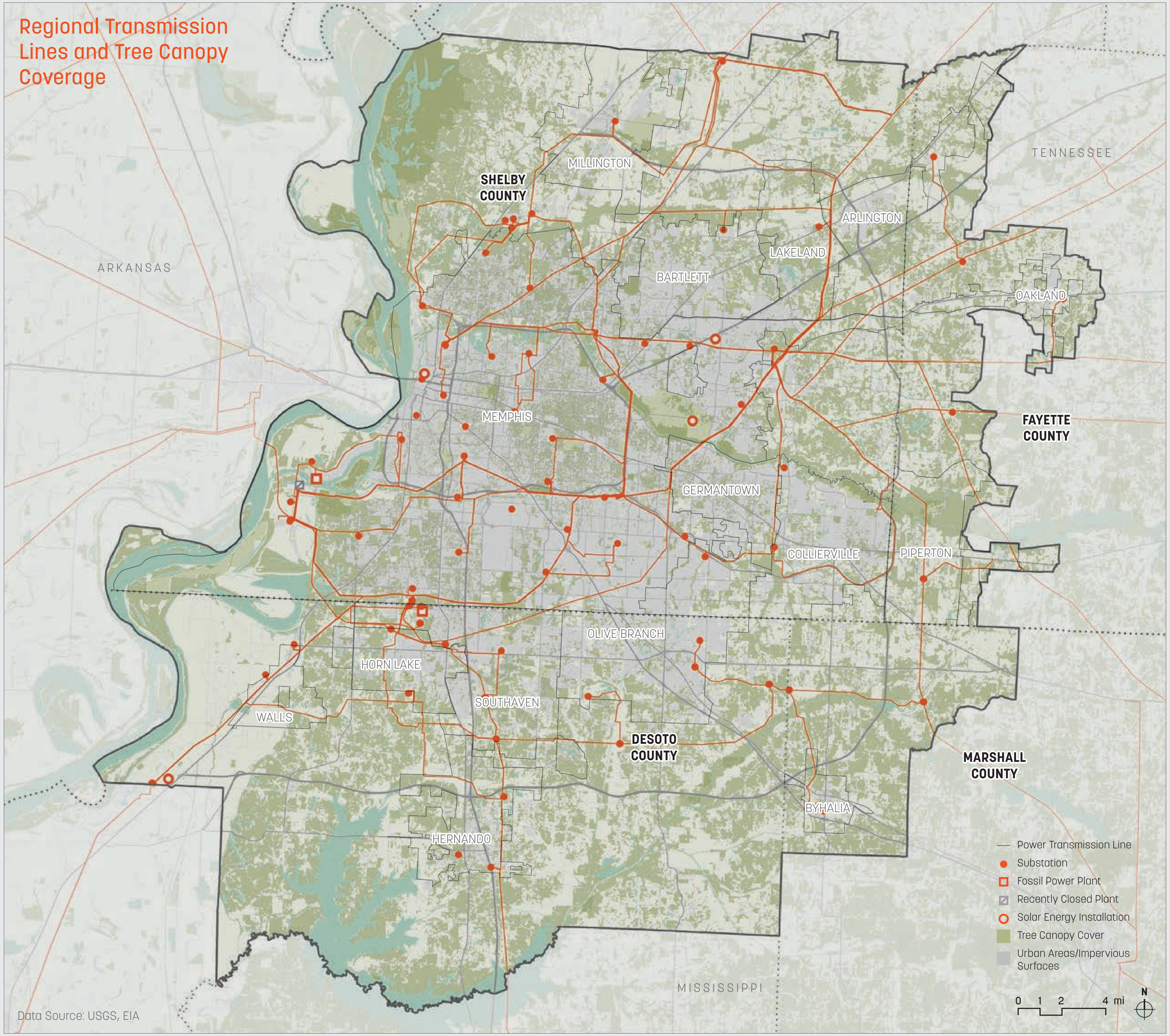
Potential Issues with Overhead Power Lines



Post-burial of Power Lines



Regional Transmission Lines and Tree Canopy Coverage



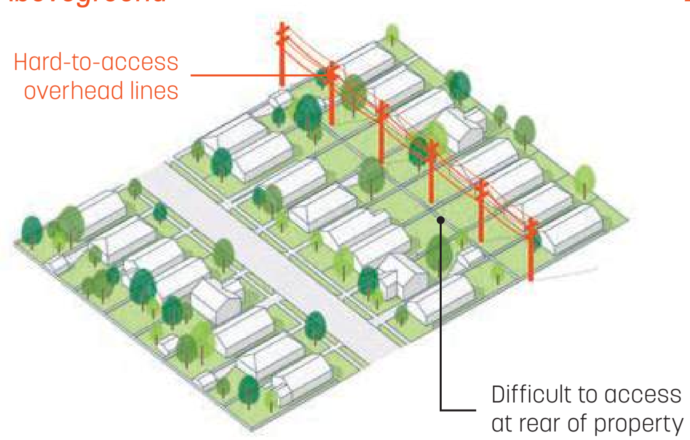
5.2.1 Bury Hard-to-Access Overhead Lines

In parts of the region, overhead power lines are located along rear property lines. This creates challenges for utility crews trying to conduct maintenance operations at reduced risk of a power outage, such as tree-trimming or equipment upgrades and replacement. Since access must be granted by property owners, it can be a create a hurdle for utility crews who must access the lines for repair in the event of an outage.

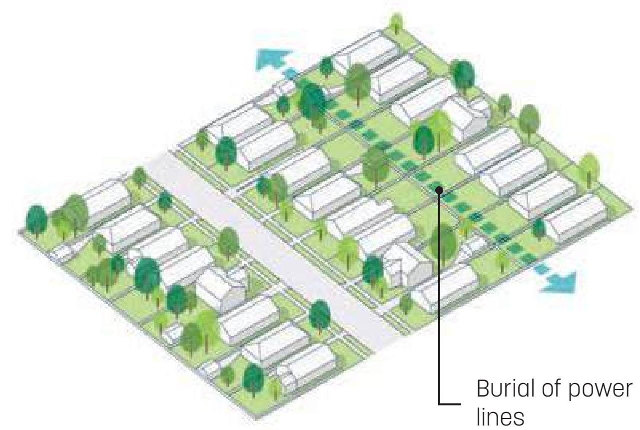
In Memphis, this condition is most often found in older parts of the city which have relatively high density, with more customers served per mile of electric line than in other parts of the region.

In these areas, MLGW should evaluate the cost effectiveness of burying overhead electrical lines based on the frequency of outages, duration of outages, customers affected, and the direct and indirect cost of the outages.

Aboveground



Below Ground



5.2.2 Bury Power Lines on Major Tree-Lined Corridors

Many power outages in the region are the result of straight-line or tornado wind events which cause trees and their branches to fall onto power lines, causing them to break.

Primary distribution lines, distribution lines along heavily-treed corridors, and distribution lines in neighborhoods targeted for economic development are all candidates for undergrounding of electrical lines.

5.7 See 5.7 Trees for more information on tree-lined streets and infrastructure.

(Right) Burying power lines under existing right-of-ways in Seattle, Washington.

5.2.3 Require New PDs to Bury Power Lines

New planned developments (PDs) in the Mid-South are prime candidates for underground electrical service. A significant portion of the cost of undergrounding utilities includes excavation of land and then restoring conditions at-grade. The wide variations in terrain conditions, soil types, and other existing obstacles accounts for the wide range in cost estimates. In new PDs, utility trenches must be excavated for other utilities, such as waste and water pipes. Thus, the potential for joint-use trenches significantly reduces the marginal cost of underground electrical service as compared with overhead lines.

Requiring new PDs to bury electrical service would reduce the frequency of outages for residents of the new community while reducing the duration of outages for other customers. Customers in the new PD would still be susceptible to outages along distribution lines between the substation and the point of undergrounding but would benefit from portions of their electrical distribution service being housed underground. This directly benefits existing customers outside of the PD, as existing maintenance and repair teams have fewer of the more-susceptible-to-damage overhead lines to potentially maintain or repair. As many of the new PDs are sited on the outskirts of existing development, burying these service lines would correlate to fewer vehicle miles traveled for repair teams, who are able to focus in the urban core.

Though there may be some additional marginal cost associated with undergrounding power lines even in PDs, the aesthetic benefits and potential to reduce power disruptions increase the value of the proposed properties. In Maryland, the assessed value of new homes with underground electrical service was 2.5% more than new homes with overhead electrical service when controlling for other variables.

(Above) Burying power lines in new PDs adds value by preventing unsightly overhead wires.

Implementation

Undergrounding, or burying, electrical lines is often the purview of electricity distribution companies or agencies. For existing overhead power lines, this task will likely need to be coordinated with local Departments of Public Works who will either assist with digging up the roadway and re-paving or hiring and approving a contractor for this task. Ideally, undergrounding of existing lines along roadways would occur at the same time as other roadwork to minimize disruption and mitigate costs. For utility lines that must be accessed (or are most easily accessed) from private property, property owners must be identified, notified, and grant permission before work may start. For new electrical power lines, often intended to serve future planned development sites, the underground installation can occur at the same time that other underground utility infrastructure is installed, such as waste and water pipes.

Process

1 Identification	Identify neighborhoods where electrical distribution lines are located at the rear property lines Identify neighborhoods where distribution lines are frequently felled by downed trees during wind storms
2 Design and Implementation	Design segments for undergrounding that include comprehensive distribution segments Establish rate increase tables for customers to pay for undergrounding Schedule undergrounding construction in tandem with other utility and roadwork projects.
3 Maintenance	Assign routine maintenance responsibilities Monitor routine maintenance to ensure completion

1 Identification

The identification stage is the first step in the process of selectively undergrounding electrical service lines. It will not be cost effective to bury all existing overhead electrical lines. Instead, feeder distribution lines that are in hard-to-maintain or particularly-susceptible-to-damage areas should be buried.

Outage data should be used to prioritize which electric lines to bury first. Feeder distribution lines that provide service to large numbers of downstream residents should be reviewed first; those with the highest System Average Interruption Frequency Indicator (SAIFI) numbers should take the top priority.

Next, feeder distribution lines that have the highest System Average Interruption Duration Indicator (SAIDI) numbers should be buried. These are likely to be those in hard-to-reach areas, including power lines located along rear property lines. In all cases, historic data from electricity service providers should be used to prioritize lines for undergrounding.

In some instances, feeder distribution lines may provide service to critical facilities or important economic impact sites; in these cases, these lines should also be prioritized. Funding partners may be identified to defray the costs if possible, including owners of private companies or owners and operators of critical facilities.

2 Design and Implementation

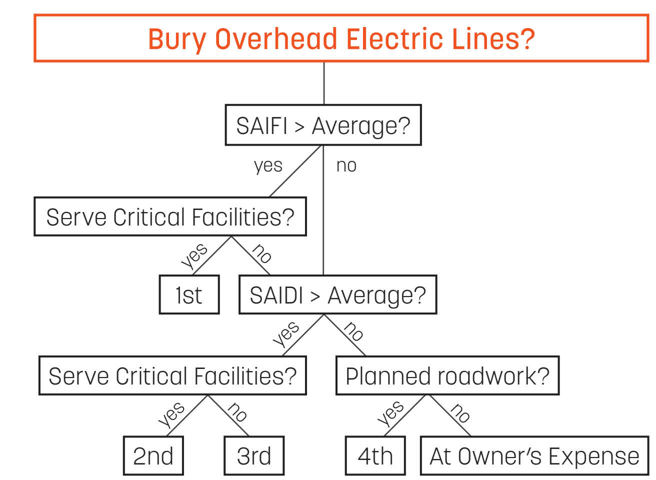
Design and implementation of underground electric service is most typically done in partnership with the energy distribution agency (MLGW, Entergy, or Southwest Tennessee Electric Membership in the Mid-South) and the local department of public works. The local DPW would typically be responsible for construction and excavation of the underground facilities, and the distribution agency would install the underground electric lines. The excavation work can be disruptive to local businesses and residents, impeding access to buildings for durations up to a week under normal conditions. Prior to construction, community engagement meetings could give businesses and residents the opportunity to raise concerns related to the schedule, duration, and process of undergrounding utilities.

3 Maintenance

Maintenance of underground utilities can be more complicated than maintenance of overhead electrical lines due to issues around identification of the problem source, as well as access to make the repair. Both identification and resolution of the problem are more challenging, and likely require some excavation, which can be costly.

In spite of this, total maintenance costs per mile for underground utility lines are typically less over time than maintenance costs for overhead utility lines as they are less susceptible to damage and require less overall maintenance. Though direct maintenance costs of overhead lines do not typically exceed the initial costs of burying a power line, even over a 30-year time horizon, indirect costs can support the decision to bury existing overhead power lines. In 2009, a study prepared for the U.S. Department of Energy indicated that an 8-hour power outage cost the average residential customer $10.70 per instance, cost a small commercial or industrial customer $4,768, and cost a medium to large commercial or industrial customer over $90,000.[1] Repeated power outages of significant duration would be considered enough of an operational cost that some commercial or industrial customers would relocate from the region, having a negative economic impact.

Prioritization Decision Tree



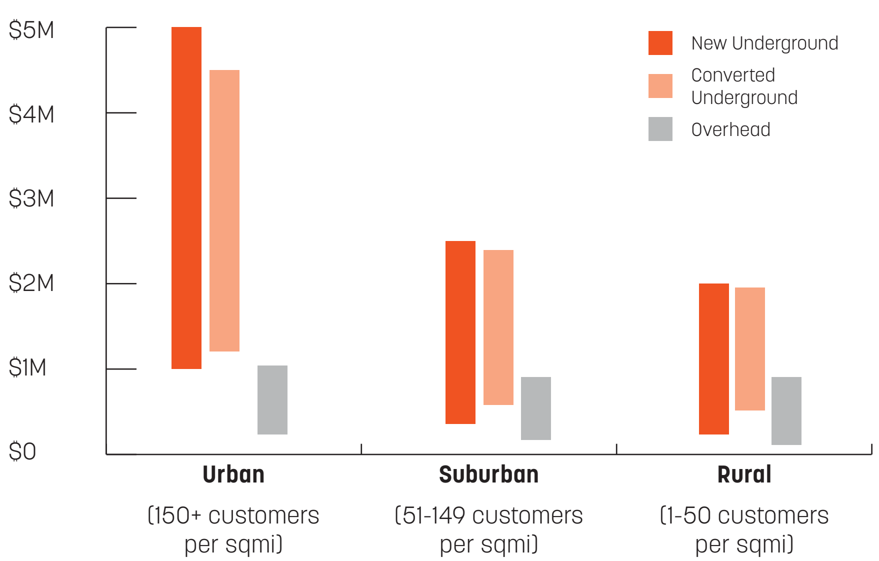
Costs

Typically, most of the cost of undergrounding utilities is born indirectly by customers. For conversion projects, initial funding is provided by energy distribution agencies and local governments. Local governments may then pass the cost on to energy distribution agencies in the form of a charge. Local energy distribution agencies then typically pass all costs on to customers. In some instances, there may already be a fee associated with infrastructure resilience that can wholly or partially offset this cost. Though the total cost of undergrounding electricity infrastructure is high, the fees passed on to customers are typically limited by existing agreements with energy distributors, so the average monthly increase in payments is less than a few dollars a month over the course of several years. For planned new developments, the marginal cost of undergrounding utilities, beyond the baseline overhead utility connections that an energy distributor would provide, is often passed on to developers, who then pass that cost on to new property owners as part of the purchase price of the property.

Costs to bury electrical lines also vary widely depending on site conditions. Urban locations are often more costly due to the relatively complex site conditions beneath roadways. Generally speaking, less dense areas have fewer utilities and other site elements competing for space, and burying electrical lines costs less. In order to understand the full picture, the number of affected customers per mile of buried power lines should be considered as well, i.e., cost per mile per customer.

Conversions of overhead power lines to underground power lines are often able to take advantage of some existing electrical infrastructure, so can have lower maximum costs. Burying new electrical lines requires the same site work as a power line conversion, but is often part of a larger development project where the cost of the site work would be included across several project budget lines. This is similarly true if power line conversions are done in tandem with planned roadwork. This significantly mitigates the marginal cost of burying power lines. Approximately 75% of the cost of burying power lines is due to necessary site work, including excavation.

Construction Cost Per Mile[2]



Cost Sharing

Electric distribution lines have traditionally been placed underground for three reasons: customer request, at the request or requirement of a municipality, or because the local electric distribution utility has determined that it is required for safety, reliability, or cost reasons. Depending on the reason for the undergrounding or the source of the request, the cost of undergrounding is born by different parties in different ways.

1. **First few feet free.** A utility company may offer the first hundred feet of underground service free to a customer (often the builder of a planned development), charging the customer only for the connection from the feeder line to an individual residence or building.
2. **Cost difference approach.** A utility company may charge a new customer the cost difference between an overhead line and an underground line, with the utility covering the difference as the cost of the overhead line would have been borne by the company anyway.
3. **Rate based approach.** A utility company may charge a standard fee to all customers that pays for undergrounding over time. This may be to meet customer demand for undergrounding, municipality undergrounding targets, or part of standard operations on the part of the utility to improve reliability or reduce maintenance costs.
4. **Matching funds or services approach.** A utility company may work with a municipality to underground electric service. The municipality may provide trenching services (based on unrelated roadwork plans) to defray the cost to the utility. The remaining cost to the utility can either be assumed as part of standard operating costs, or passed on to customers through a fee.[3]

Case Study

Multi-stakeholder Collaboration, Washington DC[4]

Extreme weather events between 2010 and 2012 triggered scrutiny of Washington DC's electric system. A task force comprised of representative stakeholders, including local government officials, the Public Service Commission, Pepco (the local electric utility), and business and resident representatives evaluated options to improve resiliency and reliability of the electricity system during severe weather.

Using outage data and service value to the community for all overhead feeder lines, the task force identified criteria for moving electric feeder lines underground. The criteria included frequency of outages, duration of outages, and economic impact of outages. The first six feeder lines will be buried over a two-year period. They collectively serve 7,858 customers, and the estimated cost of the project phase is $134 million. The total project cost for the six-year initiative is $500 million.

Before construction began, many community engagement events were held to inform customers about the project, including the expected impact of construction, the anticipated benefits of a more reliable electric grid, and the estimated costs of the project.

Half of the cost of the project will be borne by Pepco. This cost will be passed on to customers through controlled increases to monthly charges. The estimated impact for a typical residential customer is $0.05 to $0.14 per month. Nearly 38% of the cost of the project will be funded by the District through a charge imposed on Pepco. It is expected that these costs will also be passed on to customers. The estimated impact for a typical residential customer is $1.05 per month. The District Department of Transportation will contribute $62.5 million to the project. The total monthly bill impact for a typical residential customer is expected to be between $1.10 to $1.19 per month. Customers who receive discounts based on income qualification will not experience fee increases.

Oftentimes, there are specific electric system components that are less reliable (or more susceptible to damage) than others. This can be due to aging equipment, environmental context, or a combination of the two. Thus, it is not often necessary to underground an entire electricity distribution network in order to significantly improve system reliability and resilience.

Cost Sharing

Stakeholder	Contribution
Pepco	$250 million
District of Columbia	$187.5 million
District Department of Transportation	$62.5 million

2010 Study of the Feasibility and Reliability of Undergrounding Electric Distribution Lines in the District of Columbia[5]

Option	Total Cost	Reliability Improvement
Undergrounding all existing overhead assets	$5.8 Billion	1,030 fewer outage events annually
Undergrounding all mainline primary and laterals	$2.3 Billion	924 fewer outage events annually
Undergrounding all mainline primary	$1.1 Billion	462 fewer outage events annually

Prior to commencing the undergrounding project in Washington, DC, a consultant team found that undergrounding the entire system would cost $3.5 billion more than undergrounding only the mainline primary and lateral lines, but only approximately 100 annual outages would be prevented. Thus, when the City was ready to move forward with an undergrounding project, a more nuanced, data-driven approach was used to establish the criteria for selection of the lines to be buried.

Endnotes

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2 Hall, Kenneth L., PE, Out of Sight, Out of Mind An Updated Study on the Undergrounding of Overhead Power Lines. (Edison Electric Institute, 2013), 31.

3 Hall, Kenneth L., PE, Out of Sight, Out of Mind An Updated Study on the Undergrounding of Overhead Power Lines. (Edison Electric Institute, 2013), 41-42.

4 Smith, Aaron, Ronald Williams, and Morgan O'Donnell, District of Columbia Power Line Undergrounding (DC PLUG) Initiative (2017).

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5.4 Smart Grid

Implement a Smart Grid System to Mitigate Power Outages

Key Benefits

1. **Makes buildings more resilient to power outages**
2. **Improves building comfort during extreme heat and cold weather**
3. **Can be combined with other social assistance programs**

Limitations

1. **Replacement of entire electrical grid is a very large scope and may divert funds from other services**
2. **Does not provide relief from power outages near generation sites**

Overview

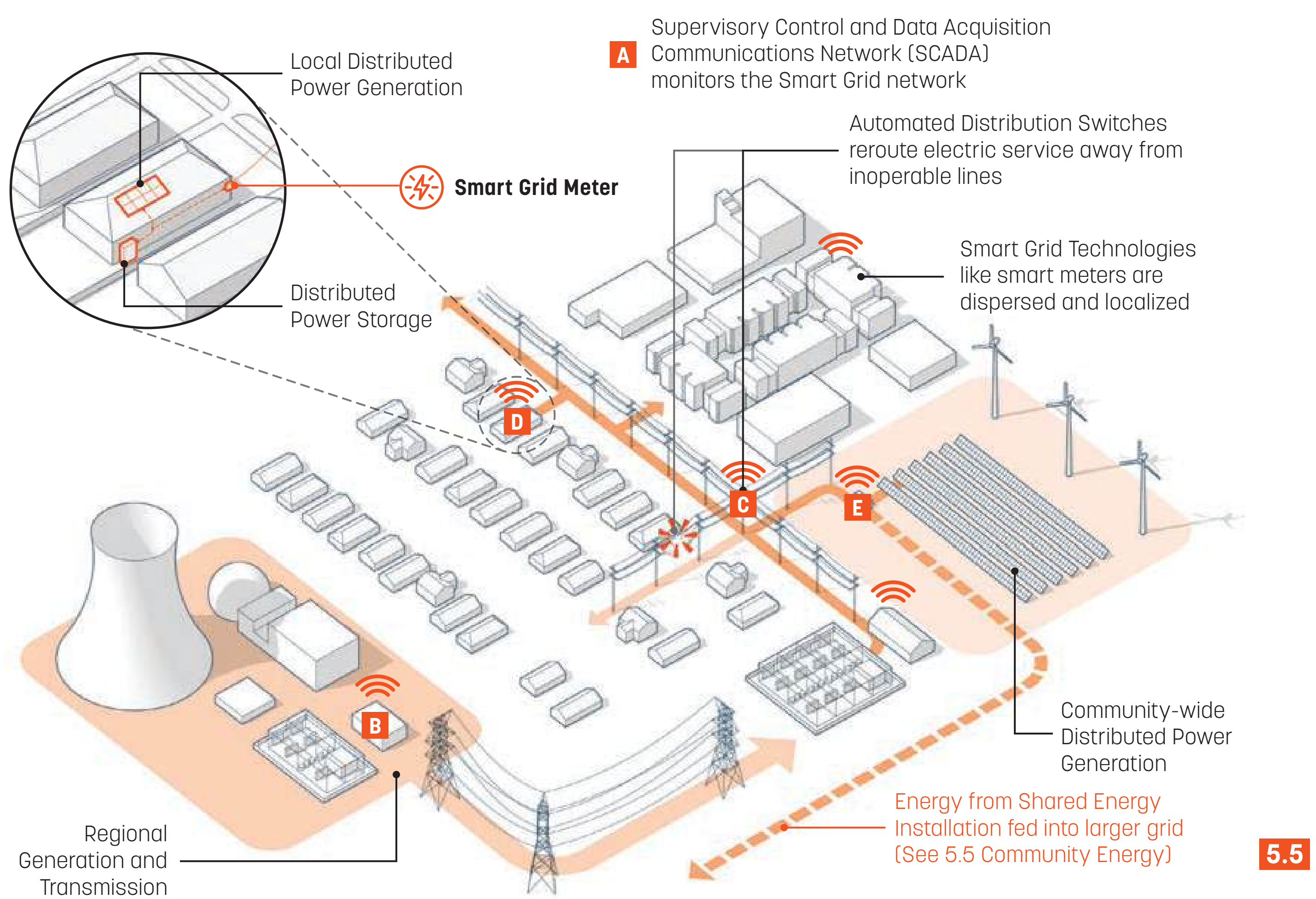
As most of the frequent power outages in the Mid-South occur between the neighborhood transformers and the distribution lines that carry electricity to houses, the outages need to be addressed at the local scale. The traditional power distribution systems that are predominant in the region operate similarly to string lights: one outage due to a broken line or transformer causes a power outage for every customer "downstream" of the issue. A distribution automation (or Smart Grid) system relies on a series of components at the local scale, such as smart meters at every building address, to the neighborhood scale, such as automated switches. All of the components rely on dynamic system controls that receive messages of outages from individual smart meters to identify issues and reroute power distribution through alternative switches. This system also helps pinpoint the place of damage for repair crews, enabling them to fix the problem faster and restore normal operations.

(Right) Localized power outages leave parts of Manhattan completely dark after Superstorm Sandy.

What is a Smart Grid?

“Smart Grid” refers to a network of devices and technology that help ensure continuity of electric power delivery by monitoring and protecting electricity delivery through automated, or “smart”, system monitoring.[1] By automating the monitoring systems, electricity distribution can be more dynamic, avoiding downed power lines and ultimately can provide increased energy security in the event of natural disaster or in defense against local disruptions. Smart Grid technology can manage a wide range of inputs (such as local energy generation) and optimizes outputs (electricity delivery) across a variety of residential, commercial, and industrial customers. The diagram below illustrates the use of Smart Grid technology to manage electricity distribution across the grid with sensors and automated switches that optimize energy use and protect the system when disruptions happen.

Smart Grid Technology within a Larger Distribution Network



Not to scale, for diagrammatic purposes only.

5.4.1 Smart Grid Technology

Smart Grids are comprised of many components. Some of the components can be implemented in relative isolation and provide benefits to consumers or distributors in the form of reliability, cost savings, or energy efficiency. The individual components are listed below from the most local to the most remote. Recommendations in this section only address power outages during distribution (as opposed to generation or transmission).

A Supervisory Control and Data Acquisition Communications Network

The supervisory control and data acquisitions (SCADA) communications network is the system that controls and monitors all of the software and hardware components in the Smart Grid network. The SCADA communications network is the hub for the Smart Grid and offers a human interface and data management component. Within the SCADA, human operators can adjust the triggers or thresholds for other components of the Smart Grid.

B Smart Relays

Smart relays monitor the electrical system for changes in voltage, currents, or frequency, serving as early-warning systems in the event of failure at any point in the grid. They operate at the transformer level. They send signals to switches and other devices that can control electric power distribution across the electric grid. Smart relays are part of the communication link within the grid, and as such can adjust signals automatically, based on predefined thresholds, or can be adjusted remotely from the central communications hub. The smart relays can also store data to provide utilities with information about power system conditions.

C Automated Distribution Switches

Automated distribution switches are part of the communications link in the Smart Grid, shown as letter B in the diagram on the page to the left. They operate at the distribution line level. They can detect if power distribution has been disrupted at any point in the grid network and automatically “self-configure” to redistribute power through other distribution lines. This helps reduce the length and frequency of power outages to consumers.

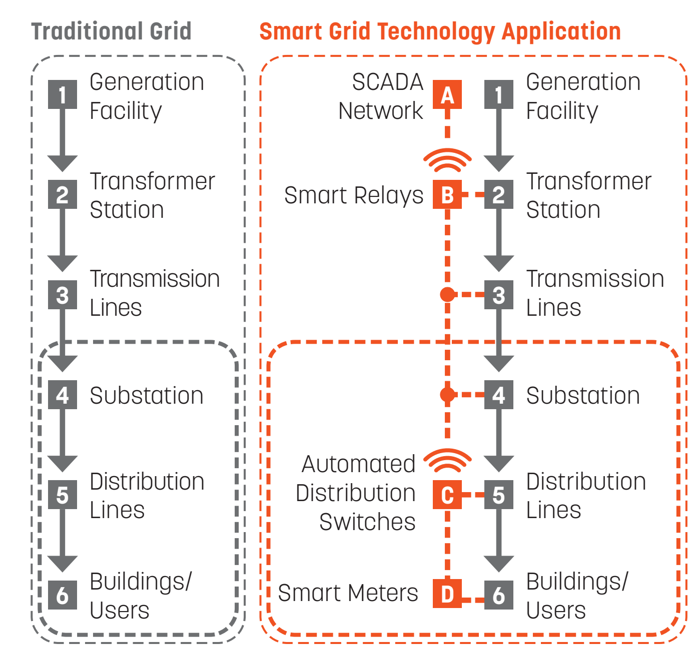
D Smart Meters

Smart meters replace the conventional electric meter at individual residences or buildings. They have a communication link with the electric grid communications network. This communication link allows remote power quality and load monitoring, so that outages can be immediately detected and located. While smart meters can support broader Smart Grid improvements, on their own, paired with a central communications center, they can offer valuable information about the location of power outages, expediting repair. In 2017, MLGW finished installing smart meters at all residential locations and saved $1.75 million in connection and reconnection fees in that year alone. Commercial and industrial meter installation will be completed in 2019.[2]

E Equipment Condition Monitor

A smart equipment condition monitor can provide real-time information about the condition of any smart asset connected to the Smart Grid. The monitors help identify necessary maintenance or replacements prior to failure, improving reliability.

Smart Grid Application (Generalized Example)



(Above) Smart Grids can benefit each stage of the electricity generation, transmission, and distribution cycle. A disruption at any stage can cause cascading power outages throughout a traditional grid system while in a Smart Grid Network, communication technologies allow the grid to share information across each node.

5.4.2 Energy Production and Storage

Energy production can be an important part of any Smart Grid system. When power outages are due to events at the generation site or along the transmission lines, a local source of energy production can help keep the local grid supplied with power. Local energy production sites are connected to the local distribution network, with output that can be controlled by other Smart Grid components.

Distributed Generation

Redundant power generation significantly contributes to the reliability of the electric grid. Local, distributed power generation, often in the form of renewable energy production modes such as solar panels or wind turbines, can offer additional sources of power for automated distribution switches. Due to the existing arrangements with the Tennessee Valley Authority, local electric power distribution companies are limited in power generation opportunities. A few pre-negotiated community-wide power generation projects exist within the region. However, more exploration into the feasibility of community-wide power generation is needed. See 5.5 Community Energy for more information.

5.5

Individual property owners are also able to generate their own power. More information on opportunities for local photovoltaic systems and energy savings can be found in 3.5 Green Building Retrofits.

3.5

Distributed Energy Storage

Distributed energy storage is commonly referred to as "backup battery storage." Energy storage is often paired with energy production. The size of energy storage devices is often related to the required energy to power emergency systems. Energy storage devices are mostly owned and maintained by individuals, but contribute to the reliability of the overall grid by reducing total demand on the electric system during a time of reduced supply.

Implementation

Potential Partners

The project leads for Smart Grid implementation in the Mid-South would be the utility distributors, including MLGW and Entergy. Potential partners for Smart Grid implementation include Departments of Energy at the state or federal level, who may offer technical, logistical, or financial support to utility distributors, and the Tennessee Valley Authority (TVA), the primary energy producer for the region. The TVA could help create or maintain a distributed power generation system that ensures one plant failure does not leave the region without power.

Cost/Benefit Factors[3]

Most of the costs of a distributed automation system are paid at the front end of implementation: purchasing and installing the components, training staff on the SCADA system, and various other licensing, software, and IT fees.

The benefits of a distributed automation system are realized over the life of the system. The benefits include:

- Labor cost savings as repair teams can be directed to the exact location of an outage and spend less paid time "searching" for the issue.
- Labor cost savings as outages are proactively identified during work hours, rather than waiting for customer calls which come during overtime hours.
- Health and safety benefits as automated distribution requires fewer person hours during hazardous conditions, allowing employees to focus on system improvements rather than maintenance or repair.
- Cost savings due to fewer vehicle miles traveled (cost of wear and tear on the vehicles and cost of gasoline).
- Environmental savings with fewer carbon emissions from repair trucks searching for the source of an outage (and less traffic on the roads).
- Consumer cost savings include greater protection from business interruptions or lost food supplies during outages of extended duration.

Funding Sources

Most costs associated with Smart Grid implementation will be paid by electric utility distributors, MLGW and Entergy. Previously, federal grants specifically designed to improve utility reliability or fund Smart Grid improvements paid for up to 45% of project implementation, but these programs largely concluded at the end of the American Recovery and Reinvestment Act (ARRA). This initial federal program allowed 99 pilot projects to be implemented across the country, and the results have demonstrated positive returns on the investments. In Chattanooga, a $50 million investment in a Smart Grid yielded $1.4 million in direct cost savings from one storm alone, which does not factor in the indirect costs avoided by customers. Duke Energy, which serves customers in five states, made almost $190 million worth of Smart Grid investments to their system in 2011. Over a twenty year period, they expect the revenue and benefit streams of the investment to exceed $190 million in 2011, which does not include the avoided costs on behalf of customers experiencing an outage.[4]

Costs

In the Mid-South, MLGW has already begun implementation of a Smart Grid. The installation of the communications infrastructure and distribution automation system cost $11,482,935 and realized $500,000 in reduced troubleshooting and maintenance costs in the first year. This initial investment was part of the Smart Grid Investment Grant program, which was part of ARRA.[5] Since then, MLGW has completed the replacement of all residential electric meters with Smart Meters, with plans to continue the replacements for commercial and industrial customers through 2019.

Case Study Costs[6]

Case Study	Distribution Circuits Impacted	Total Customers	Total Cost
Electric Power Board of Chattanooga	232 (of 370)	172,079	$49.8M
Duke Energy	N/A	4,514,000	$189.5M
Consolidated Edison	840 (of 2,297)	3,578,188	$272.3M
Centerpoint Energy	188 (of 1,516) and 31 (of 240) Distribution Substations	2,320,156	$120.6M
PPL Electric Utilities Corporation	50 (of 1,152) and 10 (of 376) Distribution Substations	1,396,751	$38.1M

Case Study

Distribution Automation in Chattanooga, TN

The Electric Power Board (EPB) is a municipal/public utility operating across Chattanooga in both Tennessee and Georgia. The EPB received funding from the American Recovery and Reinvestment Act (ARRA) to upgrade several aspects of their system. The EPB used its Smart Grid Investment Grant (SGIG)[7] to install a fiber optic communication system, advanced metering infrastructure, and automatic feeder switches. The results from this upgrade have had tangible effects on the reliability, efficiency, and resiliency of the EPB system.

Between 2011 and 2014, EPB spent $49,878,568 to install 1,294 automated feeder switches. These switches automatically identify and isolate issues and re-route around system disruptions.

The EPB Smart Grid Project as a whole cost $232,219,350, of which the Federal government paid for nearly half. A focus of the overall project included laying "an ultra-speed, high-bandwidth," fiber optic network for system communication and other services.

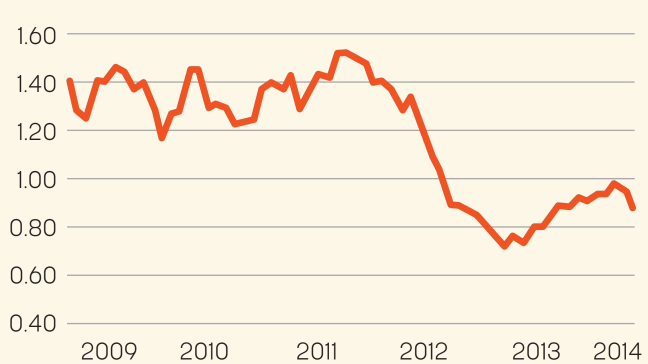
The 2016 U.S. Department of Energy Distribution Automation report includes a detailed study of the effect of automated feeder switches on the EPB system. Key metrics used to measure system improvements include the number of customers interrupted (CI) and the number of total customer minutes of interruption (CMI). These numbers are averaged across the system to show how frequently and for how long power was typically interrupted i.e., the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI). The results are summarized below.

EPB Distributed Automation Summary:

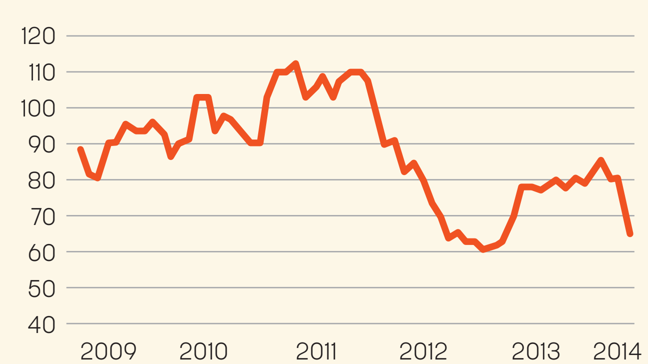
- Total cost: $49,878,568
- Automatic feeder switches Installed: 1,294
- Number of impacted distribution circuits: 232 (63%)
- Associated reduction in SAIFI: 30%
- Associated reduction in SAIDI: 20%

In addition to resiliency from weather events, the SGIG grant has improved customer experience on a day to day basis. New automatic metering infrastructure (AMI) combines smart meters on individual meters with an online portal. Customers with smart meters now have better access to data on their own electricity use and faster communication with EPB about service issues. A time-based rate program allows customers to pay less for electricity at non-peak times. This saves customers money and reduces the peak demand on the grid.

Reduction in SAIFI From 2009 to 2014



Reduction in SAIDI from 2009 to 2014



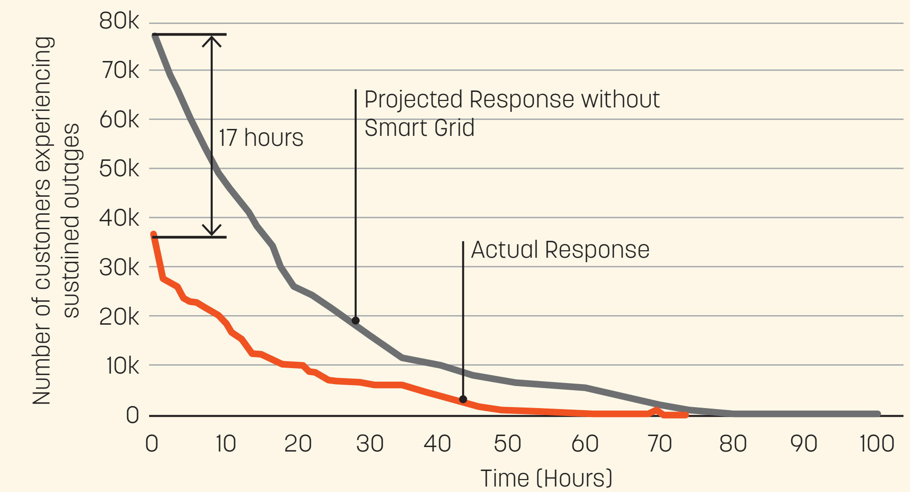
(Above) SAIFI and SAIDI Performance for EPB, 2009 to 2014. Adapted from Distributed Automation, 36.

Distribution Automation Performance

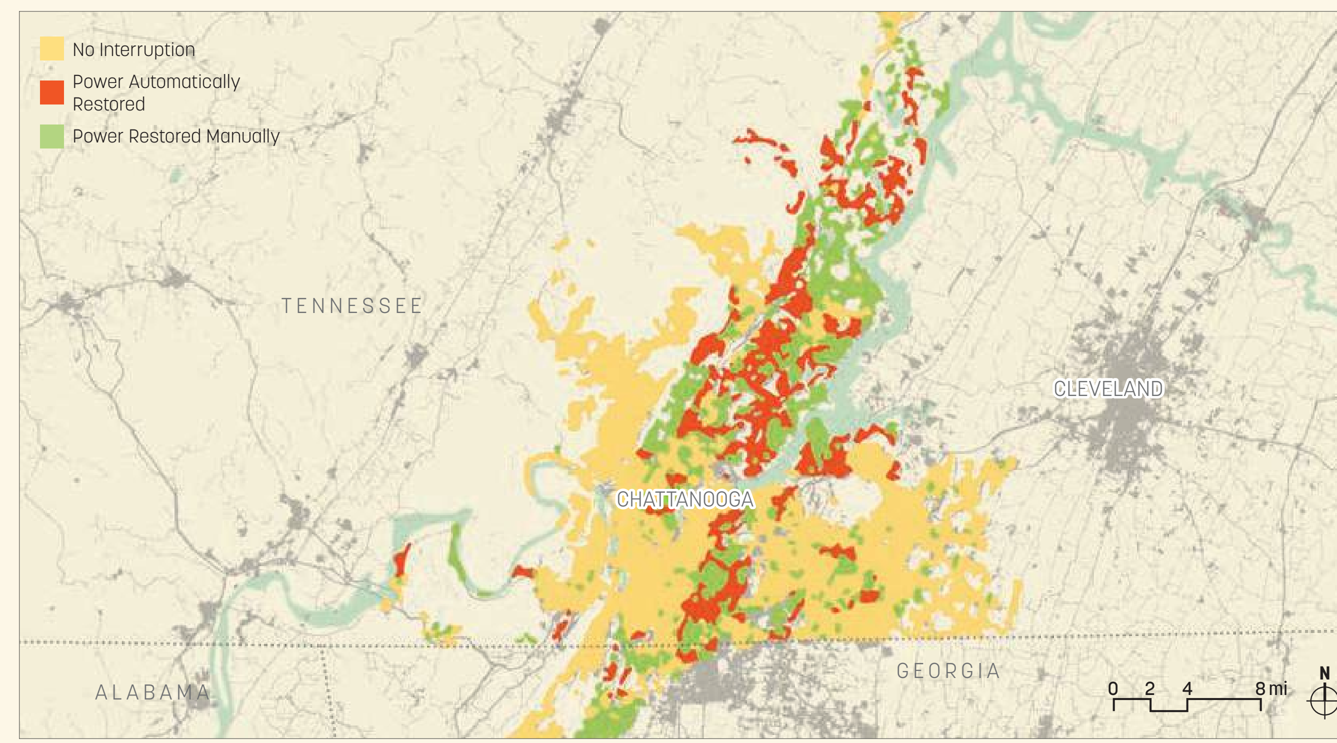
Two specific storms, in 2012 and 2014 respectively, are used as examples to illustrate how the Smart Grid helped improve system resiliency.

2012: Faster Power Restoration

During a July 2012 storm, it is estimated that the average length of an outage was cut in half, down to 17 hours.



(Right) Improvement in Service Restoration by EPB Following a Storm in July 2012. Adapted from Distributed Automation, 38



(Above) PB MAP of Outage and Restoration Patterns during a Snowstorm in February 2014. Adapted from Distributed Automation, 39

2014: Automatic Restoration

During a 2014 snowstorm, the EPB estimates that 37,000 customers avoided power outages because of the automated switches. Due to the avoided outages and the better fault detection systems, EPB restored service 36 hours faster than they would have with the old system. The financial savings were estimated at $1.4 million.

Endnotes

1 More on what defines a "Smart Grid" can be found within the Energy Independence and Security Act, H.R. 6 110th Cong., 1st Sess. (2007), 299. https://www.govinfo.gov/content/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf.

2 Memphis Light Gas and Water, 2017 Annual Report, http://www.mlgw.com/images/content/files/pdf/MLGWAnnualReport2017-web.pdf, accessed March 2019.

3 *Distribution Automation: Results from the Smart Grid Investment Grant Program*. U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, September 2016.

4 *Distribution Automation: Results from the Smart Grid Investment Grant Program*. U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, September 2016.

5 *Implementation of Smart Grid Technology in a Network Electric Distribution System*

6 *Distribution Automation: Results from the Smart Grid Investment Grant Program*. U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, September 2016.

7 The SGIG program was authorized by the Energy Independence and Security Act (EISA) of 2007, Section 1306, which provides matching federal funds for smart grid investments.

References

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5.5 Community Energy

Expand Cooperative and Community-Based Energy Systems

Key Benefits

1	**Decentralized control over energy promotes autonomy in energy management and can mitigate widespread power outages and high administrative costs**
2	**Community-ownership models can promote resource conservation**
3	**Provides renewable energy options for those who cannot implement systems on their own property**

Limitations

1	**Operations may be hindered with loss in economies of scale and complexities of governance**

Overview

Community-scale systems (such as microgrids) can help build systemic resilience and mitigate the danger of overall systemic failure by decentralizing critical aspects of energy and water distribution. This section elaborates on the steps needed to implement a community-based system within the larger network. Special emphasis is given to the differences in utility companies that share energy distribution territory within the Mid-South and the ownership structures that enable localized distributed energy infrastructure. Additionally, this section directs interested communities, utility and government personnel, and green entrepreneurs to important resources for expanding on community-scale solutions.

(Right) The West Tennessee Solar Farm in Haywood County, TN. Operated by Chickasaw Electric Cooperative and the Tennessee Valley Authority.

Utility Cooperatives in US History

When it comes to infrastructural systems, scale matters. This is especially true given the technological and managerial complexity inherent in electricity generation and delivery systems. Outside large metropolitan areas, decentralized, local utilities have played a critical role in powering rural communities. When it comes to resilience, decentralization and localization bring certain benefits. Larger, centralized systems often lack adequate redundancy in their networks and may be prone to failure. Localized systems may offer a buffer to widespread power outage. Larger organizational structures such as investor-owned enterprises may also not be as attentive to local needs, leaving gaps in coverage or creating other inefficiencies. Through local management structures and the implementation
5.4 of smart grid technologies (See 5.4 Smart Grids), many infrastructure systems can withstand a range of hazards. A key organization in the development of electric infrastructure in the United States was the creating of rural electric cooperatives.

In the 1930s, as many of the urban areas had already built comprehensive electric infrastructure, much of the rural area of the country had been left behind. Being too large of an area with too-few inhabitants, it was simply unprofitable for larger companies to build infrastructure and deliver these services to rural areas. To help develop rural economies, electrification was necessary, so the federal government stepped in to develop rural electric cooperatives: local democratic organizations that could build and maintain electric infrastructure. These organizations were modeled on other forms of rural organizational life at the time, but promoted local ownership in order to build infrastructure that served the needs of the local population and retained wealth in the community rather than build for the sole purpose of profit.

Today, nearly 900 rural electric cooperatives exist throughout 47 states, delivering power over to over 56% of the total area of the US.[1] These organizations also work with larger regional associations of cooperatives and contract with many types of power generation enterprises to obtain energy. In many places, these cooperatives can also generate their own electricity. Given the lower energy costs they can offer their members, many coops are now targeting for 100% renewable energy generation.[2]

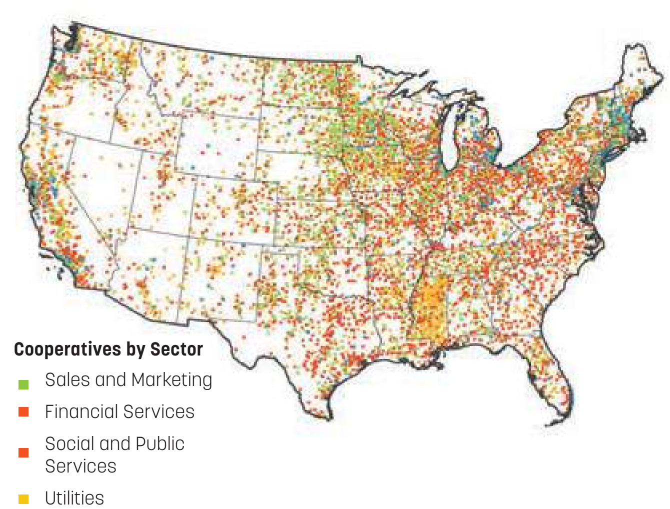
Given the organizational structure of power generation and delivery between the TVA and its local utility

Rural Electric Cooperative Coverage Across the US

900+ Electric Cooperatives in 47 States

Source: U.S. Department of Homeland Security, Homeland Infrastructure Foundation-Level Data

Diversity of Cooperatives Across the US

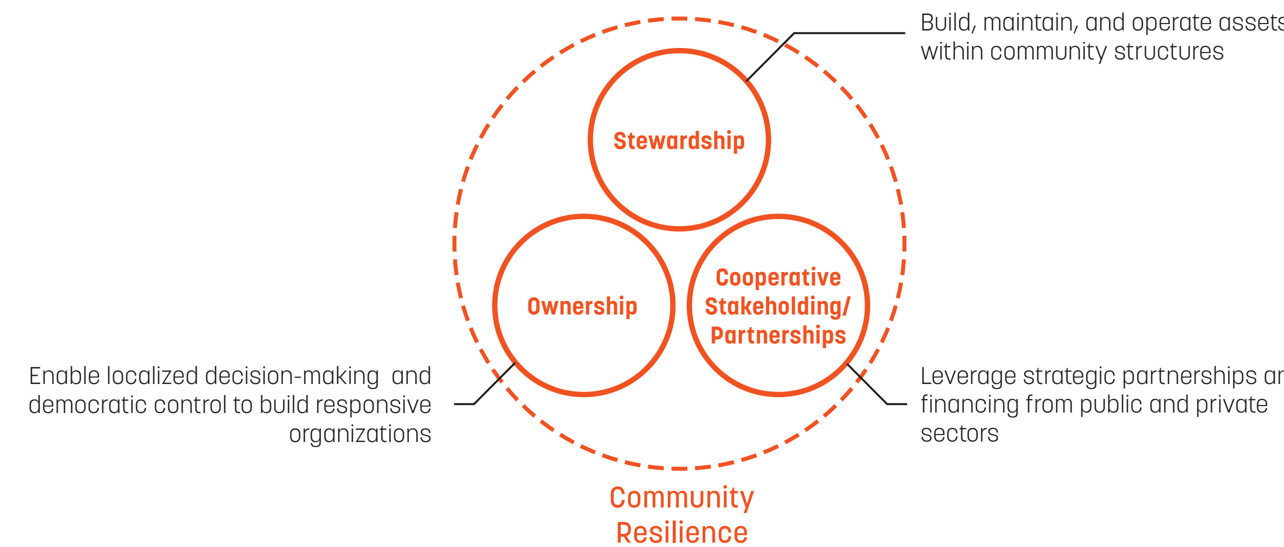


Source: University of Wisconsin Center for Cooperatives, Research on the Economic Impact of Cooperatives (2009)

customers, renewable power generation must be done in close coordination. To facilitate this, the TVA has established the Green Power Providers program (see Implementation section). Within this program, green energy measures like community-solar can be funded and facilitate green energy choice for local residents.[3]

Community resilience is tied to a number of interconnected factors. These factors are

Sharing Models and Community Resilience



predicated on the development of social networks and organizational partnerships that allow for communication and closer relationships, which in turn allow a larger group of stakeholders to coordinate and manage facilities in ways that promote resilience. A few organizational relationships are listed below:

- *Stewardship* of a resource means that a community may build, maintain, and operate facilities, but ownership is maintained elsewhere.
- *Ownership* structures based on sharing can enable more direct, localized decision-making to build organizations responsive to community needs.
- *Cooperative Stakeholding and Partnerships* may allow communities to leverage strategic partnerships and financing from both public and private sectors.

There are many kinds of organizations that exist within a larger context of socially-focused work. Community development financial institutions (CDFIs) are one such organization that can support local organizations and the development of community development projects through partnerships and funding. CDFIs also promote stewardship within communities that help to build capacity. Municipal organizations are also an important part of promoting key factors in community resilience through the use of State and Federal resources, as well as their organizational capacities in managing a wide array of social and infrastructural programs. Municipal ownership has also been an important model for promoting equitable distribution of resources throughout the US. A 2014 study also found that municipal ownership models allowed for residential users to pay 14% less on electricity than users of investor-owned utilities.[4]

While existing utility companies are only beginning to address some key resilience issues, when it comes to cooperative and community-based utilities in the Mid-South, these organizations should be leveraged in terms of the programs and services offered. It is critical to begin community-based projects through coordination with these entities—as when it comes to even energy generation and distribution, scale is important in developing community-based systems.

These concepts are also related to community vulnerability.
See 7.3 Vulnerable Communities for more information. 7.3

Utility Cooperative vs. Investor-owned Utility

The operations of a utility cooperative and an investor-owned utility are essentially the same. The main difference between the two is that a utility cooperative is a not-for-profit organization owned by those it serves whereas an investor-owned utility are owned by stockholders, who may or may not be the customers. Cooperatives provide services at-cost to its members. Profit margins of a cooperative may be invested in the facilities and equipment, or where financially viable, may be returned to the members of the cooperative through a capital credit check.

In this way, cooperatives address market failures by providing important services and utilities in sparsely populated areas and are otherwise able to address local needs more directly and responsively.

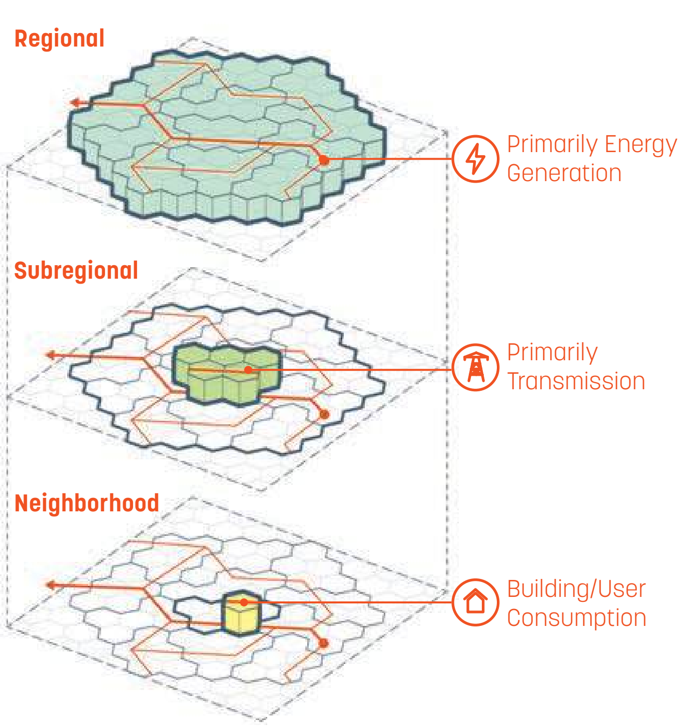
Energy Generation and Delivery Context

Scales of Operation

There are three primary scales of importance to consider in situating a community-based system within a larger energy network:

- *Regional* companies are usually governed by, federal laws, such as interstate commerce laws, as well as by state laws. These organizations typically organize energy generation and interstate or long-distance transmission.
- *Subregional* companies operate below a higher structure and may also be involved in electricity generation and transmission, but most typically contract with regional companies for generation services and manage local delivery.
- *Neighborhood* scales are where energy is delivered to buildings for consumption. Companies or organizations at this level must interface with both regional and subregional companies for coordinating energy generation and transmission. These organizations rarely operate systems larger than a few blocks and usually only manage the operations or ownership of a specific installation or small group of installations. This scale is where shared models operate.

Scalar Diagram



Shared Utility Systems

Shared utility systems operate at the neighborhood scale but interface with subregional and regional companies in key ways. Neighborhood systems must link up to larger systems. Within this, there are two primary ownership /operational models that mediate the relationship between neighborhood installation and (sub)regional systems:

- *Cooperative- or Municipally-based Systems*
  This involves cooperative or municipal utilities that may implement a system and receive credits on the electric generation cost from the energy generation utility (such as the TVA) that can benefit all of its members. This is usually managed at a regional or subregional scale.
- *Community-based Systems*
  This works in a similar way to the above method by receiving credits on their utility bills based on local ownership of the system. This is usually managed at a neighborhood scale.

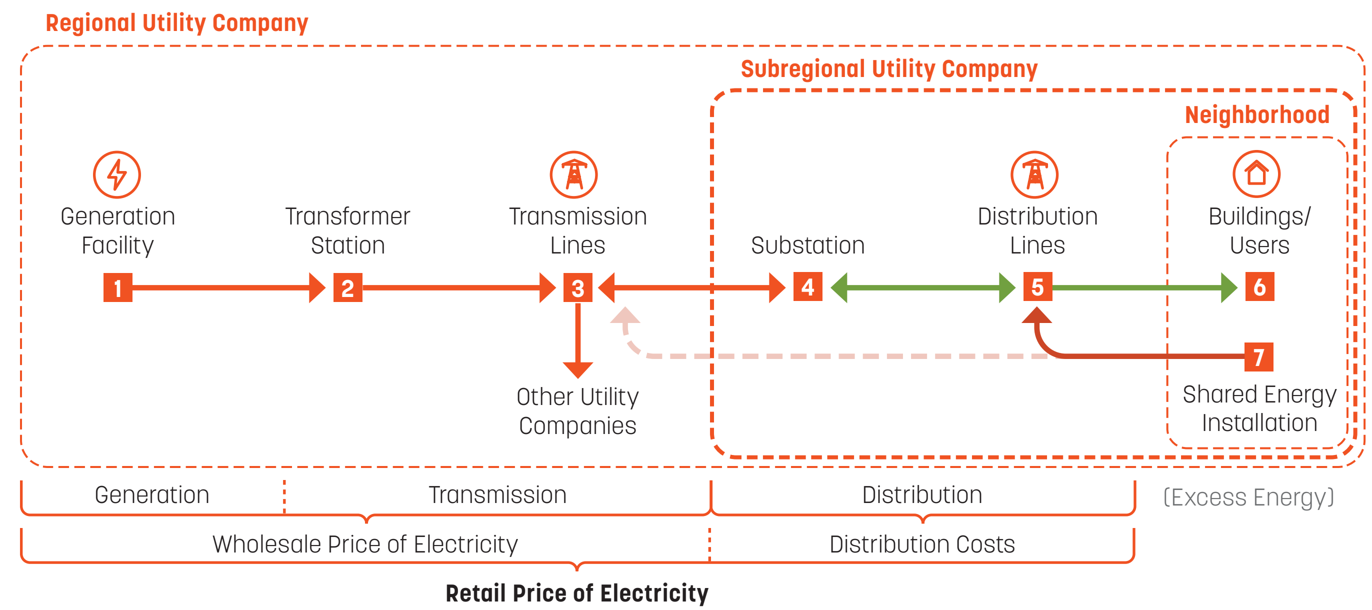
Key Constraints to Shared Systems

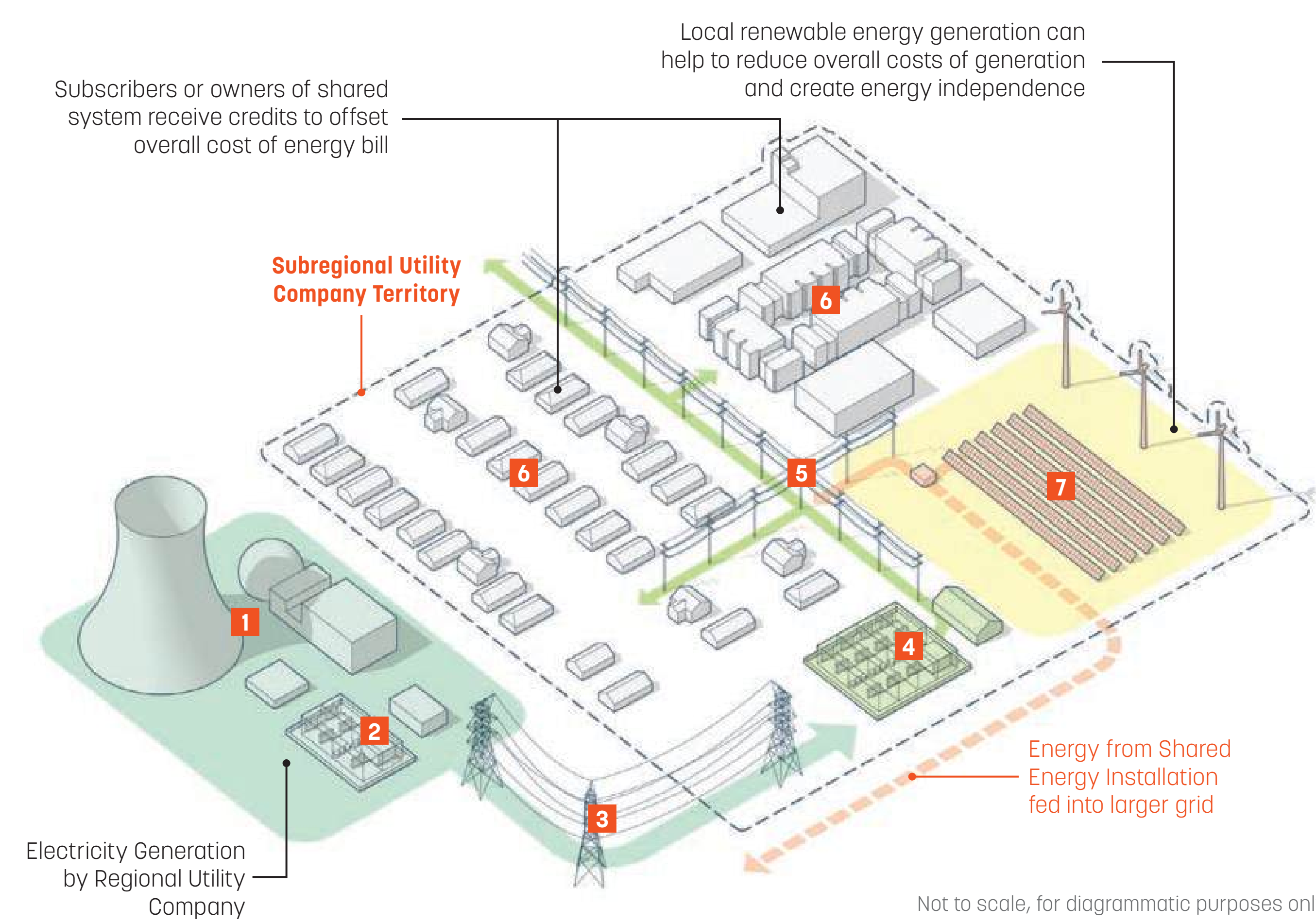
There are also a few key aspects to consider that may enable or limit the implementation of shared energy systems:

- *Enabling Policy and Regulatory Context*
  Many large-scale utilities have been slow to adopt renewable energy standards. State legislation is important in promoting or enforcing renewable energy standards, including shared utilities.
- *Organizational or Generation and Delivery Context*
  Coordination and contracting between generation utilities and delivery utilities can constrain the implementation of shared utility projects
- *Availability of Financing*
  Funding for project implementation is a universal constraint on many project types. This is no different for shared utilities. Partnerships are crucial for leveraging different financial resources.

See Implementation section on page 429 for more information on working within constraints to construct cooperative and community-based shared systems.

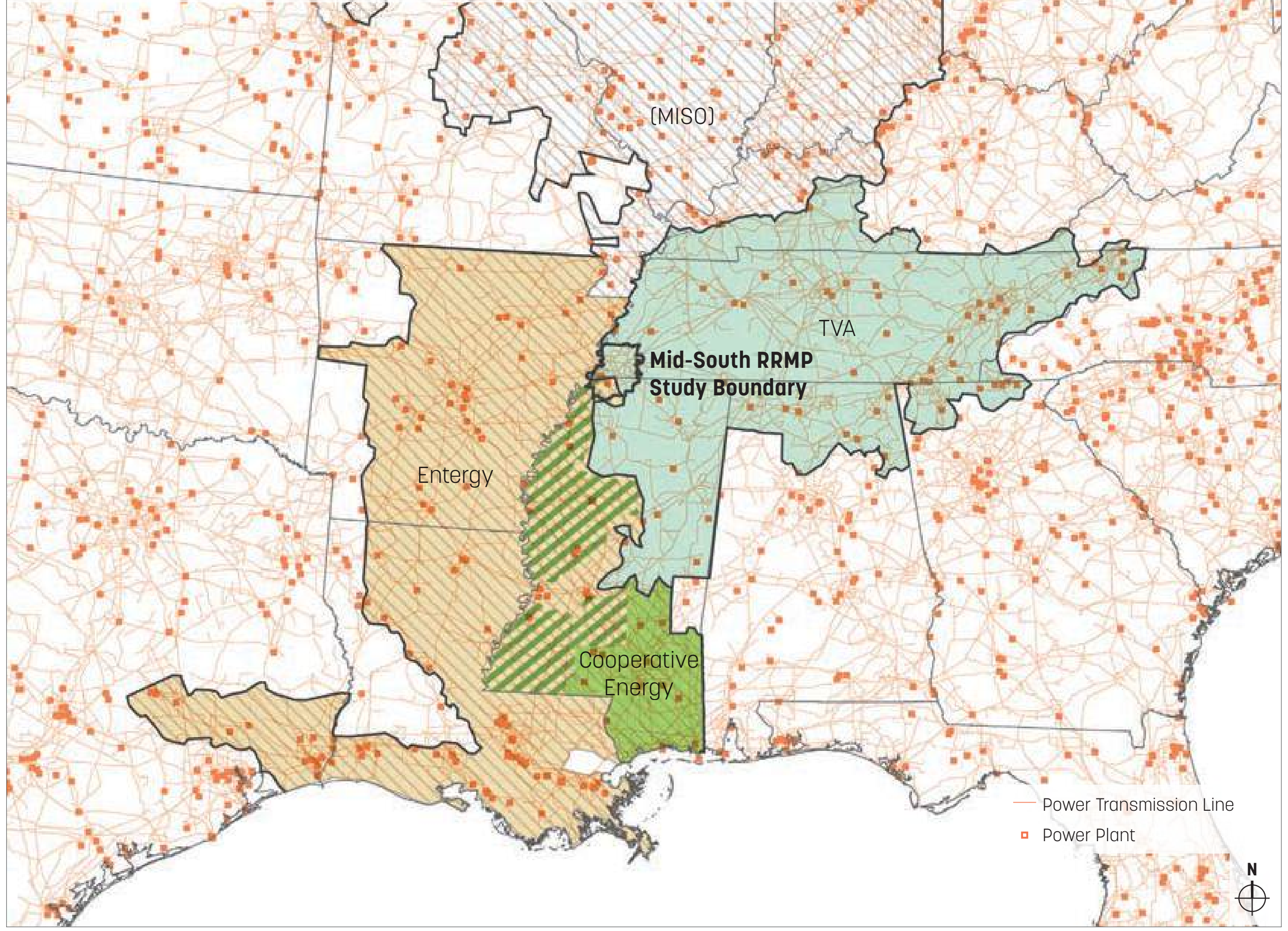
Scales of Electric Generation and Delivery





Not to scale, for diagrammatic purposes only.

TVA, Entergy and Cooperative Energy Service Areas



Existing Energy Companies in the Mid-South

There are two primary operational types of energy utilities: generation and delivery. Many organizations do a little bit of both, but may operate within a variety of contractual relationships governing energy generation and distribution. These relationships include various ownership types. Within the Mid-South, there are four primary types:

- *Federal and Regulatory*
  The Tennessee Valley Authority (TVA) is a federally-owned, non-profit electricity generator. It serves a large territory encompassing all of Tennessee, and parts of Kentucky, Virginia, North Carolina, Georgia, Alabama, and Mississippi. Distribution companies purchase energy from the TVA at low-cost to deliver to consumers across the region. The Midcontinent Independent System Operator (MISO) was formed and has expanded over recent years in order to regulate and manage interstate grid networks and facilitate interstate commerce in relationship to energy transmission. Both Cooperative Energy and Entergy work within MISO along these regulatory lines.
- *Municipal*
  MLGW is the only municipal utility in the Mid-South project area. It operates within the departmental structure of the City of Memphis and buys energy from the TVA.
- *Cooperative*
  There are several utility cooperatives in the area that deliver electricity to its members. The Southwest Tennessee Electric Membership Corporation obtains its energy from the TVA. Another such cooperative, the Coahoma Electric Power Association, obtains its energy from Cooperative Energy (a generation and transmission cooperative) which is mutually owned by 11 of its member cooperatives in Mississippi.
- *Investor-owned*
  An investor-owned utility operates on the basis of profit for a group of shareholders. Entergy is the only investor-owned utility in the Mid-South and extends across Arkansas, Texas, Louisiana, and Mississippi. It generates and delivers electricity directly to its users.

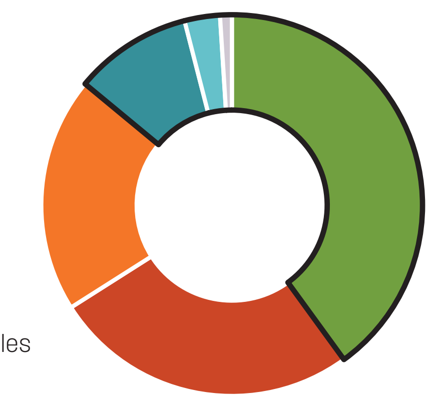
Mid-South Energy Companies by Scale and Service Type

Jurisdiction	**Energy Operations**		
County, State	Regional		Subregional
Shelby County, Tennessee	Tennessee Valley Authority (TVA)		Memphis Light, Gas, and Water
			Chickasaw Electric Coop, Inc.
DeSoto County, Mississippi			Northcentral Mississippi Electric Power Assn
	Midcontinent Independent Service Organization (MISO)	Cooperative Energy	Coahoma Electric Power Assn
		Entergy	

TVA Energy Mix

54% non-carbon energy sources

- **40%** Nuclear
- **26%** Coal
- **20%** Natural Gas
- **10%** Hydro
- **3%** Wind & Solar
- **1%** Other Renewables

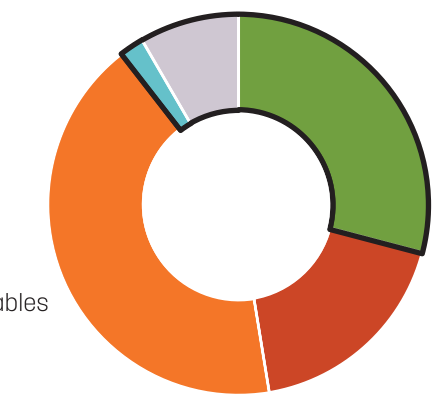


Source: TVA FY2018

Entergy Energy Mix

40% non-carbon energy sources

- **29%** Nuclear
- **18%** Coal
- **42%** Natural Gas
- **2%** Wind & Solar
- **9%** Other Renewables



Source: Entergy 2017, Calculated with MISO supply mix as proportion of energy bought

Differences Between Delivery Zones

Within the TVA, rates tend to be much cheaper than in investor-owned energy generators like Entergy. The TVA also has a comparatively low carbon footprint as a percentage of its overall generation mix with 54% coming from non-carbon sources while Entergy utilizes around 40%.

The generation mix of the TVA is increasingly dependent upon nuclear energy. With this comes other environmental concerns related to nuclear power generation and the use of water for cooling the plants. As water temperatures rise, the extraction of water is likely to place a strain on water resources in the region. However, some studies have indicated a gradual reduction in need for water withdrawal due to technological innovations.[5]

There are other issues related to the TVA's ability to manage their renewable energy programs. The Tennesseans for Solar Choice coalition has pointed out that the TVA has lagged in its commitments to promote key renewable energy programs such as the Distributed Solar Solutions (DSS) for large-scale community solar and a Request For Proposals (RFP) process for large-scale solar installations. Many solar proponents in the region have voiced their concern at the "red-tape, inconsistent policies and fees, and incredible delays in application approval."[6]

Entergy has also begun to take steps toward enabling community solar. In 2015, Entergy implemented its Mississippi Solar System pilot project which includes installations in Hinds, Lincoln, and DeSoto counties. However, Entergy's speed in implementing solar options throughout its territories has also been criticized as not going fast enough.[7]

Power Distribution

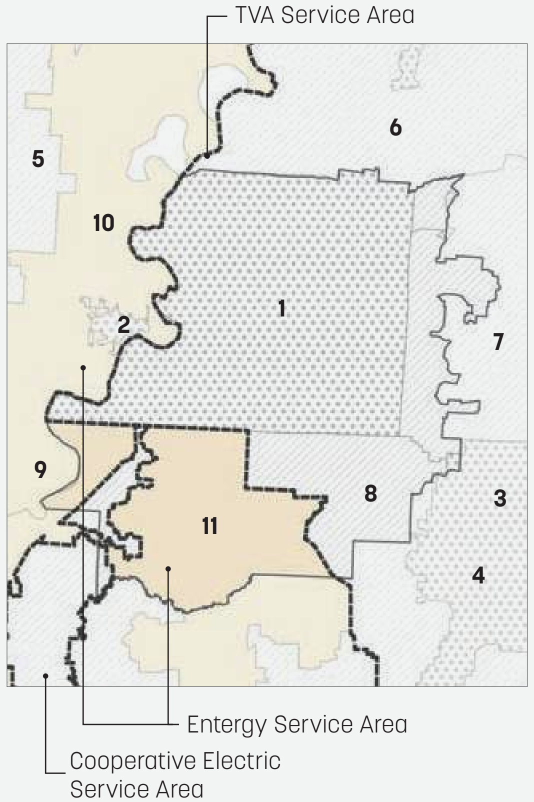
The map to the right illustrates major power line distribution across the Mid-South. It also indicates subregional-level utility ownership (see below for diagram of breakdown). Within the map, potential locations for solar installations have been selected based on the following criteria:

- Publicly-owned parcels greater than 1 acre
- Located outside the 500-year floodplain
- Located within 1,000 feet of a transmission line

Additional locations are also viable, but assessments of feasibility must be carried out in coordination with the local utility company.

Mid-South Energy Companies by Ownership Type

Generators



Distributors

Municipal

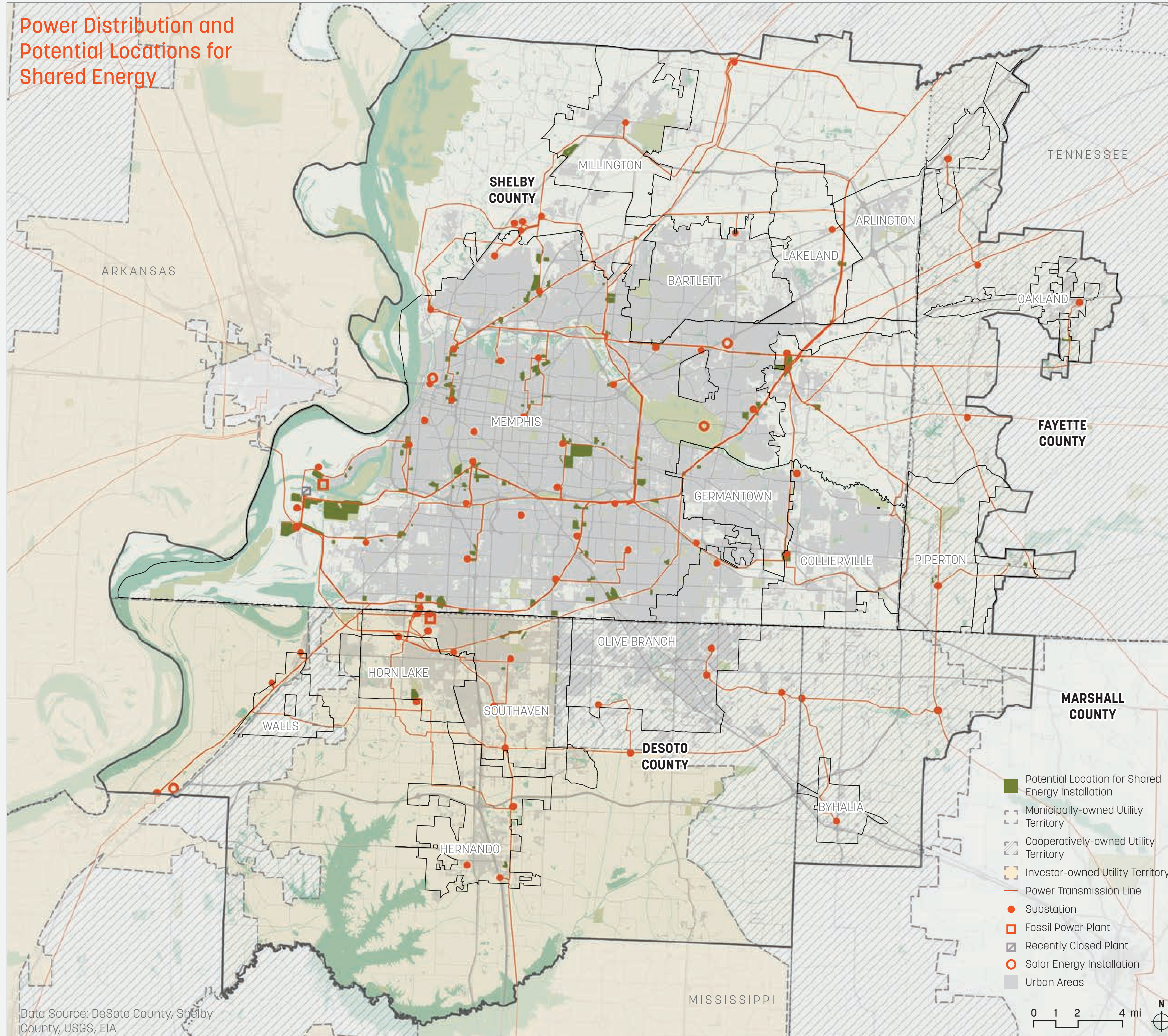
1. Memphis Light, Gas, and Water
2. West Memphis Utility Commission
3. Holly Springs Utility Department
4. New Albany Light, Gas, and Waste

Cooperative

5. Woodruff Electric Coop Corp
6. Southwest Tennessee Electric Membership Corp
7. Chickasaw Electric Coop, Inc.
8. Northcentral Mississippi Electric Power Assn
9. Coahoma Electric Power Assn

Investor-owned

10. Entergy Corp



Community-based Energy

Benefits

A key benefit to community based energy is that it is accessible to those who may not be able to afford or implement an individual installation on their property. This is either due to non-favorable conditions, renters,
7.3 or for low-income populations (See 7.3 on Vulnerable Communities). Community solar is generally more accessible to these residents and can allow for creative structuring and subsidy for low-income consumers.

Community-based energy systems can also be implemented with smart grid technologies that allow for greater autonomy with a potential failure in the larger grid.

Existing Projects and Programs Around the Region

Middle Tennessee Electric's Cooperative Solar Project, https://www.mtemc.com/content/mtemc-cuts-ribbon-cooperative-solar-project.

Appalachian Electric Cooperative, Co-op Community Solar, http://aecoop.org/content/co-op-community-solar.

Entergy Mississippi Solar System pilot project in DeSoto County, http://www.entergy-mississippi.com/solarproject/.

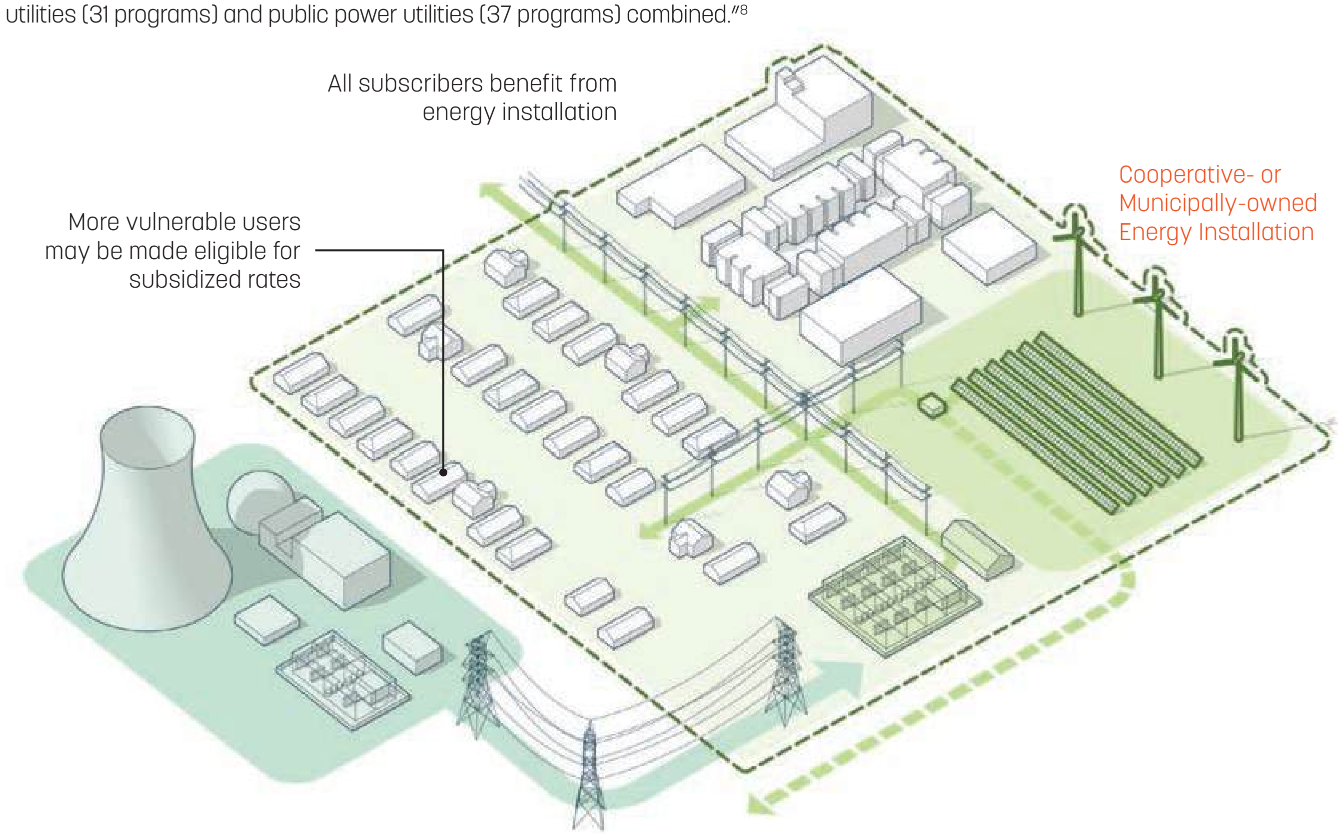
Mississippi Cooperative Energy Solar Projects, https://www.myelectriccooperative.com/solar/.

TVA EPA Solar Photovoltaic (PV) Project, https://www.tva.gov/Environment/Environmental-Stewardship/EPA-Mitigation-Projects/Solar-Photovoltaic-Installations.

TVA's Green Power Providers Program, https://www.tva.gov/Energy/Valley-Renewable-Energy/Green-Power-SwitchVirtual.

5.4.1 Utility-led Energy System

The utility-led model is a viable model for promoting localized renewable energy generation systems. This is where a local utility company owns and operates the installation while distributing the benefits across their territory to all customers / members. A recent study has pointed out that over "160 cooperative utilities have a community solar program in their territory. This far exceeds the total in investor-owned utilities (31 programs) and public power utilities (37 programs) combined."[8]

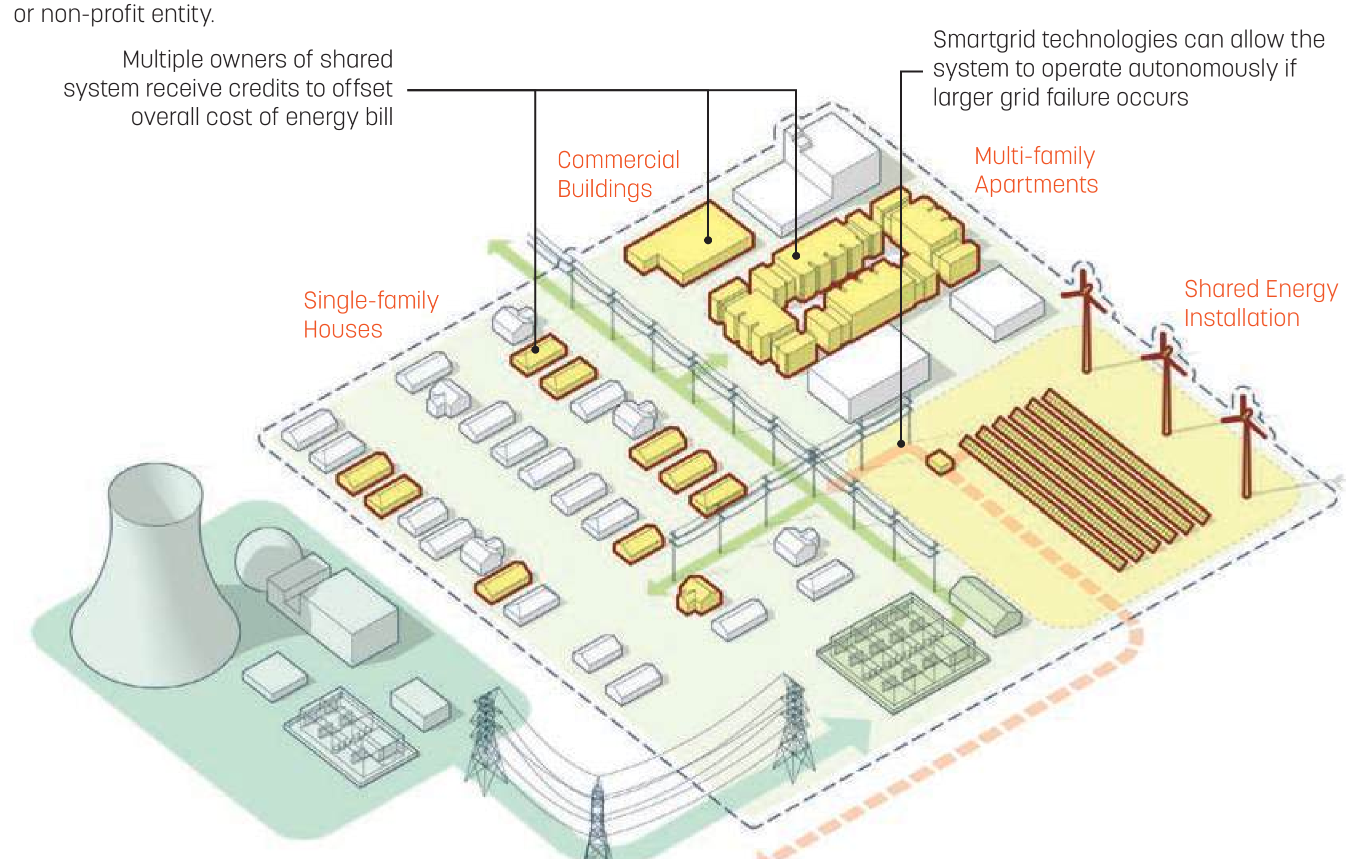


(Above) A touring of the 21-turbine Kingdom Community Wind project in Lowell, Vermont.

(Above) The Shelby Farms Solar Farm in Memphis, Tennessee.

5.4.2 Third-party-led Energy System

Third-party models of renewable electricity generation allow a group of owners (like stockholders) to receive a credit on their electric bill based on the share of ownership in the system that is implemented. This may be managed by a for-profit or non-profit entity.



Implementation

1 Leverage Existing Programs and Resources

Given that the Mid-South encompasses jurisdictions in both Mississippi and Tennessee, as well as its inclusion of several different utility operators, the identification of policies and programs applicable to a specific jurisdiction is a key first step to identifying the feasibility of implementing a community-based energy system. Local utility (delivery) companies may have contractual restrictions with their generating companies that may govern the way a system is implemented and managed. These can be discussed through coordination with the local utility company itself (see 2 Coordinate and Locate Sites for Implementation).

Across both Federal, State, and local jurisdictions there are many programs and policies to consider leveraging when looking to expand and promote local energy projects. A few key programs and resources are listed below.

TVA's Green Power Providers Program

Homeowners, businesses, and communities can install solar, wind, biomass, and low-impact hydropower systems generating 50 kilowatts or less and TVA will pay for every kilowatt hour generated by that system. Project costs may be fully funded using revenues generated through a purchased power agreement (PPA) with TVA.

This is closely coordinated with local power companies. Systems must comply with an associate-level certification from the North American Board of Certified Energy Practitioners (NABCEP). Once installation and approval from the local power company is acquired, the TVA will buy the green energy output for a period of 20 years while retaining the Renewable Energy Credits (RECs) for the full 20-year term. All of the local power companies within the TVA area in the Mid-South participate: MLGW, Chickasaw Electric Cooperative, Inc, and Northcentral Mississippi Electric Power Association.

See: TVA, Green Power Providers, https://www.tva.com/Energy/Valley-Renewable-Energy/Green-Power-Providers

TVA's Green Power Switch

This program allows homeowners to buy 150 kWh blocks in $4 increments for renewable energy supplied from TVA managed sources.

See: TVA, Green Power Switch, https://www.tva.com/Energy/Valley-Renewable-Energy/Green-Power-Switch/Green-Power-Switch-for-Home

TVA's Dispersed Power Production Program

Renewable energy facilities that generate or co-generate between 7kW and 80 MW may qualify to participate in TVA's Dispersed Power Production program. This allows the power generation facility to connect to TVA's power lines allowing the facility to sell excess power to the TVA at TVA's wholesale rate. For systems below 50 kWh, coordination with a local power company is required.

See: TVA, Dispersed Power Program, https://www.tva.gov/Energy/Valley-Renewable-Energy/Dispersed-Power-Program

Business Energy Investment Tax Credit (ITC)

Offers corporate tax credits of up to 10-30% of expenditures on a variety of renewable energy technologies such as solar, wind, geothermal, etc. for non-residential sectors.

See: DSIRE, Business Energy Investment Tax Credit (ITC), http://programs.dsireusa.org/system/program/detail/658.

Energy Efficiency and Conservation Loan Program (EECLP)

Provides loans to finance energy efficiency improvements for commercial, industrial, and residential consumers. Eligible utilities such as rural utilities services can borrow money tied to treasury rates of interest and re-lend the money to implement energy projects such as solar within their operating territory.

See: USDA, Energy Efficiency and Conservation Loan Program, http://www.rd.usda.gov/programs-services/energy-efficiency-and-conservation-loan-program

STEM, Energy, Economic Development (SEED): Coalitions for Community Growth

A program supported by a partnership between the U.S. Departments of Energy, Housing and Urban Development, and Education that encourages local, place-based initiatives to promote energy literacy, STEM education, and job-driven skills-building.

See: HUD, STEM, Energy, Economic Development, http://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/seed

Renew 300: Advancing Renewable Energy in Affordable Housing-Tools and Resources

The Department of Housing and Urban Development (HUD) encourages organizations to commit to reaching energy targets of around 300 megawatts of on-site or community-scale renewable energy capacity, such as solar.

See: HUD, Renew 300, https://www.hudexchange.info/programs/renewable-energy/

Section 108 Loan Guarantee Program

The Department of Housing and Urban Development (HUD) provides communities with a source of funding for economic development, housing rehabilitation, public facilities, and renewable energy additions that can increase a communities resilience against natural disasters. This is a component of the Community Development Block Grant (CDBG) program.

See: HUD, Section 108 Loan Guarantee Program, https://www.hudexchange.info/programs/section-108/

The CDFI Fund Program

Provides financial and technical assistance. Grants can be issued for a one-to-one match to private, non-federal entities for community development projects such as solar energy installations.

See: US Department of the Treasury, Community Development Financial Institutions Fund, https://www.cdfifund.gov/Pages/default.aspx

The Bank Enterprise Award Program

Gives out grants to FDIC-insured financial institutions that invest in CDFIs or provide assistance and services to vulnerable communities.

See: US Department of the Treasury, Community Development Financial Institutions Fund Bank Enterprise Award Program, https://www.cdfifund.gov/programs-training/Programs/bank_enterprise_award/Pages/default.aspx.

The New Markets Tax Credit (NMTC) Program

A tax incentive program that allows investors to access a 39% tax credit against Federal income taxes for Qualified Equity Investments (QEIs) into Community Development Entities (CDEs). This includes eligible community projects such as solar energy installations. Between 2002 and 2013, over $78M in NMTC has been awarded in Tennessee and over $276M in Mississippi.

See: US Department of the Treasury, Community Development Financial Institutions Fund New Markets Tax Credit (NMTC) Program, https://www.cdfifund.gov/programs-training/Programs/new-markets-tax-credit/Pages/default.aspx.

2 Coordinate and Locate Sites for Implementation

There are a few constraints to consider when locating an area for a shared utility project or microgrid. It is most likely required that approval will have to be obtained from a local utility company for the implementation of a shared utility system in order to coordinate generation, supply, and billing. From this engagement, access to financing and further coordination between entities (see Existing Energy Generation and Delivery Context section) for providing energy and water services can be established. This an essential first step in the implementation of shared utility projects.

Available land may also have ownership constraints as well as optimal connections to the grid. For instance, if an interested community has no place to implement a shared solar project, other hosts may be approached. These may include local utilities, local governments, partnering businesses, and community groups. Utilities have data on the supply and demand of the grid and will be aware of optimal locations for distributed energy installations.

Contractual arrangements may vary widely in scope for shared projects. Public sector entities may also engage in promoting shared solar projects through partnership and the offering or leasing of land to a utility company or interested group. Key aspects of the program will also have to be established early on. This includes the ownership structure (see 3 Define Ownership Model), contract length, subscriptions, eligibility rules, and more (see 4 Determine Subscription Services).

3 Define Ownership Model

Utility-led Program

Utility-led program models are made up of two types: limited-scope and broad-based. While these models may involve third-party contracts, this is primarily led by a utility with the desire to include key consumers such as institutions and vulnerable communities, or to reach all consumers within their territory. Municipalities and cooperatives may also be able to take advantage of implementation methods such as Promote Energy Savings Performance Contracts (ESPCs) (see page 304 on Promote Energy Savings Performance Contracts (ESPCs)).

Limited-scope

In a utility-led limited-scope model, a utility company may initiate implementation or partner with a third-party organization (such as a non-profit) and take on management responsibilities. Through this model a utility may select or work with a limited number of its customers/members to provide renewable energy options. Partnership with these consumers may involve cost-sharing and service agreements with a limited scope, and generally for a limited-scale installation. In this model, members of the program may use a portion of the electricity generated within the installation against their demand on their electricity bill, thereby reducing their payments. The utility company may also contract with a third-party to provide support services.

Broad-based

A broader model reaching a larger consumer-base and involving a larger-scale installation may be more economical, yet requires a larger investment. Utilities may make distributed energy systems a larger part of their offering and can support larger-scale programs that reach a broader customer/member base—often including all of their consumers. This provides a model that is much more financially viable to vulnerable communities. Utilities may also offer storage capacities within larger installations.

Third-party-led Program

There are two generally different models for third-party-led programs: for-profit and non-profit or shared. Although led by a third-party, the implementation of installations and provision of services is always done in partnership with a local utility.

For-profit

Third-party private companies may also offer community-scale systems and can partner with utilities to offer these services. Private companies may utilize different financing methods to implement local systems and contract with a utility to offer their services. Since these systems are driven by profit, they are intended to maximize participation and will usually be larger-scale installations.

Non-profit or Shared

This refers to a model that may be managed by a non-profit entity whereby individual consumers own or lease a portion of a distributed system. This is usually done in partnership with a utility and can involve the creation of a special purpose non-profit entity for implementation and the provision of services to the owner/leaseholder group. However, if the community has formed a special purpose entity for the implementation of community solar or wind systems, the Income Tax Credit may be difficult as the organization does not have substantial tax liability. Like the utility-led limited-scope program, this model allows "shareholders" to use the electricity generated against their demand on their electricity bill, thereby reducing their payments and/or supporting renewable measures.

4 Determine Subscription Services

Regardless of ownership model, most community-based or distributed energy projects are managed through a subscription service managed by the local utility company or through a utility contract with a third-party. An agreement made with a local utility company at the outset of implementation (2 Coordinate and Locate Sites for Implementation) governs the subscription and billing details.

Within subscription services for distributed energy projects, there are a few key aspects to consider:

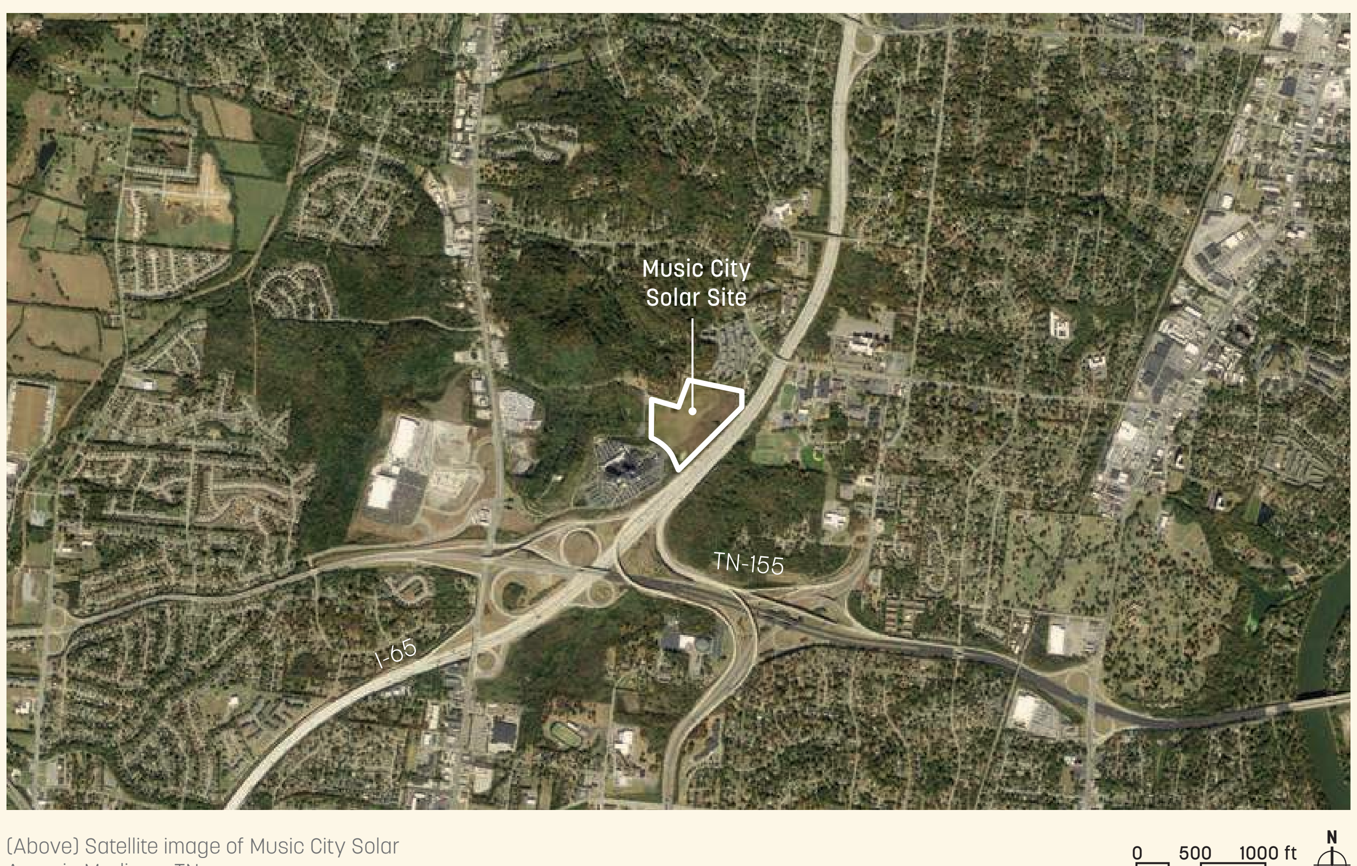
- *Subscriber Payment Structure*
  Is there an upfront payment, ongoing rate payment, or a hybrid of the two?
- *Subscriber Credit*
  Are subscribers charged at a retail rate (virtual net or dual metering), a partial rate, or a community energy credit rate?
- *Generation Guarantee*
  Is there a guaranteed monthly generation or is it variable generation?
- *Target Customer Class*
  Is this intended for residential consumers, select commercial and industrial consumers, vulnerable or low-income communities, or everyone?
- *Unsubscribed Energy*
  Is it fully recovered from ratepayers, partially recovered at avoided costs, recovered from subscribers, or left unrecovered?
- *Participation Limit*
  Is it limited to residential consumers only? This may depend on location and generation capacity.

Case Study

Music City Community Solar, Madison, TN

Nashville Electric Service (NES) is the city's municipal electric delivery company. In 2018, NES partnered with LightWave to commission the Music City Community Solar project to be built on a site in North of Nashville on an old landfill site.[9] The Music City Community Solar project was one of seven projects selected to be built through a TVA pilot program called Distributed Solar Solutions, which also allows the local power company that manages the community solar array to sell excess energy to the TVA grid. This pilot program Community use of the panels is managed by NES which allows its customers to 'buy' the panels at $215 each in order to receive a solar credit to their monthly electric bill.

With over 17,000 solar panels, this array will contribute over 2.8 million kWh to the grid each year, enough to power close to 210 homes.



(Above) Satellite image of Music City Solar Array in Madison, TN.

(Top) Artist rendering of Music City Solar Array in Madison, TN.

(Bottom Left) Photograph of the solar panel array.

(Bottom Right) Photograph of the solar panel array.

Case Study

Appalachian Electric Cooperative Community Solar, New Market, TN

The Appalachian Electric Cooperative (AEC)[10] is a non-profit electric cooperative that provides affordable energy to several counties in East Tennessee. It is governed by over 45,000 member-owners and provides many other community services to its communities. It implemented a community solar project in 2016 on a seven-acre site adjacent to its New Market Substation in New Market, TN. Over 9,000 solar panels were installed on the site that can generate enough energy to power 130 homes per year.

It was funded by a grant from the Tennessee Valley Authority as one of two initial pilot programs in the region. The project costs are also funded by the revenue generated through a purchased power agreement (PPA) with the TVA. It also contracted with ARiES Energy for the construction of the project and partners with the National Renewable Cooperative Organization for assistance in project management.

The installation also has an educational component through partnership with local schools to help educate youth on renewable power generation.

(Above) Satellite image of AEC Community Solar Array in New Market, TN

(Top) Aerial view of the community solar project at New Market, TN.

(Bottom Left) Installation of panels at New Market site.

(Bottom Right) Educational tent and project initiation.

Endnotes

1 National Rural Electric Cooperative Association (NRECA), *America's Electric Cooperatives: 2017 Fact Sheet*, (2017), https://www.electric.coop/electric-cooperative-fact-sheet/.

2 Herman K. Trabish, "Join or die: How utilities are coping with 100% renewable energy goals," Utility Dive, (December 13, 2017), https://www.utilitydive.com/news/join-or-die-how-utilities-are-coping-with-100-renewable-energy-goals/512664/.

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4 Amercian Public Power Association, P*ublic Power: Shining a Light on Public Service*, (Arlington VA: APPA, 2014), http://www.les.com/pdf/public-power-fact-sheet.pdf.

5 Charles E. Bohac and Amanda K. Bowen, W*ater Use in the Tennessee Valley for 2010 and Projected Use in 2035*, (Tennessee Valley Authority River Operations and Renewables, 2012), http://152.87.4.98/river/watersupply/water_use.pdf.

6 Kelsey Misbrener, "Tennesseans for Solar Choice coalition says TVA's solar programs are broken," *Solar Power World* Online, (June 21, 2018), https://www.solarpowerworldonline.com/2018/06/tennesseans-solar-choice-tva-solar-programs-broken/.

7 Jessica Williams, "City Council approves first steps toward 'community solar' power program," The Advocate, (June 21, 2018), https://www.theadvocate.com/new_orleans/news/article_2a9507c6-749b-11e8-82a0-7ff66bf8f063.html.

8 Smart Electric Power Alliance (SEPA), *Community Solar Program Design Models*, (2018), https://sepapower.org/resource/community-solar-program-designs-2018-version/.

9 "Lightwave Solar Installs 2 MW Community Solar Project," LightWave Solar online, (August 10, 2018), https://lightwavesolar.com/lightwave-installs-nes-community-solar/.

10 For more information see: Appalachian Electric Cooperative, "Community Solar Project Information Sheet," http://aecoop.org/sites/aecoop/files/PDF/FINAL-Information-sheet-for-CCS-groundbreaking.pdf; Appalachian Electric Cooperative, Website, http://aecoop.org/content/co-op-community-solar.

Resources

Community Energy Development Programs

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Community Energy Development Resources

Opportunity Finance Network. https://ofn.org/.

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Coughlin, Jason, Jennifer Grove, Linda Irvine, Janet F. Jacobs, Sarah Johnson Phillips, Leslie Moynihan, Joseph Wiedman. *A Guide to Community Solar: Utility, Private, and Non-profit Project Development*. (US Department of Energy, 2010). Available at https://www.nrel.gov/docs/fy11osti/49930.pdf.

Renewable Energy Systems Resources

US Department of Energy Office of Energy Efficiency and Renewable Energy. *Small Wind Guidebook*. https://windexchange.energy.gov/small-wind-guidebook.

North American Board of Certified Energy Practitioners. http://www.nabcep.org/.

Consumer Energy Council of America, Distributed Energy Forum. http://www.cecarf.org/.

Florida Solar Energy Center, Research. http://www.floridaenergycenter.org/en/research/index.htm.

Tennessee Solar Energy Association. http://www.tnsolarenergy.org/.

National Association of State Energy Officials. https://www.naseo.org/.

North Carolina Solar Center. http://nccleantech.ncsu.edu/.

National Renewable Energy Laboratory. http://www.nrel.gov/.

Solar Energy Industries Association. http://www.seia.org/.

The Coalition for Community Solar Access. http://www.communitysolaraccess.org/.

US Department of Energy, National Community Solar Partnership. https://www.energy.gov/eere/solarpoweringamerica/national-community-solar-partnership.

5.6 Snow and Ice

Fund Additional Resources for Post-Storm Snow and Ice Removal

Key Benefits

1. **Protects roadways and critical infrastructure from hazardous snow and ice conditions**
2. **Improves cost-effectiveness of equipment, planning, and mobilization through local government cooperation**

Overview

Cities and counties across the northern US often prioritize their road networks for snow and ice removal. Much of this removal work employs expensive equipment such as snow plows and salt trucks. While the Mid-South may not experience as much snow and ice-related weather as northern areas, this makes the region more vulnerable when faced with these challenges. It is important for the region to work together to face this issue. Roads in one jurisdiction continue into others while many residents live and work across the entire region.

This recommendation provides a short overview of snow and ice removal planning and looks for ways to share equipment and maintain preparedness in the case of a hazardous winter weather event. Emphasis is given to regional cooperation in equipment purchasing, planning, and mobilization. Leveraging local government cooperative agreements for shared equipment, services, or bulk material purchasing can be effective cost-reduction techniques and improve the region's overall resilience in the face of harsh winter weather conditions.

(Right) Apart from creating dangerous traffic conditions, hazardous roads can cripple emergency response generally.

Snow and Ice Removal Measures

While the Mid-South may not receive much snow and ice overall, between December and February, the average snowfall precipitation is just under 2 inches, while rainfall is much closer to 4 to 6 inches. Snowfall and freezing temperatures can have negative effects on a variety of infrastructure but it is most felt when it impacts transportation. When the Mid-South does receive freezing precipitation, it can be more hazardous as residents are less familiar with driving in such conditions.

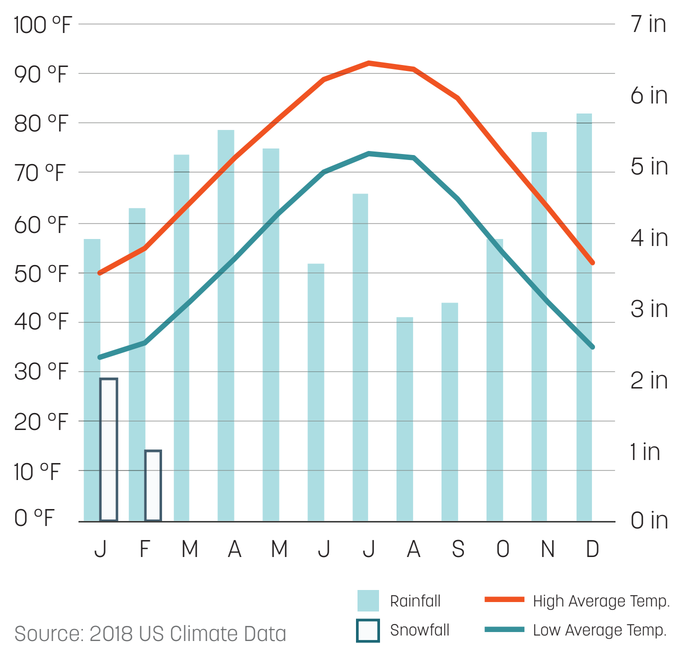
There are two primary activities currently carried out by public organizations, like the state Department of Transportation and local public works departments, in dealing with snow and ice removal from roadways:

- *Dispersing Salt/Brine and Sand*
  This is a proactive measure that can mitigate light snowfall before it has a chance to accumulate. The use of salt, brine, and sand is usually done with attention paid to the precipitation type. If it rains during or after these are laid out, the rain could wash it away.
- *Snow Plowing*
  This activity is usually in response to accumulated snowfall and removes the topmost layers of snow without removing it all the way to the pavement. This leaves a thin layer of compacted snow that is easier to manage but can still be dangerous for inexperienced winter weather drivers. This activity also requires coordinated planning in the use of heavy-duty equipment and vehicles that may not be readily available in places that receive little snow.

State, County, and Local Response

Given that there are different jurisdictions when it comes to the maintenance of roadways, the salting and plowing of roads is typically also done by different organizations operating within these jurisdictions. State organizations such as the Tennessee and Mississippi Departments of Transportation (TDOT and MDOT) manage state roadways such as the highways running through the region, while local jurisdictions, such as Shelby County, DeSoto County, and other local cities and towns, manage the remaining roadways. This distinction in territory of operations requires coordination in the planning, sharing, and mobilization of equipment to remove ice and snow.

Mid-South Climate Chart



Source: 2018 US Climate Data

Advisories Related to Snow and Ice

The National Weather Service has classified specific warnings for winter weather-related threats and advisories to convey hazards to residents. These terms are useful and Shelby County utilizes these terms with slightly reclassified criteria for the Mid-South:

- *Winter Weather Advisory:* Issued ahead of dangerous winter conditions.
  Criteria: 1 to 3 inches of snow in 12 hours or ice of less than ¼ in.
- *Winter Storm Watch*: Winter weather is possible. Avoid travel. Have a "safe place" prepared.
  Criteria: 50/50 chance a warning will be issued in 12 to 24 hours.
- *Winter Storm Warning*: Winter weather may pose a threat to life and property.
  Criteria: 4 or more inches of snow in 12 hours and / or ice of greater than ¼ inch.
- *Ice Storm Warning*: Severe weather may pose a threat to life and property.
  Criteria: 0.25 inches or more of ice in 12 hours.
- *Blizzard Warning*: Conditions pose a threat to life and property.
  Criteria: visibility may be less than ¼ mile with sustained winds or gusts of 35 mph for 3 hours.

Salting Vehicles and Attachments

Heavy-duty Sand and Salt Spreaders

Can be attached to heavy-duty vehicles with open bodies

General Cost: $7,000+ (per unit)

Small Sand and Salt Spreader

Lower-volume spreader for use on a variety of smaller-scale open-bed trucks

General Cost: $800-$4,000 (per unit)

Snow and Ice Removal Vehicles and Attachments

Tractor Plow Attachments

Plow attachments can turn many tractor types into effective snow plows

General Cost: $1,000-$5,000 (per unit)

Small Snow Plow Attachments

It is common for many trucks to support smaller plow attachments

General Cost: $1,000-$8,000 (per unit)

Heavy-duty Snow Removal Vehicles

Specialized snow removal vehicles and equipment is more common in regions where winter weather is more severe and frequent

Plow Tractor (reuse)

Other agricultural equipment such as tractor plows could be reused for snow removal as is done in many rural areas

(Suggested reuse)

All-Season Tires

All-Season Tires

New rubber material technologies have improved traction for these special cold weather tires

General Cost: $100-$400 (per tire)

Coordinated Planning for Snow and Ice

Coordinate Monitoring of Winter Weather Emergencies and Disseminate Planning

At the level of local government, many departments can be made responsible for reporting on snow and ice conditions to departments directly responsible for removal. The observations of various government departments (such as the parks department) may alert the need for a first response made during operational hours. In critical situations, operations may need to be adjusted to handle after-hours work to mitigate potential hazards of heavy snow and rainfall.

While there are many newsletters and broadcasts that can alert the public of snow and ice hazards, the promotion of public knowledge of planning and mobilization efforts through the dissemination of mobilization plans brings other benefits. This can prepare the public for other inconveniences brought by equipment and plowing measures and educate the public on why mobilization efforts are done in a certain way. For instance, it may be important to inform the public that many local residential streets may remain unplowed for a long time as primary streets require immediate attention for safety reasons.

Coordinate Mobilization Efforts through Cooperative Agreements and Planning

Roads do not end where jurisdictions do. While state-managed highway infrastructure is more pertinently managed by a state DOT, primary arteries that run between city and town governments could be managed through coordinated efforts to share costs and equipment through cooperative agreements.

Through the development of a coordinated group of counties/cities in the region, equipment sharing and other agreements can be made to leverage scarce resources. Snow plowing services could be made in exchange for certain road maintenance measures in other times of the year to distribute and capitalize on the costs of equipment and labor. There are several organizations that may be involved:

- Tennessee and Mississippi Department of Transportation (TDOT and MDOT)
- Shelby County Emergency Operation Center
- DeSoto County Emergency Management Agency
- Memphis Public Works Department
- Other city and town public works departments

Enabling Legislation

Both Mississippi and Tennessee have passed legislation in the past 40 years enabling cooperative purchasing agreements that could enable resource and service sharing pursuant to the cause of snow and ice removal (among other things). These are located within:

- Tennessee Cooperative Purchasing Agreements (Local) (T.C.A. § 12-3-1009)
- Tennessee Cooperative Purchasing (Local in State and Local Out of State) (T.C.A. § 12-9-101)
- Tennessee Cooperative Purchasing Agreements (State) (T.C.A. § 12-3-216)
- Mississippi Code governing "Public Business, Bonds and Obligations" on "Public Purchases" (M.C.A. § 31-7)

Assess and Expand Available Resources

There may be hundreds of vehicles and equipment available in the region. To better organize potential sharing measures, or in consideration of purchasing more vehicles or equipment, an assessment of regional resources should be carried out.

Investments could be made for more snow plow and salting units that can detach from, or attach to, various public works vehicles (see diagram on previous page) that can be used in times of snow and ice emergencies while maximizing vehicle use and allowing for compact storage of winter equipment.

To expand resource sharing, local governments can work with other nearby governments and state DOTs to develop sharing and mobilization plans. See the case study for an example of local government cooperation.

Types of Cooperative Agreements

Cooperative agreements can be made between several types of jurisdictions ranging from townships and cities to counties and states. According to enabling legislation these may also be made across state lines. Special consideration must be given to the emergency basis for owning snow and ice removal equipment through coordinated mobilization planning. There are three primary types:

Joint Ownership Agreements

These are not the most common but can result in higher savings in the purchasing of equipment that local governments may find difficult to afford or may use for only part of the year. Costs may be apportioned according to anticipated use or managed according to other resource exchange and sharing agreements.

Group Purchasing Agreements

Group purchasing agreements can also help to reduce costs through lower unit costs for items bought in bulk. This usually entails the bulk purchasing of material, such as salt or brine, or groups of purchases of equipment that would be owned individually by local governments.

Resource Exchange and Sharing Agreements

Local governments can also save costs on purchases or administrative costs through other forms of exchange such as equipment rental, direct purchasing of salting or snowplow services from other governments, or trade responsibility for snowplowing border roads, or exchange personnel and equipment for similar in-kind services from other governments.

Prioritize Areas for Removal

Roadway Treatment Priorities

In prioritizing sand, salt, and plowing, it is key to focus first on high-volume arterials, while lower-volume roads receive a lower priority. These priorities are embedded within a city or county snow and ice removal plan that would be implemented as soon as viable after a winter storm event.

1. Primary arterials and intersections, bridges, and overpasses, including roadways providing access to emergency response and otherwise critical facilities.
2. Primary collectors and minor arterials and intersections, including roads that provide access to major office and commercial areas such as groceries and other service facilities.
3. Secondary intersections and other areas with moderate-to-high volume traffic flow.

The Airport

The airport has emergency snow removal assistance to maintain safety of the runways. Much of this is driven by the importance of air traffic to the Memphis economy. Hundreds of commercial flights by companies like FedEx interchange at the airport daily. Temperature sensors in the runways keep management alert of dangerous conditions where it can mobilize around 30 snow removal vehicles, including snow plows and de-icing trucks.

Private Areas: Residents and Business Owners

It should be communicated to residents and business owners that they should have responsibility to snow and ice removal around their property. This is secondary to an immediate emergency response but can be an important effort to open up access to address other post-storm issues such as the cold or pedestrian safety.

County Examples of Snow/Ice Removal Planning

King County Code Chapter 14.48

In event of a snow emergency, King County has identified and will clear emergency routes and alert the public.

King County Code Chapter 14.48, http://aqua.kingcounty.gov/council/clerk/code/17_Title_14.htm#_Toc422296104.

Pierce County Snow and Ice Plan

Provides inventory of snow plowing equipment, four-phase response plan for snow and ice events, and guidelines for snow plowing and chemical application.

Pierce County Snow and Ice Plan, (2010), http://mrsc.org/getmedia/2abc6641-6d79-4574-8252-24fc98dbd162/p5snowPlan.pdf.aspx.

Case Study

Wisconsin Town Agreements

Throughout the US, there are many examples of local government cooperation in road maintenance. A large proportion of local government expenditure is spent on road maintenance. As the size of the local government gets smaller, nearly half of local government expenditure could be spent on roads alone. In Wisconsin,[1] this is the case, and these costs can present major issues for smaller governments facing rising costs associated with winter. An assessment of local government cooperative agreements for road maintenance revealed the success of these agreements in reducing costs and promoting cooperation between local governments across the state. Many of the agreements centered on exchanges of equipment and services that ranged from snowplowing, mowing medians, repairing potholes and cracks, to resurfacing roads. Local governments also cooperated to share equipment and make bulk purchases of materials.

In organizing these agreements there were several issues that had to be solved for the successful formation of the agreement: maintenance responsibility, liability and insurance concerns, and union contract prohibitions. Working closely with agents involved was an important factor in success.

An example of an exchange agreement for snow removal is illustrated on the following page. The contents and extent of service arrangements is open, yet contingent upon local conditions.

(Right) Image of Snowplow in Wisconsin

Example of an Exchange Agreement

AGREEMENT BETWEEN THE TOWN OF COMMONWEALTH AND THE TOWN OF FLORENCE FOR SNOWPLOWING FOR THE 1994-1995 SNOWPLOWING SEASON

WITNESSETH, This Agreement made between the Town of Commonwealth, Florence County, Wisconsin, hereinafter referred to as Party of the First Part, and the Town of Florence, Florence County, Wisconsin, hereinafter referred to as Party of the Second Part.

In consideration of the following rights and covenants, Party of the First Part and Party of the Second Part do agree as follows:

A) That during the 1994-95 snowplowing season, which the parties agree shall run from November 1, 1994 through April 1, 1995, the Party of the First Part will furnish a truck for snow removal, which will include the plow, underbody, and sander for snowplowing in the Town of Commonwealth and in the Town of Florence.

Further, it shall be the responsibility of the Party of the First Part to make all major repairs to the truck, plow, underbody, and sander. By major repairs, the Party of the First Part and Party of the Second Part envision major repairs to consist of items such as broken axles, faulty or broken transmissions, or substantial engine failure. Further, the Party of the First Part will be obligated to carry adequate and sufficient insurance on the complete unit, consisting of the truck, plow, underbody, and sander.

B) The Party of the Second Part will supply the labor, parts, and supplies for all light maintenance required on the above truck as well as supplying all of the fuel for the truck. Light maintenance is envisioned by Party of the First Part and Party of the Second Part to consist of such things as oil changes, oil filters, air filters, etc.

C) Party of the Second Part will also supply the driver for the truck for the purposes of snowplowing, and, based on a forty (40) hour week, will split the wages for said driver with Party of the First Part on a 50/50 or equal basis (i.e., should the driver work a 40-hour work week, Party of the First Part would be required to pay for 20 hours of work and Party of the Second Part would be required to pay 20 hours of wages).

D) In the event that snowplowing requirements, during any given week during the term of this contract, not cover the twenty (20) hours, Party of the First Part may use the balance of the driver's time for labor for the purpose of brushing, road repairs, etc. These particular hours may be accumulated or "banked" and may be used by Party of the First Part after the 1994-1995 snowplowing season has ended.

E) The Party of the Second Part further agrees to put up or set aside two hundred (200) yards of sand for the use in sanding Party of the First Part's roads; however, the cost of the two hundred (200) yards of sand will be borne by, and be the responsibility of, the Party of the First Part.

F) It is further agreed that the Party of the Second Part will supply a road grader and operator to "wing back" snow banks for Party of the First Part.

G) It is further agreed that Party of the Second Part will submit billing statements to the Party of the First Part for the driver's wages once per month. Any adjustment required, such as hours not used or extra hours not paid for, will be made in the spring of 1995 after snowplowing requirements have ceased.

WITNESS our hands and seals this ___ day of _____, 1994.

GARY STEBER - Chairman
Town of Commonwealth, Florence County, Wisconsin and Party of the First Part

RAY STEBER - Chairman
Town of Florence, Florence County, Wisconsin and Party of the Second Part

Source: A Best Practices Review: Local Cooperation to Maintain Roads and Streets, Appendix VIII, (1999)

Endnotes

1 Wisconsin Joint Legislative Audit Bureau, *A Best Practices Review: Local Cooperation to Maintain Roads and Streets*, Appendix VIII, (1999), https://lgc.uwex.edu/files/2016/04/99-1bestreport.pdf.

Resources

General

"Resources and publications dealing with snow and ice." *US Department of Transportation Federal Highway Administration* online. Last accessed December 2018. https://ops.fhwa.dot.gov/weather/weather_events/snow_ice.htm.

"Winter Weather Terminology." *National Weather Service* online. Last accessed December 2018. https://www.weather.gov/bgm/WinterTerms.

Examples of Snow/Ice Removal Planning

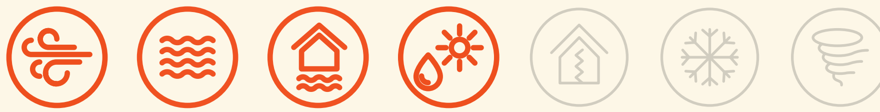
King County Code Ch. 14.48, http://aqua.kingcounty.gov/council/clerk/code/17_Title_14.htm#_Toc422296104.

Pierce County. *Snow and Ice Plan*. 2010. http://mrsc.org/getmedia/2abc6641-6d79-4574-8252-24fc98dbd162/p5snowPlan.pdf.aspx.

"A Best Practices Review: Local Cooperation to Maintain Roads and Streets, Appendix VIII." State of Wisconsin Joint Legislative Audit Bureau, 1999. https://lgc.uwex.edu/files/2016/04/99-1bestreport.pdf.

5.7 Trees

Modify Tree Programs for Improved Resilience and Ecological Health



Key Benefits

1	**Reduces the Urban Heat Island Effect**
2	**Improves ecological health and resilience**
3	**Improves long-term strength of trees and power lines**
4	**Improves air quality**
5	**Reduces stormwater runoff and flash flooding**

Limitations

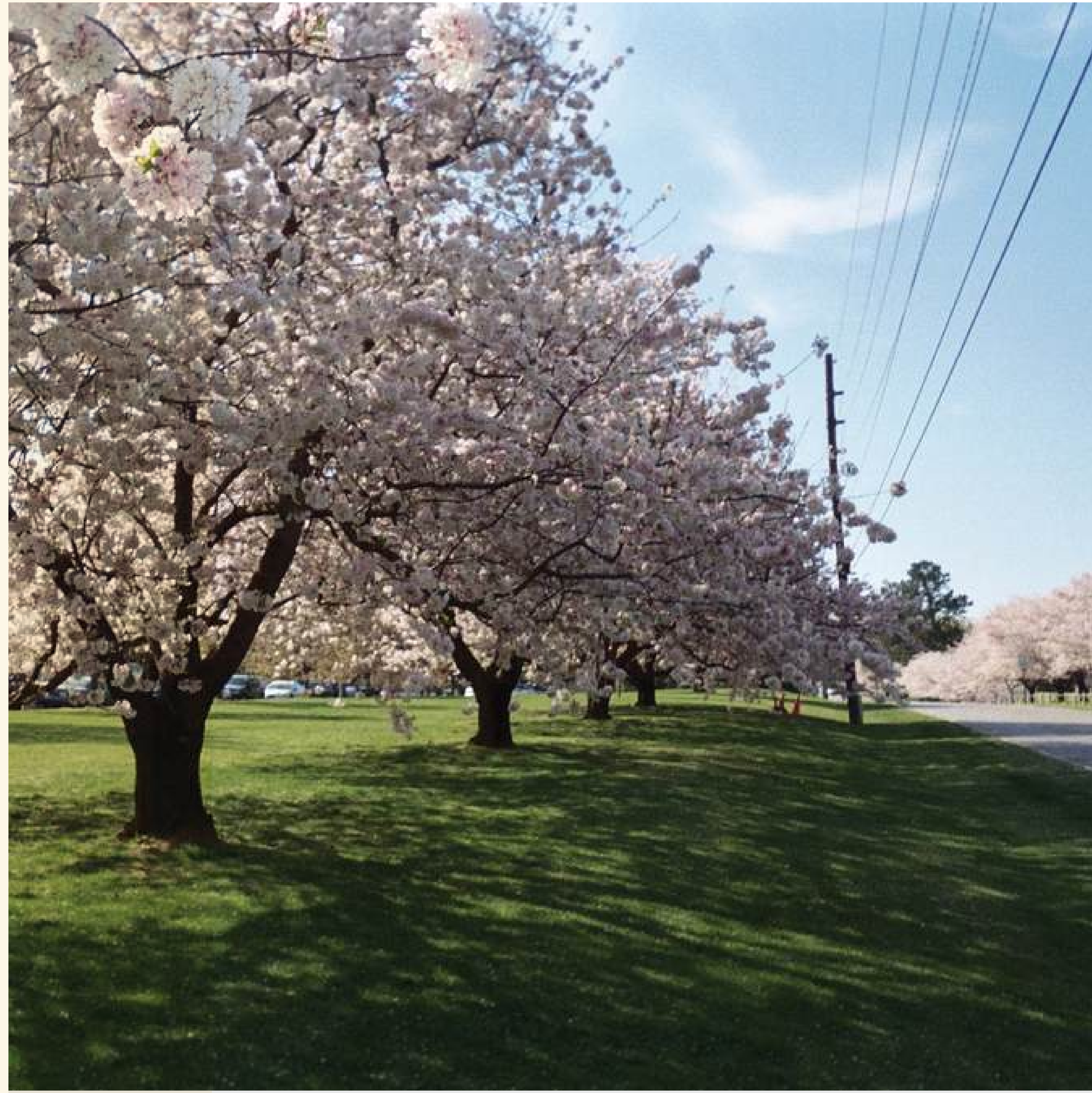
1	**High capital and maintenance costs**
2	**Potential increased risk to power lines if not well-planned or maintained**

Overview

Trees are an essential part of Mid-South ecology. Aside from their aesthetic value, trees provide invaluable ecosystem services that would be costly to replicate artificially. This section highlights best practices to maximize the productivity and resiliency of urban trees. In this case, it is vital to create a strategic plan for planting and maintenance to avoid the damage that trees can cause to homes and utilities during storms.

Prior to modern development, the Mid-South was nearly entirely covered by tree canopy. Now, Memphis only has about 31% canopy coverage, and the surrounding area has up to 37%. After extensive study, the Memphis Regional Canopy Action Plan (MRCAP) estimates that there is room for an additional 29% of planting coverage to be added. As part of its goals, the Office of Sustainability should continue to advance urban canopy in conjunction with all available local partners. Three components for successful canopy expansion are (1) developing design guidelines, (2) coordinate planning and maintenance efforts among relevant organizations, and (3) support tree planting beyond the street.

(Right) Cherry Trees at Memphis Botanic Garden by Flickr/ Andrea)



The Urban Tree Canopy as Infrastructure

Trees in the public realm add value and benefits to their surroundings. Many cities have seen a financial return of $2 to $5 for every $1 invested in street trees. The return comes from reduced stormwater runoff, air quality improvements, cooling, and other benefits. For home and business owners, the return comes in higher foot traffic, higher property values, and faster property sales. Of course, this is on top the primary benefits of street trees—human health and comfort.

Achieving the full benefits of street trees requires careful design, planting, and maintenance. This section focuses on how to improve the urban canopy through excellent design guidelines and maintenance programs.

Value of a Resilient Urban Forest[1 2 3 4]

Financial

- Rates of return for street trees are usually up to five times their investment.
- Trees can reduce indoor air conditioning by 30%.
- Trees can reduce home heating needs by 20-50%.
- Trees cool cities: shaded surfaces can be up to 45°F cooler than sunny spots.
- Trees, when healthy and attractive, can increase home values substantially.

Environmental[3]

- Stormwater reduction saves millions in reduced burden on grey infrastructure.
- Biodiversity increases both above and below ground.
- Reduced use of fossil fuels for air conditioning.

Public Safety and Human Health

- Trees reduce air pollution, which causes millions of deaths worldwide each year.
- People walk farther on tree-lined streets.
- Trees-lined streets have less violence, more commercial activity, and fewer car crashes.
- Street trees have been shown to be correlated to less domestic and street violence.
- Street trees also reduce stress and incidence of heat stroke.[5]

The Value of Robust Design and Maintenance Programs

- Due to poor planting and maintenance practices, the average life of a street tree is approximately a decade, four to seven times shorter than it could be.
- The cost to restore power after storm damage usually ranges in the millions of dollars per event. This cost is passed on to consumers.
- Anticipated cost of an effective urban tree program is only $8-10 per person per year.[5]

Large trees can take up a hundred gallons of water per day during the growing season.[2] This reduction in runoff helps mitigate flash flooding and river flooding.

Urban Canopy Goals

Reduce Storm Damage

One of the more common design problems is planting trees too near power lines, or power lines put too near trees. This proximity creates unnecessary damage. This damage contributes to 20% of power outages, makes homes unlivable, and impedes traffic.

Design guidelines and thorough maintenance can reduce storm damage significantly. Selecting the "right tree for the right place" involves looking at species characteristics, particularly anticipated mature height and wood strength.

Increase Biodiversity

Designing for biodiversity involves making sure that there are several species of trees and shrubs in an area, in sufficient numbers to create an attractive habitat.

While the ordered appearance of identical street trees has long been a preference, monocultures are susceptible to species specific pests and limit habitat types for birds and animals. Planting only one type of tree lets pests and disease spread faster. If the species dies out as a result, there will be no trees left.

Reduce Urban Heat Islands

3.4 Trees help keep cities cool during the hot summer months. As shown in 3.4 Roof Design, urban areas are consistently several degrees hotter than rural areas due to materials that allow for heat gain, such as those found in buildings and surface paving (impervious surfaces). Increased heat from this effect can exacerbate heat-related health issues such as heatstroke or respiratory disease and especially affect vulnerable populations such as the elderly and children. Areas of high impervious surface area coverage may not have been designed to host trees to prevent heat gain. These areas may be retrofitted to accommodate more trees and thus more shaded area to prevent urban heat islands. Trees may also help by casting shade onto buildings and through evapotranspiration of water.

The Climate Action Plan has a goal of achieving 60% tree canopy coverage in Shelby County by 2050.

5.7.1 Develop Design Guidelines

Enable Municipalities to Achieve Benefits of Street Tree Planting

A standard set of design guidelines across the Mid-South would help ensure resilient tree planting policies. Design guidelines help practitioners understand how to implement planting principles while maintaining flexibility in the application of these principles. These guidelines should take into account several factors. To prevent storm-related damage, guidelines must specify the location, height, and stability of potential street trees. To reduce urban heat island effect, trees should be planted on the south and west sides of buildings and parking lots. To increase ecological resilience, the species diversity and number of trees should be high.

Priority 1: Urban Tree Resiliency

Right Tree, Right Place

A common motto among tree caretakers is "right tree, right place." This phrase emphasizes that planting a tree requires careful consideration of the characteristics of both the site and the tree. Information about selecting site-appropriate trees is widely available through organizations such as the Arbor Day Foundation (ADF) whose list is adapted below.

Species Characteristics to Consider

- Height (when full grown)
- Canopy spread (when full grown)
- Type: deciduous or evergreen
- Form and shape
- Growth rate typical of the species
- Whether it drops fruit, seeds, or leaves that may create a maintenance problem
- Hardiness (the maximum and minimum temperatures the species can usually withstand)

Planting and pruning trees by height and stability characteristics around homes and power lines can reduce storm damage. Most utilities have established best practices for planting around power lines, which should be incorporated into design guidelines.

Maximum tree heights under service lines are based on the height of the line, which varies from 10-12' for residences to 18' in commercial areas. Vertical height clearance should be at least 5'. Transmission lines have stricter clearance requirements which already prevent most storm damage.

Sourcing Strong Trees

In addition to choosing the right species, sourcing a strong, healthy tree helps ensure tree stability.

Factors that May Affect Susceptibility to Storm Damage Include

- Fast growing trees (weak wood)
- Root-bound / poor root systems
- Trees with poor branch structure (multiple leaders, etc.)
- Trees that have had branches grafted onto a separate trunk stock (a common practice for commercially available trees)

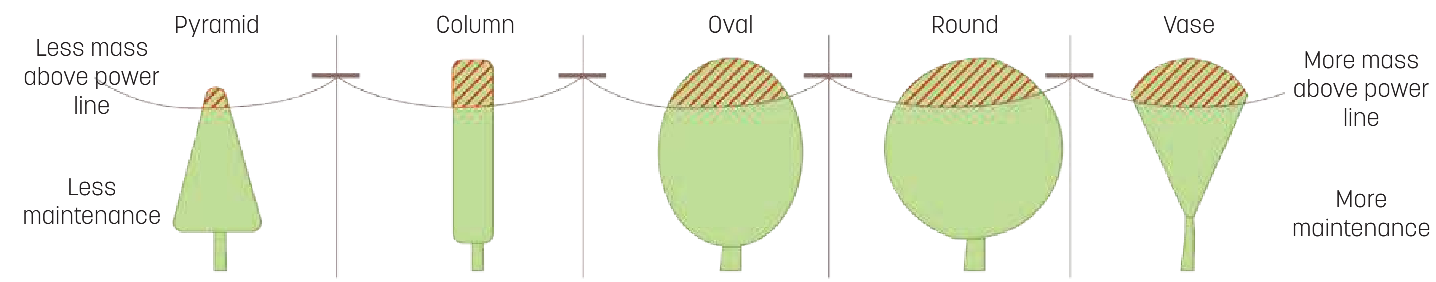
Typical Features of Resilient Trees

- Grow at a slow to medium rate
- Grown regionally
- Do not have grafted roots, trunk, or branches
- Robust root systems

To maximize the benefits of tree planting, jurisdictions in the Mid-South should develop a relationship with regional nurseries that grows its own stock.

Tree Form

Trees typically can be grouped into five forms. Form helps predict which trees may pose a maintenance challenge when located near power lines.



Pruning for Resiliency

Design guidelines for public space trees should address pruning techniques that maintain a tree's natural strength. Ideally, pruning occurs across the entire tree by selective cutting. Pruning should maintain the form and branch structure of the species (oval, pyramid, round, etc.). Pruning to these guidelines will likely raise costs. However, it will also likely reduce the long-term need for maintenance and the long-term risk of diseased and week branches falling off. In addition, good pruning practices lead to a more attractive streetscape with healthier shade trees.

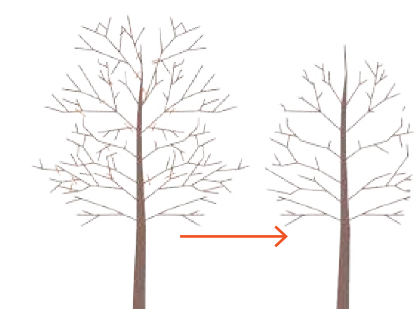
For existing trees that conflict with power lines, pruning is a major issue. Power lines need to have a 10-15' clear zone to reduce the risk of storm damage. However, aggressive tree trimming around power lines often puts the structural stability of the tree at risk. Improper trimming often results in fast replacement growth that is actually weak. Common problems include:

Side or "L" trimming makes trees lop-sided and prone to fall over into yards and onto homes.

Through or "V" Trimming removes a trees central leader, making it less stable. The tree may replace it with several side leaders, which are more likely to break.

Disease may be spread by aggressive pruning. The wounds from cut branches are open to infection and infestation. At the same time, the reduced canopy makes the tree less able to fend off pests. This can result in more branches dying or the tree falling over.

The Effects of Pruning



Careful pruning increases tree strength and moderates growth rates.

(Left) Aggressive and uneven pruning destabilizes trees and causes fast but weak branches to sprout.

(Left) Pruning to accommodate power lines often results in "L" or "V" shaped trees that are very likely to break, die, fall over, or become infected.

Priority 2: Reduce Urban Heat Island

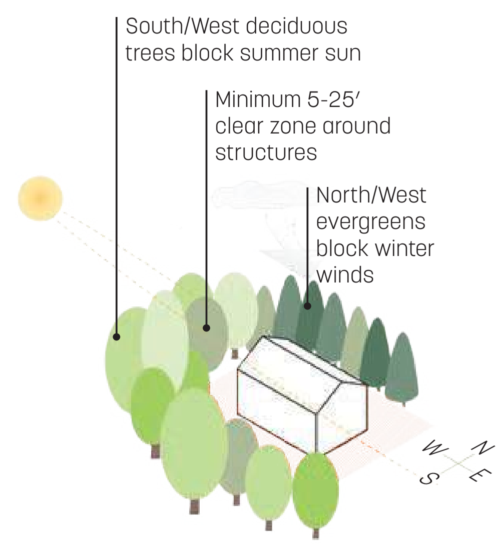
Trees Can Reduce Dangerous Urban Heat

Street trees can help reduce urban heat islands by increasing solar reflectance, evapotranspiration, shade, and air quality. Large trees have the most substantial effects and should be planted and maintained as valuable assets.

Best practices for large tree layout include:

- Plant coniferous trees northwest of a site to temper winter winds.
- Plant deciduous trees on the south and west sides of the site to cool buildings in the summer.
- Follow "Right Tree, Right Place" guidelines for power lines and utilities.
- Plant large trees on the side opposite power lines.
- Avoid planting in small street tree pits with no aeration or drainage. The tree will not thrive and will die within a few years.
- Plant in adjacent yards or parks where the sidewalk does not adequately allow the soil volume required for a tree.
- Engage volunteer caretakers to plant and maintain trees on their own.
- Keep trees a safe distance away from buildings and foundations. Distance is species specific and depends on the height, strength, and root spread of the tree.

Ideal Solar Orientation



Building the Urban Tree Canopy

A robust and well planned urban tree canopy (UTC) is made up of many components. Each site type supports a variety of species which together build species diversity. Large trees that may pose powerline conflicts are welcome in yards, parks, vacant lots, and road medians.

Sample species for each location type are highlighted in green. There are 20 species shown.

Priority 3: Healthy Biodiversity

Planting different species makes it harder for pests to spread and wipe out all the trees in an area while also creating diverse habitats.

The benefits of species diversity include:

- Layering: species of different heights creates a more dense canopy and more stormwater uptake.
- Habitat: birds and animals have habitat requirements including living in or near a certain tree species.
- Resilience: pest and diseases tend to be specific to a certain species, family, or genus of trees and shrubs. Tree species diversity ensures that pests and disease will not wipe out all of the canopy at one time.
- Pollution mitigation: different plant species are able to take up different soil and air pollutants, including lead, cadmium, VOCs, and particulate matter.

Recommended Tree Diversity

Follow the 5:10:15 rule to ensure a diverse urban canopy:[6]

No more than 5% of same species

No more than 10% of same genus

No more than 15% of one same family

This means that there should be at least 20 species of trees in a given area, such as the street trees on and around a boulevard or a park. Those 20 species should represent 10 different genuses and 7 families.

Sample BMPs and Design Guidelines

Recommended best practices to include in design guidelines and Unified Development Code

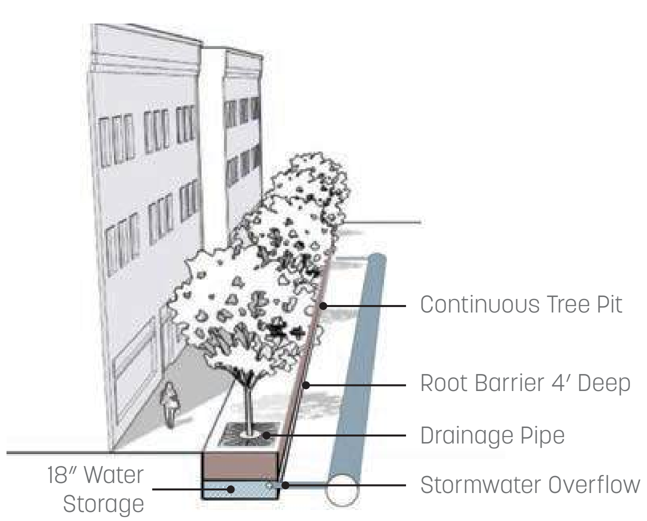
The Memphis and Shelby County Unified Development Code (UDC) has outlined the arrangement of streetscape plates for several different development scenarios. These cross-sections provide ample space for most street trees (8' minimum). The UDC would benefit from the addition of below-ground details including minimum soil volumes, aeration, and drainage. It would also benefit from recommendations for the layout of trees on a site for solar shading, biodiversity, and minimal storm damage. Recommended sample language is shown in gray.

The section 4.6.9 Approved Plant List includes several species that are known to have challenges as street trees (e.g., Norway Maple can be invasive, zelkova branches are prone to breaking off).

Drainage, Depth, and Trenching

An example of underground design details is shown here, overlaid in color over the UDG 4.3.5 S-1 Streetscape Plate.

- Contiguous tree pit is highly encouraged. Exemptions for minimum soil volumes may be granted in the case of contiguous tree pits wider than 6′.
- Minimum 18″ gravel drainage area under tree pit. Where possible, connect overflow pipe to storm drain.
- Root barrier at least 4′ deep and as long as anticipated height of tree.



Biodiversity Layout

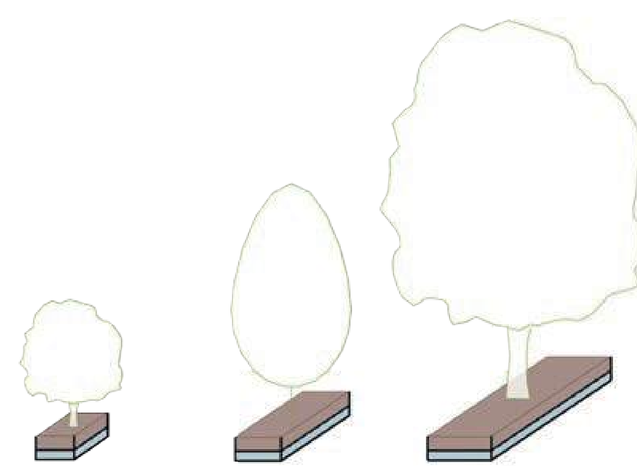
Encourage the use of multiple species, families, and genuses by providing guidelines such as:

Below are recommended species distributions for tree planting, intended to promote biodiversity and tree canopy resilience.

- 1-5 Trees: 1 Species
- 6-10 Trees: No more than 50% 1 species
- 11-20 Trees: No more than 50% 1 species; at least 2 families
- 20-50 Trees: No more than 25% 1 species; at least 2 families
- 50+ Trees: Follow 5:10:15 rule (See Priority 3)

Minimum Soil Volumes

Trees need certain minimums of soil volume in order to thrive. The volume depends on the size of the tree. The depth of a tree pit usually does not need to be more than three to four feet because most roots are two feet of the surface.



Small Tree
4′W x 10′L x 4.5′D
120 ft³ of soil
18″ drainage layer

Medium Tree
8′W x 20′L x 4.5′D
500 ft³ of soil
18″ drainage layer

Large Tree
8′W x 32′L x 5′D
1000 ft³ of soil
24″ drainage layer

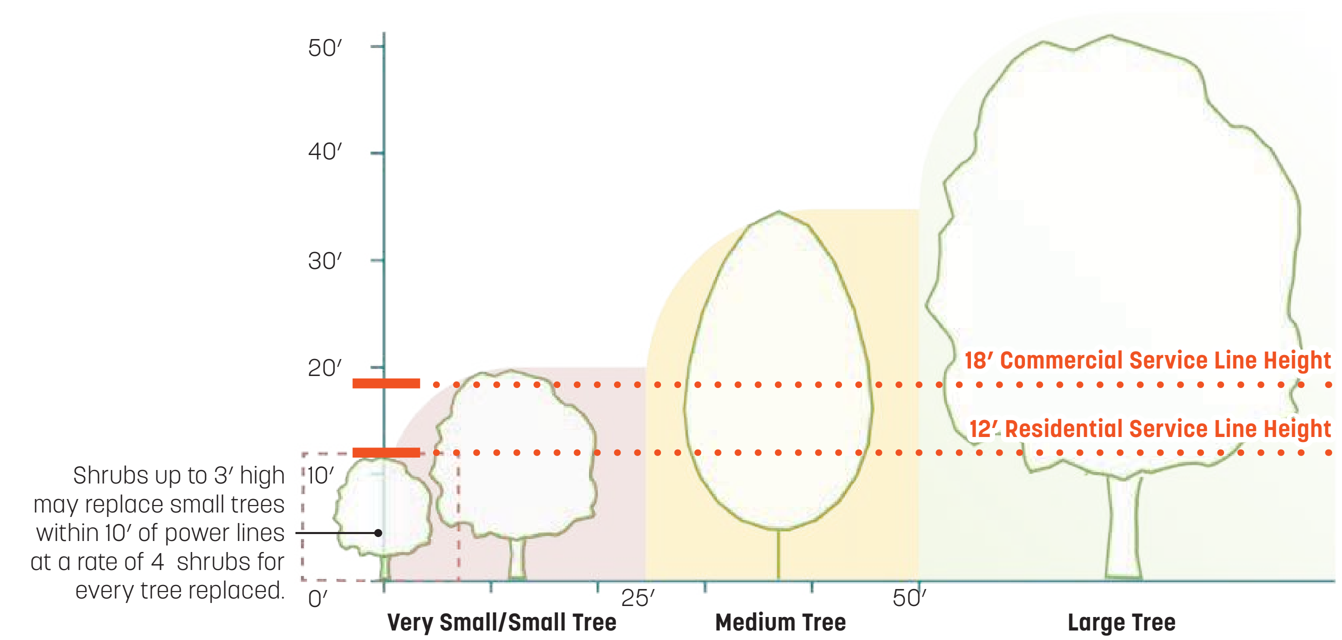
Planting Near Power Lines and Utilities

Very few species are small enough to grow under power lines, which range from 12 to 18 feet off the ground in most areas. There are only three small trees on the Memphis Tree Board Street Tree List.

Guidelines and code should make every effort to support appropriate plantings in and around power lines. Sample Guidelines:

Development within 50′ of an overhead power line shall comply with the following guidelines based on anticipated mature height (AMH) and other species characteristics.

- Directly underneath and up to 10′ on either side of a 12′ line must have an AMH of 12′ or less. Replace unsuitable trees with hardy 3′ shrubs as needed at a ratio of at least 4 shrubs per tree.
- Directly underneath and up to 16′ on either side of a 18′ line must have an AMH of 20′ or less.
- 10′ and up: AMH must be no more than 5′ more than the horizontal distance to the power line.
- Species planted with 50′ of any power line must not be prone to breakage by disease or wind (see species lists).
- Underground utilities. No trees shall be planted within 10′ of an underground utility unless contained from the utility by a root barrier at least 4′ deep and as long as the AMH of the tree. Small and medium trees may be planted within 11-20′. Large trees must be planted at least 20′ away.



Pruning for Tree Health

Given the risk of lop-sided and infected trees falling over, design guidelines should provide graphic representation of pruning practices and tree removal.

Lop-sided | Topped | Top-heavy

Lop-sided trees, topped trees, and top-heavy trees may be removed from public or private property if they are determined to be a fall hazard. When on private property, the owner may keep the wood/mulch from the downed tree. Private owners may also receive up to 5 appropriately sized replacement trees.

5.7.2 Coordinate Recommendations

Coordinate Across Agencies and Municipalities

Recommendations, implementation, and maintenance should be coordinated across the Office of Sustainability, the Memphis Tree Board, MLGW, and Mid-South municipalities. The organizations and governing bodies tasked with street tree resilience will be more successful with increased coordination and mutual support. Between the Memphis Tree Board, Office of Sustainability, Memphis and Shelby County Office of Planning and Development, MLGW, Memphis Division of Park Services, Memphis City Beautiful, and the West Tennessee Section American Society of Landscape Architects (ASLA), the Mid-South has the foundations for a robust network of tree management. Memphis also has a part-time urban forester. In Mississippi, the DeSoto County Soil and Water Conservation District supports tree planting and Entergy, the primary electricity supplier, routinely trims trees.

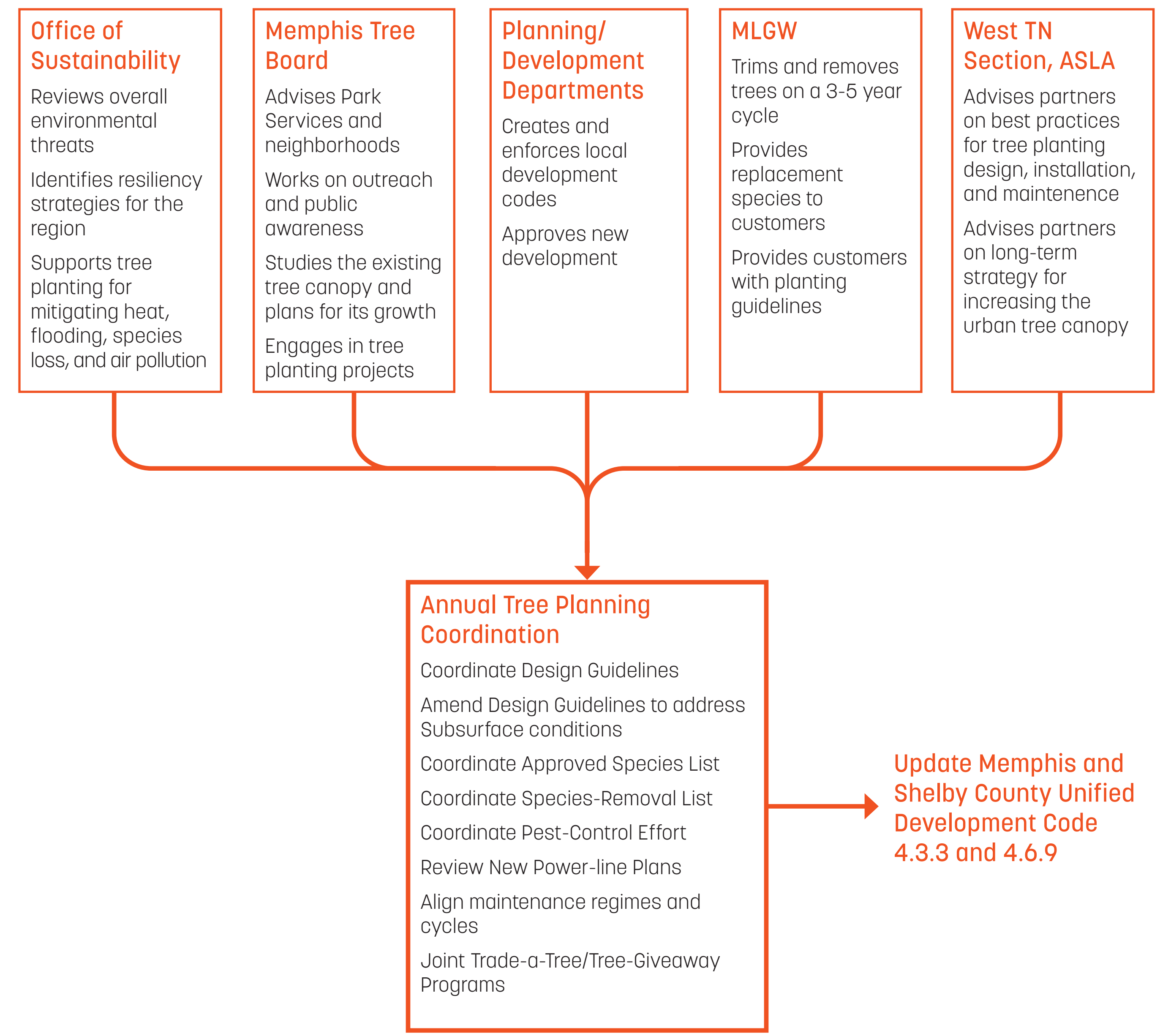
This strategy proposes setting up annual coordination meetings to maximize each group's expertise and align strategies. The first meetings must address the following topics: design guidelines, approved tree species, species diversity goals, and maintenance. Subsequent annual meetings would cover ongoing maintenance, special programs, new threats to approved species, and planting plans. Coordination must also address the location of new power lines and how they may impact tree planting plans within communities.

Approved planting lists demonstrate the need for coordination. While MLGW conducts the majority of tree pruning and replacement with respect to power-line conflicts, its planting list is short and not aligned with that of the Memphis Tree Board. Neither list aligns with the Memphis and Shelby County UDC. The MLGW Trade-a-Tree program offers Bradford Pear and Crape Myrtle as options for replacement trees for customers. However, the Memphis Tree Board identified Bradford Pear as invasive and Crape Myrtle as susceptible to bark scale.[7] Coordinating MLGW's maintenance services and the UDC will help ensure future maintenance and development align to common goals and standards.

(Left) Bartlett, TN General Maintenance. Source: CityofBartlett.org

Coordination Effort

Coordination between partners on an at-least annual basis is necessary to maximize the effectiveness of any tree planting plan. Below is a sample organization chart for Shelby County, which could be adapted to all Mid-South counties.



5.7.3 Think Beyond Street Trees

Public and Private Land for Publicly-supported Tree Planting

While street trees are an important part of the urban canopy, the vast potential for its expansion lies on the public and private land just beyond the sidewalk: parks, yards, vacant land, parking lots, and more. The 2015 Memphis Regional Canopy Action Plan (MRCAP) found that parks and schools have the highest potential to add tree canopy to the urban environment: over 12,287 acres across 2,528 parcels. Following close behind, residences could provide an additional 3,000 acres across 2,900 parcels. In addition the MRCAP mapped priority planting areas that take into account the most socially beneficial and financially efficient places to increase canopy.[8]

Municipalities can encourage and incentivize tree planting on public and private land through a variety of methods. For public land, municipalities can intervene directly or offer grants and assistance to local groups for planting projects. For private land, encouragement could come through the form of subsidies, seeking out grant partners, education, and consulting. Incentives could include utility or tax credits, matching funds, or additional development rights. For future development, design guidelines can help ensure a robust canopy.

(Above) Tree planting event at the Medical District vacant lot, Memphis

Benefits

- Improved tree health due to larger soil pits.
- Expanded target area.
- Trees maintained by home and business owners.
- Greater funding opportunities including grants, volunteers, and non-profit support.
- Direct engagement with local population.
- Ability to plant more diverse vegetation types, heights, and densities.

Methods

Vacant Lots and Parks

Many cities have begun to convert vacant lots into vegetated areas. In areas where this has been successful, such as Chicago, the city government has made it easy to obtain permission to clear and work the land regardless of whether the property is private or publicly-owned. The NRDC report "Greening Vacant Lots: Planning and Implementation Strategies" is a thorough resource for case studies, funding, and implementation strategies.

(Right) An old baseball field was converted into a burgeoning poplar forest by Greenprint Partners (formerly Fresh Coast Capital)

Parking Lots

Existing and proposed parking lots are ideal places to add tree canopy. For proposed and major renovations to parking lots, local landscape ordinances can be used to encourage the abundant inclusion of trees. The Pottstown, PA Tree Fund has compiled several sample ordinances for reference.[10] Including one tree for every 2-6 parking spaces is ideal to create a full and distributed canopy. For existing parking lots, tree pits can be added between rows (right), in converted spaces and along the edge of the lot.

(Right) Tree islands include curbs to protect trees and allow for drainage

Homes and Businesses

Even though land may be considered private property, that does not mean it is not available for publicly supported tree planting. Municipal governments can encourage tree planting in several ways. Free or reduced rate tree sales are a simple way to encourage homeowners to plant specific species of trees. A good resource for this type of program is the Arbor Day Foundation (ADF). ADF works in conjunction with local utilities and other partners to offer Energy-Saving Tree Programs.

Another way to encourage tree planting is to offer free or subsidized installation assistance to those who are unable or unwilling to plant on their own. Such assistance also assures that trees are planted responsibly, away from power lines, underground utilities, homes, and in amenable soil conditions.

Beyond encouragement and assistance, municipalities and utilities can reduce water, sewer, or electricity fees based on canopy coverage, since trees can help reduce the demand on such utilities. For example, as part of its stormwater management program, Philadelphia offers credits to businesses that have a certain amount of canopy coverage.[9]

5.7.4 Recommended Trees for Dense Urban Areas

Recommended Street Trees

Urban trees should be carefully chosen to survive the heat, drought, soil compaction, and alkaline soils of cities. When planted in a sidewalk, use large tree pits, compaction protection, aeration, and drainage. This list highlights trees that are most likely to survive in urban tree pits and require the least maintenance. These species are already on the Memphis Tree Board Street Tree List and have been proven to succeed in other cities.

Criteria for Street Tree Short List

- Tolerates compact and alkaline soils
- Survives flooding and drought
- Roots will not lift up the sidewalk
- Resists breaking limbs in high winds
- Maintains visibility for drivers and pedestrians
- Can be limbed up to 12' above road and sidewalk
- Native/not invasive (existed prior to development)
- Hardy in Plant Hardiness Zones 7b and 8 (within the Mid-South)

Sourcing Non-Grafted, Local Trees for Wind Resistance and Hardiness

Finding regional nurseries that grow their own stock helps prevent street tree death and damage. Trees grown at regional nurseries are better adapted to the local climate. Many commercial nurseries 'graft' trees, joining the roots, trunks, and branches of different trees together. Grafting weakens the joints between roots, trunks, and branches, making it more likely that storms will break off branches. Trees grown on their own root and trunk are more wind-resistant.

Some cities have established their own nurseries in parks and vacant lots to create an inexpensive supply of durable, locally-adapted, custom trees. A nursery can also be contracted to grow city trees on public land at a reduced rate.

'Limbing up' for Street Tree Form

Street trees ideally have a strong central leader and are limbed up to allow at least pedestrian views and passage. Most trees require 'limbing up', or cutting off lower-branches, to attain a this form at a young age. Tree species specified for street tree use should be canopy trees and noted for lowest limb to be 5 ft above grade.

Nuttall Oak

(*Quercus nutallii*)

A strong unbranched tree that grows up to 60 ft tall with a 45-ft wide spread.

Overcup Oak

(*Quercus lyrata*)

This oak can grow up to 45-70 ft with a 45-ft wide spread. It tolerates most soil conditions.

Willow Oak

(*Quercus phellos*)

A realtively fast-growing tree that tolerates poorly drained soil. It can grow to 40-50 ft with a 35-ft wide spread.

Shumard Oak

(*Quercus shumardii*)

This oak grows up to 60-75 ft in good conditions. It is drought and pollution tolerant.

Allee Elm

(*Ulmus parvifolia* 'Allee')

Can grow to 40-50 ft tall with a 40-ft wide spread. It is adaptive to many soil conditions.

Ginkgo biloba 'Princeton Sentry'

(*Ginkgo biloba*)

Grows to 40-50 ft tall with a spread between 20-30 ft.

Recommended Trees for Non-Street Urban Areas

The following trees will do well in urban parks, yards, and plazas.

Small Trees for Less Stressful Sites

Less stressful sites are those with better soil and drainage conditions with larger planting areas than a typical tree pit. Many small and medium trees need soil in a better condition than a tree pit will allow. These trees will do well in urban areas as long as care is taken in planting. Parks, yards, sheltered plazas, and wide medians are preferred.

- Winter King Green Hawthorne
- Two-winged Silverbell
- *Deciduous Holly (aka Possumhaw) 'Council Fire and 'Warren's Red'
- American Hornbeam (Carpinus Carliniana)
- Eastern Redbud
- Flowering Dogwood 'Cloud Nine' and 'Cherokee Princess'
- Trident Maple
- Southern Blackhaw

Large Trees for Large Sites

These trees perform well in urban environments and show wind resistance. Each requires a lot of space to spread canopy and roots. These trees are suitable for parks, lawns, yards, large rain gardens, and wide medians.

- Princeton American Elm (shallow roots)
- *Black Tupelo
- 'October Glory' Red Maple
- Willow Oak
- Water Oak
- Swamp White Oak
- Tulip Poplar
- Magnolia grandiflora "Brackens" and 'DD Blanchard'

Aspirational Targets

Complete tree inventory (already in process)

Reach 40% canopy coverage in each municipality across the Mid-South

Achieve species diversity in the public spaces of each municipality (measured by genus, family, and species)

*Suitable for Rain Gardens

Non-native Trees to Consider

To add to street tree diversity, it may be worth considering the following non-native trees. They have been proven well-adapted to urban conditions similar to the Mid-South. Where possible, chose a non-fruiting or sterile variety to reduce the risk of it spreading.

- European Hornbeam 'Fastigiata'
- *Gingko biloba* 'Princeton Sentry' (male)
- 'Allee' Chinese/Lacebark Elm

Trees that Produce Fruit

Fruit and berry producing trees are great for attracting wildlife but can be impractical along sidewalks due to the maintenance involved in cleaning up bird droppings and fallen fruit. The following trees can be planted where fruit dropping is advantageous (parks and yards) rather than burdensome.

- Flowering Dogwood 'Cloud Nine' and 'Cherokee Princess'
- Deciduous Holly (aka Possumhaw) 'Council Fire' and 'Warren's Red'
- Winter King Hawthorn
- Yoshino Cherry

Recommended Trees to Remove from Existing Approved Tree Lists

Recommendations come from careful review of the Memphis Tree Board Approved Species List, which adheared most closely to current best practices. Nearly all of the trees recommended in this section were already on the list. A few species have been specifically excluded, and are listed below.

- Sugar Maple 'Green Mountain' do not tolerate heat and drought well. Sugar maples in general are prone to infection and to lose branches.
- Southern Sugar Maple has not been planted often enough as a street tree to make a recommendation, though it is heat tolerant.

Implementation

Increasing the urban tree canopy is achievable and sustainable in both the short and long run. Goals to guide coordination should include:

- Increase Funding: Increase guaranteed annual funding for street tree planting and maintenance.
- Universal Design Guidelines: Adopt design guidelines addressing utilities, biodiversity, and urban heat island issues.
- Expansive Urban Tree Canopy: In alignment with the Climate Action Plan, aim for 60% Urban Tree Canopy across each Mid-South neighborhood.

Deciding where to intervene begins with an evaluation of which areas would benefit the most, as the Memphis Regional Urban Tree Canopy Survey did. Within these areas, the sites to address first should contain the following criteria:

Primary Criteria for Planting and Pruning

- High urban heat temperatures
- Existing vegetation has low biodiversity
- Existing vegetation is threatened by a pest
- Need to address canopy/power-line conflicts
- Accessible for construction and maintenance
- Previous trimming and removal has left lop-sided trees
- Previous trimming and removal has left few trees
- Trees will help with stormwater runoff and overflow
- Minimum maintenance requirements can be met, including watering until establishment
- There is space for a tree to grow healthily or at least 120 cubic feet of soil for a small tree, 500 cubic feet for a medium tree, and 1,000 cubic feet for a large tree

Secondary Criteria

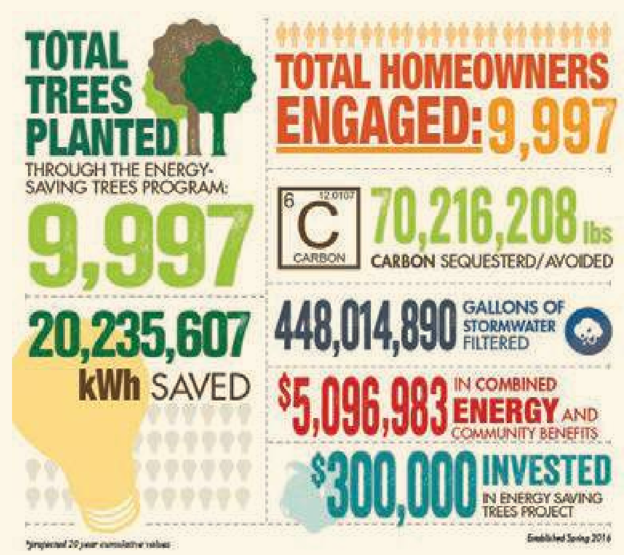
- Tree planting will improve pedestrian experience
- Tree planting will not interrupt a pedestrian right of way
- Supportive community group will help with coordination, planting, and/or maintenance (e.g., conservancy, neighborhood organization, recreation department, etc.)

Free Trees for Residents

Several cities and states offer free trees for homeowners. The programs are supported by water departments, donation, and utility companies.

Examples:

- Million Trees NYC (operated by PlanNYC, NYC Parks, and New York Restoration Project)
- Delaware: Delmarva Power partnered with Arbor Day Foundation (ADF) to give away energy saving trees.
- TreePhilly offers trees to homeowners for their own yards. Homeowners can also request street trees for the sidewalk in front of their property (run by Philadelphia Parks and Recreation, Philadelphia Water Department). In addition, PECO also participates in the Arbor Day Foundation Energy Saving Tree Program



(Above) Florida Urban Forestry Council publication on the benefits of their Energy Saving Tree Program.

Process

1 Align	Align goals across agencies and organizations involved in public tree management Coordinate ecological goals through species lists: approved species, species to remove or monitor, and species diversity best practices Develop design guidelines to reduce risk and increase street tree effectiveness
2 Prioritize and Plan	Identify priority areas for new street trees and increased urban canopy Develop a partnership with or create a regional nursery to ensure inexpensive, hardy stock for planting projects Identify priority areas for tree pruning, removal, and replacement
3 Fund	Seek community partners for assistance with surveying, planting, and maintenance Seek funding through grants, public funds, and corporate partnerships
4 Maintain	Transfer/assign maintenance responsibilities to the Division of General Services and local partners Coordinate volunteers for ongoing maintenance efforts or planned volunteer event days Establish urban forestry programs in larger jurisdictions

Policy Recommendations

Public policies can play an important role in protecting existing canopy and encouraging successful planting efforts. As discussed, above, a high level determination of goals and strategies gives direction and purpose to every organization involved. The following is a summary of recommended policy actions:

- Implement Strategy 5.7.2 Coordinate Recommendations on page 459 to create goals and strategies.
- Adopt and enforce design guidelines (Strategy 5.7.1 on page 453) across the region to ensure best practices moving forward.
- Adopt tree trimming standards that align MLGW's practices with municipal workers to help prevent storm damage. This should be accompanied by additional dedicated maintenance funding.
- Amend the Tree Preservation Ordinance to reduce the percentage allowable for tree removal and to increase the tree restitution rates. For example, currently a 10,000 sqft single family lot can remove 80% of the trees on site without replanting or restitution. Commercial lots can remove 90%. Removal rates should be based on space needs for actual construction, rather than an arbitrary percentage that allows for excessive tree removal.
- Where appropriate, offer tree give away programs that encourage voluntary planting efforts. Such programs can target individual homeowners, businesses, or municipalities.
- Offer rebates for local taxes or utilities for tree planting based on the ecosystem services provided.

Funding

Given the broad appeal of urban trees, there are many potential sources of funding. For instance, public revenue streams include:

- Discretionary spending determined on an annual basis. This is acceptable for specific projects but does not guarantee long-term maintenance.
- Dedicated funding stream from general tax revenue. It is ideal when the amount of dedicated funding can be secured for several years or indefinitely. Dedicated and reliable funding allows departments to plan both for new projects and ongoing maintenance simultaneously, increasing the likelihood of success.
- Ballot measures. Over the last 30 years, the success rate of public bonds or financing for parks and conservation projects has been 75% across the US.

Potential Partners

The Arbor Day Foundation (ADF) has several programs that may be of use to municipalities, organizations, and individuals interested in planting trees. On an ongoing basis, ADF partners with energy utilities to provide a free tree to customers in the Energy Saving Trees Program. For example, the Florida Urban Forestry Council worked with ADF to plant 10,000 trees since 2016. ADF also works with large partners to supply grants. For example, working with TD Bank, it gave $20,000 to ten cities in 2018 for planting vegetation in middle and low-income areas.

The U.S. Forest Service offers updated information on grants related to forestry on its partnership website (https://www.fs.fed.us/working-with-us/partnerships/funding).

The USDA Urban Forestry Grants can provide funding for smaller projects. The Memphis area has received three grants over the last few years, including a $24,000 grant in 2018.

The Tennessee Urban Forestry Council could serve as an important link between organizations seeking funding and those supplying funding.

DeSoto County Soil and Water Conservation District hosts an annual tree give-away.

MLGW and **Entergy** are the two primary electricity suppliers in the Mid-South. They should be included in discussions around tree policies and trimming. Through their routine trimming efforts, they can support trimming and maintenance goals.

Leverage Stormwater Connections

The value of urban trees for stormwater reduction and treatment should not be neglected. It is worth remembering that forests have an average runoff rate of about 10% to 20% while urban areas range from 50% to 95%. Several cities have begun including the urban forest as part of their stormwater management strategy.

Connecting with stormwater usually requires a more robust tree pit, with additional soil volume and diverse vegetation. These additions make the tree pit or trench able to hold and process more water. A tree pit that is 1,000 cubic feet can hold approximately 200 cubic feet of water.

When a tree planting project is able to include a documented stormwater management component, more funding opportunities open up. Government and granting organizations at all levels have funds available for green infrastructure. Federal examples include the EPA Clean Water State Revolving Fund, HUD Community Development Block Grants, and FEMA Hazard Mitigation Grant Program.[11]

The City of Philadelphia Water Department has developed and consolidated research and BMP documents for Green City Clean Waters. Within this program, trees are identified as an important stormwater infrastructure. For more information on trees and stormwater management, see 2.3 Low-Impact Development.

2.3

Leverage Public Health Connections

When an organization can clearly demonstrate the link between urban tree canopy (UTC) projects and human health, funding sources multiply.

One key step in creating a link between urban tree canopy and human health is specifying trees and vegetation as part of a plan to reduce heat related health risks. For example, a city's parks department could work with the city/county health department to create a Heat Plan. The Heat Plan would outline the city's plan to address the increasing injury and mortality caused by heat waves in urban areas.

(Right) Tree pit designed for stormwater collection as part of the Green City, Clean Waters Program. Source: Philadelphia Water Department

If, as is typical, adding strategic tree canopy (and green/cool roofs) is part of the Heat Plan, the parks department and/or health department can now apply for public health grants. See 3.4 Roof Design for more information.

3.4

The public health connection has been particularly successful when health-insurance companies offer grants for vegetation in their primary service area. For example, Kaiser Permanante donated $2 million to expand community connections to parks in environmental-justice neighborhoods in northern California.[12] Since many of the residents in the targeted neighborhoods are covered by the Kaiser Health network, any health benefits from the grant will benefit their bottom line. Such connections live out the triple-bottom line ideal of "people, planet, profits."

Maximizing Ecological and Financial Success of Tree-planting Programs

Planting and maintaining trees in the public realm is not costly and typically yields a return equal to two to fives times the initial investment. As discussed above, the return comes from improved environmental conditions, their direct effect on human health, increased foot-traffic in commercial areas, and increased property values.

ROI is correlated with tree size. Assuming there is no storm-damage, larger trees provide more ecosystem services than small trees. A second major factor is how long the trees survive. The average life of a modern urban street tree in the US is estimated to be seven to ten years. The average life-span is short because those planting the trees usually do not protect them from the harshness of the urban condition. Over the past few decades, new techniques for urban tree planting have greatly increased the survival and growth rates of street trees. Techniques include larger tree pits, aeration pipes, drainage pipe, and structural soil/containers to protect from compaction. To develop a robust and healthy tree canopy, municipalities in the Mid-South should invest in careful planting techniques.

While ROI is usually correlated to size, larger trees are not necessarily better in storm-prone areas. The above cost-benefit analysis assumes that the tree has not caused any damage to property or the power grid. In the Mid-South, such damage can be very costly to repair, making it not financially sound to plant trees. It is recommended that municipalities, organizations, landscape contractors, and landscape architects in the Mid-South work with regional nurseries (such as in Central/West Tennessee and Alabama) that grown their own stock. These nurseries will be valuable partners in determining the best suited species for a given project and will be abreast of the latest pest threats and treatments.

Case Study

Intervale Conservation Nursery, Burlington, VT

The Intervale Conservation Nursery (ICN) is an example of a regionally-specific tree nursery that was founded with government and grant support and offers low-price, high quality trees for planting projects. It was founded through an initial grant with the US Fish and Wildlife service. ICN's primary purpose is to provide hardy, native stock for conservation projects. To that end, ICN collects its own seeds and operates without pesticides and fertilizers. The nursery grows nearly 100,000 trees and shrubs at a time.

ICN prices are several times below market rate. A five-foot bareroot tree or shrub typically costs $5.75, which is ten times lower than the more typical $50 to $100 at a most retailers. This price reduction is possible for several reasons:

- ICN is a non-profit organization
- ICN operates as an enterprise of the Intervale Center, a larger non-profit sustainable food center.
- ICN's initial funding came from a small grant
- Private partners, such as Patagonia, continue to support ICN.

ICN operates as part of the Intervale Center, a 350-acre non-profit center focused on supporting local farming.

(Below) ICN is in close proximity to Burlington, VT. Source: Google Earth

Intervale Conservation Nursery participates in volunteer-based planting programs for conservation projects. For example, in May 2018, the Burlington School District organized an invasive species removal and tree planting day in Ethan Allen Woods. The planting project was the culmination of a curriculum on watersheds, which involved several visits to the site throughout the spring. The students involved were from the CP Smith Elementary School 4th grade class. The class worked with the University of Vermont Watershed Alliance to conduct sampling of the Winooski River. The planting project was organizes with the help of Winooski Valley Park District, the Burlington School District, and the CP Smith Parent Teacher Organization.

Other planting partnerships included planting 300 trees with Patagonia employees (following a $5,000 grant) and 200 trees with 20 Vermont Gas employees. The projects helped create more robust riparian buffers at the Winooski River and Allen Brook.

ICN offers several additional services to help get planting projects off the ground: custom growing, storage and packaging, delivery, planting, and stewarding.

(Below) 4th Graders from CP Smith Elementary School Planting ICN Trees. Source: BSDVT

(Above) Red-twig Dogwood crop at ICN. Source: Intervale Center

(Right) Vermont Gas workers at Volunteer Day. Source: Vermont Gas

Endnotes

1 "Tree Facts," *Arbor Day Foundation* online, last accessed March 11, 2019, https://www.arborday.org/trees/treefacts/.

2 "Tree Facts," NC State University A&T State University Cooperative Extension, last accessed March 11, 2019, https://projects.ncsu.edu/project/treesofstrength/treefact.htm.

3 Burden, Dan, *"Urban Street Trees, 22 Benefits of Specific Applications,"* Walkable Communities Inc., summer 2016, http://www.walkable.org/download/22_benefits.pdf.

4 F. E. Kuo and W. C. Sullivan, "Aggression and violence in the inner city: Impacts of environment via mental fatigue," *Environment and Behavior* 33, no. 4 (2001), 543-571.

5 McDonald, Rob, et. al, *Funding Trees for Health: An Analysis of Finance and Policy Actions to Enable Tree Planting for Public Health*, The Nature Conservancy, 2017, https://www.nature.org/content/dam/tnc/nature/en/documents/Trees4Health_FINAL.pdf.

6 "Diversity in Planting Trees," *The Morton Arboreutm* online, last accessed March 28, 2019, https://www.mortonarb.org/trees-plants/community-trees-program/community-tree-resources/diversity-planting-trees.

7 Bradford Pear is susceptible to wind damage and Cape Myrtle is frequently misused as a street tree, however it is not a suitable street tree species. Cape Myrtle bark scale is also beginning to subside.

8 Plan-It Geo. LLC for the Wolf River Conservancy, *Memphis Regional Canopy Action Plan*, (2015).

9 "Philadelphia Water Department Rates and Charges," Philadelphia Water Department, last accessed October 2018, https://www.phila.gov/water/PDF/RatesCharges.pdf

10 "Greening our Cities and Towns," *Pottstown, PA Tree Fund* online. http://www.pottstowntrees.org/.

11 A more complete list of federal opportunities can be found on the EPA website: "Federal and State Funding Programs: Stormwater and Green infrastructure Projects." US EPA Water Infrastructure and Resiliency Finance Center. May 2015. https://www.epa.gov/sites/production/files/2017-05/documents/federal-and-california-sw-funding-programs.pdf.

12 McDonald, Rob, et. Al, *Funding Trees for Health: an Analysis of Finance and Policy Actions to Enable Tree Planting for Public Health*, The Nature Conservancy, https://www.nature.org/content/dam/tnc/nature/en/documents/Trees4Health_FINAL.pdf .

Resources

Free Tree Programs

"Free trees Available to Homeowners This Spring." *State of Rhode Island.* https://www.ri.gov/press/view/32865.

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Planning and Implementation

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6

Post-Disaster Opportunities

6.1 Voluntary Buyouts

Implement a Voluntary Buyout Program for High Risk Sites

Key Benefits

1	**Eliminates future flood damages, health and safety risks, and costs incurred in disaster response or recovery**
2	**Reduces repetitive subsidized flood insurance payments and federal disaster assistance**
3	**Restores the floodplain to its natural functions in terms of floodwater storage**

Limitations

1	**May lower local property tax revenue**
2	**Lack of transparency can impair trust and legitimacy of the process**

Overview

Buyouts are a means through which to protect the health and safety of residents and can eliminate future damage to vulnerable or repetitive loss properties. In many areas, the costs of building flood mitigation measures may be significantly higher than the cost of a buyout and relocation. Buyouts are usually funded by local, state, or federal governments and range in scale from a neighborhood to an individual home. Upon purchase, the buyout properties are demolished and the land is deed-restricted to prevent future development. This section outlines the rationale and potential strategy for a local buyout program in alignment with federal buyout program funding restrictions. Buyouts can often be contentious measures for local governments to consider as this necessarily means the relocation of residents from their community and homes. Despite its purpose as a hazard mitigation program, voluntary buyouts are more often utilized as a post-disaster strategy. To promote the viability of this measure, it is important for a voluntary buyout program to (1) increase transparency, (2) emphasize relocation, (3) address long-term social inequities, (4) conduct a more holistic benefit-cost analysis, and (5) engage in participatory pre-disaster planning.

(Right) Flooding in Memphis, TN, May 10, 2011. Source: FEMA

Buyouts as a Hazard Mitigation Strategy

(Left) Aerial view of the Missouri River flooding in 1993 near Jefferson City, MO. Source: Missouri Highway and Transportation Department

In 1993 a large flood stemming from the Mississippi and Missouri Rivers devastated the upper Midwest, covering over 30,000 square miles of land. The Great Flood of 1993 was among the most costly events in the US, with over $15 billion in damages. The floodwaters damaged thousands of homes and forced entire communities to relocate to higher ground. Due to this disaster, amendments were made to the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (Stafford Act) to authorize increased federal funding of long-term hazard mitigation measures. This also included provisions for the acquisition of flood-prone properties within FEMA's implementation of the Hazard Mitigation Grant Program (HMGP).

Historically, large-scale flood mitigation infrastructure was employed to reduce the risk of flood damage to nearby communities. Since 1993, thousands of property acquisitions, or 'buyouts,' have helped to mitigate risks to the health and safety of residents in the floodplain. The implementation of non-structural mitigation measures has gained traction since then, and it has been determined to be one of the most cost-effective strategies in areas where repetitive loss rates are the highest.[1] In addition to the HMGP, Community Development Block Grants (CDBG) have been used in disaster mitigation projects. Congress utilized this program alongside the HMGP during the 1993 Great Flood to fund buyouts of property in nine affected states which facilitated the conversion of the land to public uses like recreation or allowed the land to return to a natural state.[2]

Buyouts are one among many strategies used in hazard mitigation projects and are typically not employed alone. Comprehensive planning, as done within Hazard Mitigation Plans, can help to target critical areas of investment. When considering the extended impacts of flooding on health and safety, buyouts can substantially reduce these risks while providing open space for alternative use by the community.

Buyouts may also be considered for properties in areas with high flood-mitigation potential—helping to protect denser or sensitive areas downstream. Buyouts may be essential in providing space for important infrastructure in the service of economic development. For example, in 2003, torrential rains inundated areas of Cleveland in Bradley County, TN. The flooding caused around $500,000 in damage to a large plant in the city. The 100-year old plant was owned by of one of the city's largest employer's, Whirlpool. This event caused the owners to consider closing, which would be devastating to the local economy. After studies were completed, HMGP funding was given through the Tennessee Emergency Management Agency to pursue buyouts in some of the most hazardous areas. Three dry retention ponds were constructed to reduce the risk of flooding done to the plant. This strategy proved to be cost-effective and allowed the continued operation of the plant, even allowing Whirlpool to add hundreds of additional jobs.[3]

Buyout programs may be heavily influenced by the availability of federal funding as well as the eligibility requirements stipulated by federal policy. In many local programs around the US, local governments

What Goes into a Buyout?

Federal Funding Sources and Restrictions on Buyouts

Source	Type	Federal Contribution	Post-Acquisition Deed Restrictions	Other Restrictions	Purchase Price
Federal Emergency Management Association (FEMA)					
Hazard Mitigation Grant Program (HMGP)	Voluntary	Up to 75% of project cost; over 25% from non-FEMA sources	Deed-restricted for open space, recreation, or wetlands management; cannot be sold to private ownership		Pre-disaster fair market value (FMV)
Department of Housing and Urban Development (HUD)					
Community Development Block Grant (CDBG)	Voluntary or Involuntary	Up to 25% match paired with FEMA as cost-share or up to 100% alone	No deed restrictions; redevelopment possible	70% of CDBG funds must benefit low- to moderate-income (LMI) persons	Pre- or post-disaster FMV
Community Development Block Grant–Disaster Recovery (CDBG-DR)	Voluntary	Up to 25% match paired with FEMA as cost-share or up to 100% alone	Deed-restricted within 100-year floodplain: must remain undeveloped, may be sold or transferred to private ownership with deed restrictions. No deed restrictions required outside 100-year floodplain	Appropriation may reduce or waive LMI requirements	Pre- or post-disaster FMV

Adapted from A. R. Siders (2018)[5]

obtain most of their program funding through a federal application process. But most of the federal funds are only available for voluntary programs. Although local governments have the option to use eminent domain, this would mean that the buyout would have to be entirely locally financed.

One of the sources for the greatest amount of available funds comes from the FEMA HMGP as noted in the previous section. The buyout program within HMGP may cover up to 75% of a project cost to match a 25% contribution from other sources. According to the Disaster Mitigation Act (2000), only communities that have a FEMA-approved hazard mitigation plan are eligible to receive funding from the HMGP.[4] Buyout projects funded through HMGP must be voluntary and restrict the future use of the property through deed-restricted open space, recreation, or wetlands management, and cannot be given to private ownership. To be eligible for receiving funds through this program, a project must undertake a FEMA-approved benefit-cost analysis (BCA) to assess the cost-effectiveness of a buyout against other measures. The project must also demonstrate the reduced future risk and be environmentally sound to receive FEMA approval.

Another common source of federal funding for buyouts comes from the HUD CDBG program and the CDBG-Disaster Recovery (CDBG-DR) program. For HUD funding, projects must benefit low- or moderate-income (LMI) residents in the floodplain, address public safety needs, and improve the quality of urban life. Typically, at least 70% of CDBG funds must be used to benefit LMI residents, but this can be lowered where there is shown to be an urgent need.

In most cases the use of federal funds from these programs (with the exception of CDBG-DR) also limits the ability of local governments in the use of its eminent domain or condemnation powers to enforce a buyout when using federal funds. Once applications are approved, the administering agency negotiates directly with property owners to settle on a purchase price based on the pre- or post-disaster fair market value (FMV). To be eligible for HMGP funding, programs must offer pre-disaster FMV, while CDBG may offer either pre- or post-disaster FMV. Local programs may offer incentives for participation and include planning for relocation. The entire process may take 18-36 months.

Potential Benefits of Buyout Programs

Buyout programs and successful projects have many advantages over other flood mitigation measures, provided that a buyout occurs in areas of high flood risk. 'Flood risk' is usually measured along two criteria: (1) the probability or past recurrences of floods affecting a property and (2) the damage and financial impacts that result from a flooding. Buyout programs are effective where the potential damage to property or risk to health and safety are high when compared to the relative cost or effectiveness of other flood mitigation measures. Where this situation exists, several advantageous benefits of voluntary buyout programs can be seen:

- Relocation of residents to higher ground or out of harm's way
- Elimination of future flood damages, health and safety risks, and costs incurred in response or recovery
- Reduction of repetitive subsidized flood insurance payments and federal disaster assistance
- Restoration of the floodplain to its natural functions in terms of floodwater storage
- Potential creation of community-use open spaces and other amenities

Potential Issues of Buyout Programs

Buyouts are typically engaged in after a disaster because it can be difficult to get buyout programs running in times between major disasters. The reasons for this are varied. It may be difficult for residents to consider the dangers without prior experience. Residents may also be unaware of the potential risks of flooding in their area. However, a buyout program is not primarily a disaster-relief strategy, but is a strategy to reduce risk and protect communities from future flooding. While local buyout programs vary from place to place, there are several issues that may exist depending on local conditions and the structure of the buyout program:

- Potential lowering of property tax revenue
- Displacement of low- to moderate-income groups from the community, and often to areas of similar or comparative risk
- May target vulnerable populations, but can have a negative effect on vulnerable neighborhoods without addressing key systemic causes of social vulnerability such as those associated with low-income or minority populations. See 7.4 Vulnerable Communities.

7.4

- Lack of transparency can impair trust and legitimacy in process and unwillingness to participate
- Identification process may involve highly-subjective criteria that may also impair trust and legitimacy

Vacant Lot Re-Use Strategies

In conducting a buyout program, it is also beneficial to consider a vacant lot's future potential use once it has been acquired. While a lot should have flood mitigation properties, it may also be utilized for additional values such as:

- *Agriculture Uses:* Some parcels of land may be suitable for sustainable agricultural purposes. There may already be an inclination within a community to utilize it in this manner and should therefore be explored with potential ecological issues addressed, such as any harm from runoff that could be mitigated through sustainable agricultural practices. Unless the lot is large and supports commercial farming, there needs to be a group of dedicated local residents to sustain the farm operations, which may limits this strategy in terms of feasibility.
- *Recreation:* In areas within an existing neighborhood, recreational uses may be explored with considerations to maintenance costs that may be taken up by local community organizations or managed by a local parks department.
- *Natural State:* Reversions to a natural state may be controlled with considerations for a land's potential use in filtration and flood mitigation. While it may seem the most inexpensive, this may require some planning and moderate implementation in consideration of accessibility and how its ecological functions may be constructed and managed. Also, if it is within an otherwise developed area, the lot would need some degree of maintenance to avoid becoming blighted.

Other Considerations

A buyout program should also be integrated with existing hazard mitigation planning and local land use planning processes with coordination from state and local departments and agencies. This can also promote increased transparency and legitimacy in terms of the buyout process itself.

Implementation of a Local Buyout Program

Process

1 Outline Location and Analysis	Locate potential (contiguous) sites within a Flood Hazard Area (FHA) with flood mitigation potential
2 Devise Eligibility Criteria	Determine prioritization of home buyouts based on an evaluation criteria of a property's risk and considerations of safety and feasibility
3 Support an Application Process	Make transparent the eligibility, evaluation, and potential timeline for the buyout process

Key Considerations

Planning a buyout program should include several key considerations based on best practices throughout the US. Each step should also be clearly outlined to potentially affected communities and key organizations involved in hazard mitigation planning.

Increase Transparency

Emphasize goals such as reduced costs, safety, and the value of added flood mitigation. Use clear criteria (specific and understandable) to decide which properties are eligible and will be acquired–this should be made public whenever possible.

Emphasize Relocation

Care should be taken to explore where households could relocate–within neighborhood, tax district, city, etc. and prevent residents from moving into equally flood-prone areas. Additional organizational effort may be needed to coordinate this step.

Address Long-term Social Inequities

Buyouts can disrupt communities. Make targeting of low-income groups or vulnerable populations explicit rather than happenstance or coincidence. Being direct in the criteria used should be a point for opening up dialogue with targeted communities directly.

Conduct a More Holistic Benefit-Cost Analysis

A benefit-cost analysis (BCA) is required for every project funded by HMGP to illustrate the cost-effectiveness.[6] A BCA compares the expected costs of a scenario with its estimated future benefits. Within this BCA assessment, traditional estimation methods typically include avoided structural damage, injury and death, and other quantifiable losses as compared to the costs of a buyout of the property.

A Greatest Savings to the Fund (GSTF) methodology is also used in the assessment. This methodology sets a specific time period (such as 30 years) over which the savings of a mitigation project is accrued.

The assessment of environmental benefits within FEMA programs can also be used if the assessed Benefit Cost Ratio (BCR) is already above 0.75 (if the benefits are at least 75% of the costs) using traditional methods. The environmental benefits of open space are specified in a 2013 FEMA Mitigation Policy:[7]

- $2.57 per square foot (per year) for green open space, and
- $12.29 per square foot (per year) for riparian land use.

A more holistic benefit-cost analysis should also use larger geographic scales in a cost-benefit analysis to ensure multiple variables that may affect a specific area are included. This may also include longer decision timelines within an analysis to understand costs and benefits beyond a short-term investment horizon.

Engage in Participatory Pre-disaster Planning

Pro-actively engage in conversations with homeowners about the benefits and costs of participation. This may be essential to gain more local political support for a variety of measures and can help inform the development of a buyout process.

1 Outline Location and Analysis

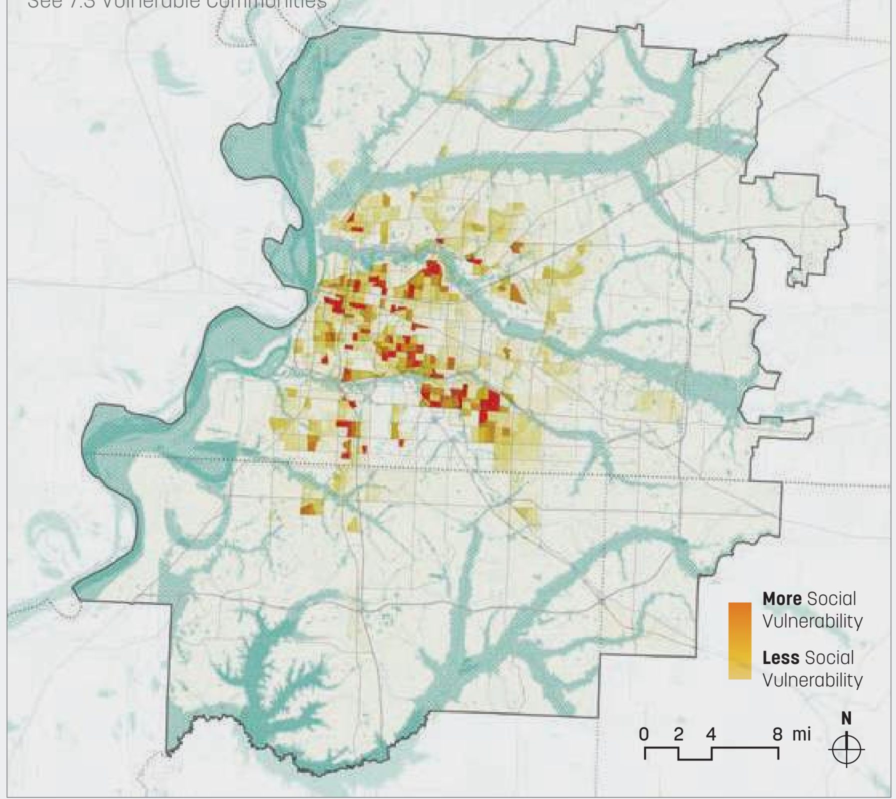
The first step in implementation is to conduct a thorough analysis to inform the scope and feasibility of orchestrating a buyout program. This should include a mapping of property at risk based on analysis of the floodplain, assessments of property type, a structure's place within the flood elevation, and engagement with the local community to mutually inform hazard mitigation planning at the neighborhood and planning level.

The map on the right is a preliminary analysis of residential properties within the 100-year floodplain. These properties are highlighted in red. More data is needed to provide a thorough analysis such as building type (data is currently lacking for building typology in DeSoto, Fayette, and Marshall County), building elevation, and other relevant information. It is important to coordinate buyout programs with other project considerations, including areas with high potential flood mitigation value. These are overlayed with
2.4 a green hatch (see 2.4 Open Space Strategies). Additional project planning may be included within the planning of a buyout program.

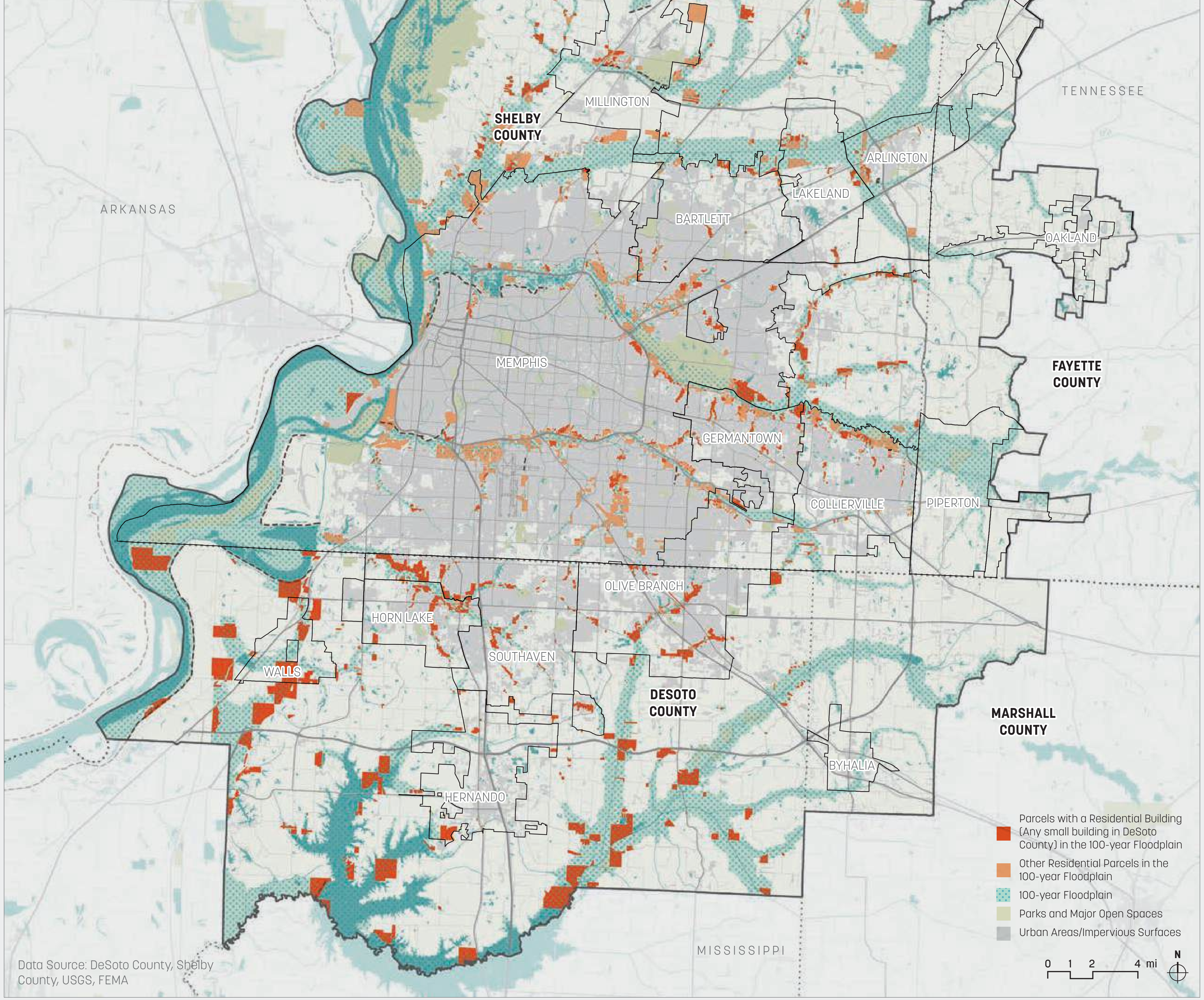
Additional analytical considerations, such as areas of social vulnerability (see map below) will be important in developing a prioritization for a buyout
7.2 program and driving a community outreach plan (see 7.2 Outreach).

Social Vulnerability Map

7.3 See 7.3 Vulnerable Communities



Parcels with Buildings in the Floodplain



Data Source: DeSoto County, Shelby County, USGS, FEMA

2 Devise Eligibility Criteria

While many federal grants are made available after a disaster declaration, federal grant money for buyouts are intended to be used to save on the cost of future flood damages. Federal eligibility criteria includes:

- Properties must be located within a jurisdiction that participates in the National Flood Insurance Program (NFIP) and have a FEMA-approved Hazard Mitigation Plan (HMP).
- The property's purchase must be cost-effective as evaluated through a FEMA-approved benefit-cost analysis (CBA).[8] This evaluates the purchase and demolition cost as compared to the cost of estimated future flood damages.
- The property must have an existing flood insurance policy for certain FEMA grants.

Whether orchestrating a program to take advantage of federal funding or otherwise, there are several important criteria to include when prioritizing locations for buyouts shown below.[9]

Source of Flooding

Riverine flooding may differ from other sources such as roadside ditches, ponds, and overland flow. These types of flooding may not be covered in a flood hazard layer which is focused on riverine flooding. A buyout program may choose to include these types in an analysis of floodable areas, but may fall outside of federal eligibility criteria necessary for federal funding.

Location and Depth within the Floodplain

Even though a property may fall within the floodplain, the elevation of a home or business may protect it from substantial damage. As buildings are deeper in elevation within a floodplain and the Base Flood Elevation (BFE) is above a critical level, substantial damage is more likely to
3.1 occur. See 3.1 Floodproof Buildings for more information.

Cost Effectiveness of Buyout Option

"Cost effectiveness" is related to the magnitude of a flood risk, or put simply: it is the cost of property less than the cost of future damage. In assessing the cost effectiveness, FEMA requires a benefit-cost analysis (BCA) be performed. This gets to the basic reason to implement a buyout: to save on tax costs of the potential repair and cleanup of flood-damaged properties buy removing the risk-prone property from hazard-prone areas. The cost of acquisition and demolition should be less than the potential cost included in the post-disaster response. The BCA should also include a cost factor of other options besides the buyout, such as the installation
costs of flood mitigation measures (see 3.1 Floodproof 3.1
Buildings).

The BCA is not without issues, however. Even though it involves a more-objective process of evaluation, it still requires subjective assumptions to be included in the criteria that are even included within the evaluation process. For instance, much of the BCA requires the reduction (or exclusion) of factors to monetary (numerical) metrics. This can be difficult and not sensitive to many qualitative factors and should include information obtained through community outreach within an evaluative process.

Potential Use of Area for Flood Mitigation

One important metric for establishing an eligibility criteria (and may be included in a BCA) is the potential benefit of the land for flood mitigation that can lessen the damage done to other areas along the floodplain. If an area presents great flood mitigation value that substantially lessens the risk in other areas, this can narrow the potential costs of future acquisitions, post-disaster repair, or the mitigation of flooding damage
altogether (see 2.4 Open Space Strategies). 2.4

Contiguity of Acceptable Parcels

To effectively provide for flood mitigation and implementation, it is more practical to gain consensus among property owners for their participation in the program so that their properties can be assembled into a larger, contiguous space.

Community Support

Community support is important for the success of a buyout program. Buyouts have the potential impact of dividing a community. The negative impacts of this may in part be mitigated through pro-active engagement. The compatibility with community and natural values for a post-buyout situation are also important to obtain within the process and can impact the criteria for buyout
prioritization. See 7.3 Vulnerable Communities for more 7.3
information on prioritizing for vulnerability.

3 Support an Application Process

While a property owner will deal directly with FEMA to obtain a federally-assisted buyout, an extended local program will require an organizational infrastructure to manage the application process. This can also support the typical federal process.

A typical federal application process is illustrated below. There may be differences between a primarily federally-managed or primarily locally-managed buyout program, but either will generally include a similar scope and timeline.

3.1 Property Owner Volunteers for Buyout

A property owner volunteers to be included in a FEMA or local grant application. The application is then reviewed by FEMA or a local organization that is charged with implementing the buyout program to ensure the property owner meets the eligibility criteria.

3.2 Grant Application

The supervisory organization may submit the application for a grant through the state for federal funding or match the application with funding for complimentary projects outside of FEMA's assistance.

3.3 Approval (or rejection) (+8-18 months)

After an analysis of the cost-effectiveness of a buyout option and other criteria, the application is either accepted or rejected.

3.4 Property Owner Meeting (+8-18 months)

It is useful for a supervisory organization to arrange a meeting with the property owner to explain the buyout process and obtain agreements that include: a property appraisal, a privacy statement that can allow for public notice to be made for the buyout, and certification of a property owner's eligibility for the program, as well as settlements for other legal matters.

3.5 Appraisal (+9-20 months)

A state-certified appraiser is necessary to make an appraisal of the property for the purposes of assessing a fair price for the acquisition. For FEMA funding, this cost would equate to a pre-disaster FMV. Other grant funding may use pre- or post-disaster valuations. This process may require an inspection and the property owner to supply documentation necessary for a full evaluation such as documentation of recent improvements.

3.6 Sale Agreement (+10-21 months)

Once funding sources have been obtained, the supervisory organization (the agency in charge of acquisition) will arrange a meeting with the property owner for the approval of the appraisal. If accepted, a sales contract will be negotiated and signed.

3.7 Determine Relocation Benefits (+12-24 months)

If relocation options are available, relocation benefits may be assessed and paid to the property owner to cover the cost of moving and purchasing a relocation home of comparable value.

3.8 Closing (+12-24 months)

Once funding, permitting, and vacancy of the property are complete, the contract will close.

3.9 Demolition (+13-26 months)

The supervising agency will demolish the structures on the land which may then become subject to deed restrictions, such as the preservation of open space in perpetuity.

Case Study

Floodplain Buyout Program, Charlotte, NC

After widespread damage from flooding caused by Hurricane Floyd in 1999, the state of North Carolina and FEMA announced a long-term disaster mitigation strategy that included a voluntary buyout program.[10 11] Local programs have been established throughout the state in flood-prone communities such as Charlotte.

Since 1999, the Storm Water Services of Charlotte has purchased over 400 properties with over 700 families and businesses relocated to less-vulnerable areas outside of the floodplain. Over 185 acres of public open space were thus created to provide flood mitigation functions that help to prevent further flooding damage.

Charlotte's voluntary Floodplain Buyout Program is managed with criteria that includes the cost effectiveness of a buyout as well as an assessment of the overall benefits such as the tax savings on emergency and disaster response, restoration of the floodplain to a natural state, safer housing and environment, and increased area for recreation. The ranking and privatization for Charlotte's program is also transparent and outlined in the Risk Assessment and Risk Reduction Plan.

It is estimated that since the program's initiation, over $25 million in losses have been avoided. The first 12 years of the program were funded by matching federal grants with local funding, but since 2011, the program has been entirely supported by local funding.

The program is also supported by parallel activities such as the routine maintenance of floodplain maps, and the adoption of higher building standards such as water body buffers in regulated floodplains, and the minimization of runoff for new developments upstream.

(Left) Hurricane Florence in Charlotte, NC, 2018.

Endnotes

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6.2 Debris Recycling

Recover and Recycle Post-Storm Debris

Key Benefits

1	**Saves money by reducing landfill fees**
2	**Earns money from selling recycled materials**
3	**Provides local, affordable rebuilding materials to residents and businesses**
4	**Creates entry-level jobs in the days, weeks, and months after a storm event**
5	**Decreases volume of waste entering landfills**

Limitations

1	**Cost increases for sorting of materials**
2	**Land needs to be set aside for debris staging**
3	**Increased time and effort for debris sorting**

Overview

Severe weather events can create millions of cubic yards of debris, which needs to be cleared quickly and efficiently for life as usual to resume. While debris creates costly logistical challenges, there are opportunities for reuse and recycling. Good debris recycling saves residents and municipalities money because they can avoid landfill tipping fees. Many materials can be resold to help cover the costs of clean-up and rebuilding. Municipalities can leverage the value of debris to find private partners to collect certain waste streams.

This recommendation outlines best practices for debris management as well as ways to reuse and recycle debris. The focus is on creating sorting, pick-up, and recycling systems that are straightforward and benefit everyone in the community.

(Right) Well sorted salvaged wood at a warehouse (from Recycled Wood Products)

Benefits of Reusing Storm Debris

There are many reasons to recycle storm debris. One is convenience. Recycling creates stockpiles of raw materials including wood, mulch,[1] soil, gravel, and scrap lumber. Having large volumes of these materials on hand can speed up cleaning and rebuilding. Another reason is financial. If the municipality decides to sell the materials, the profit will help cover the costs of the clean-up effort. A municipality may also decide to offer the material for free or reduced rates so that residents can better afford to rebuild. The environmental benefits are also clear: recycling and reusing reduce the need to source more raw materials and keep debris out of landfills.

Key Benefits

Convenient Rebuilding Materials

Creates a ready supply of material for rebuilding and restoration

Financial

Generates revenue to cover the cost of clean up and reduces the price of rebuilding.

Environmental

Reduces the amount of debris going into landfills and the need to buy new materials.

Job Creation

Creates sorting and processing jobs for those out of work due to storm events and volunteers coming to help with clean up.

Key Strategies

The first strategy, 6.2.1 Coordinate with Year-Round Programs, is to align debris management with year-round recycling efforts. These may be existing processes, such as sorting waste into common categories including household garbage and vegetative debris. Alternatively, local departments may begin collection and recycling programs that are designed to handle storm debris, but also operate year-round at a reduced capacity. For example, a Parks department may open a public mulch and compost center.

The second strategy, 6.2.2 Invest in Debris Separation Processes and Facilities, is to make pre-storm investments in both the people and equipment needed to adequately sort, collect, and process debris for recycling and reuse. Trained workers and volunteers can be deployed to neighborhoods to assist people sorting the debris at their homes and businesses. Specialized equipment enables efficient material separation, such as screeners to sort gravel by size and magnets to collect metals. Specialized workers can be assigned to process collected debris for reuse or recycling.

The third strategy is 6.2.3 Develop a Debris Management Planning Group and Plan. This group would be most effective at a county or regional level, where the combined resources of the group can be shared. Key components of debris management planning include forming a Planning Group, negotiating pre-event contracts with debris contractors, and designating staging areas for debris collection and sorting.

(Below) Sorting construction and demolition debris in Lee County, Florida

6.2.1 Coordinate with Year-Round Programs

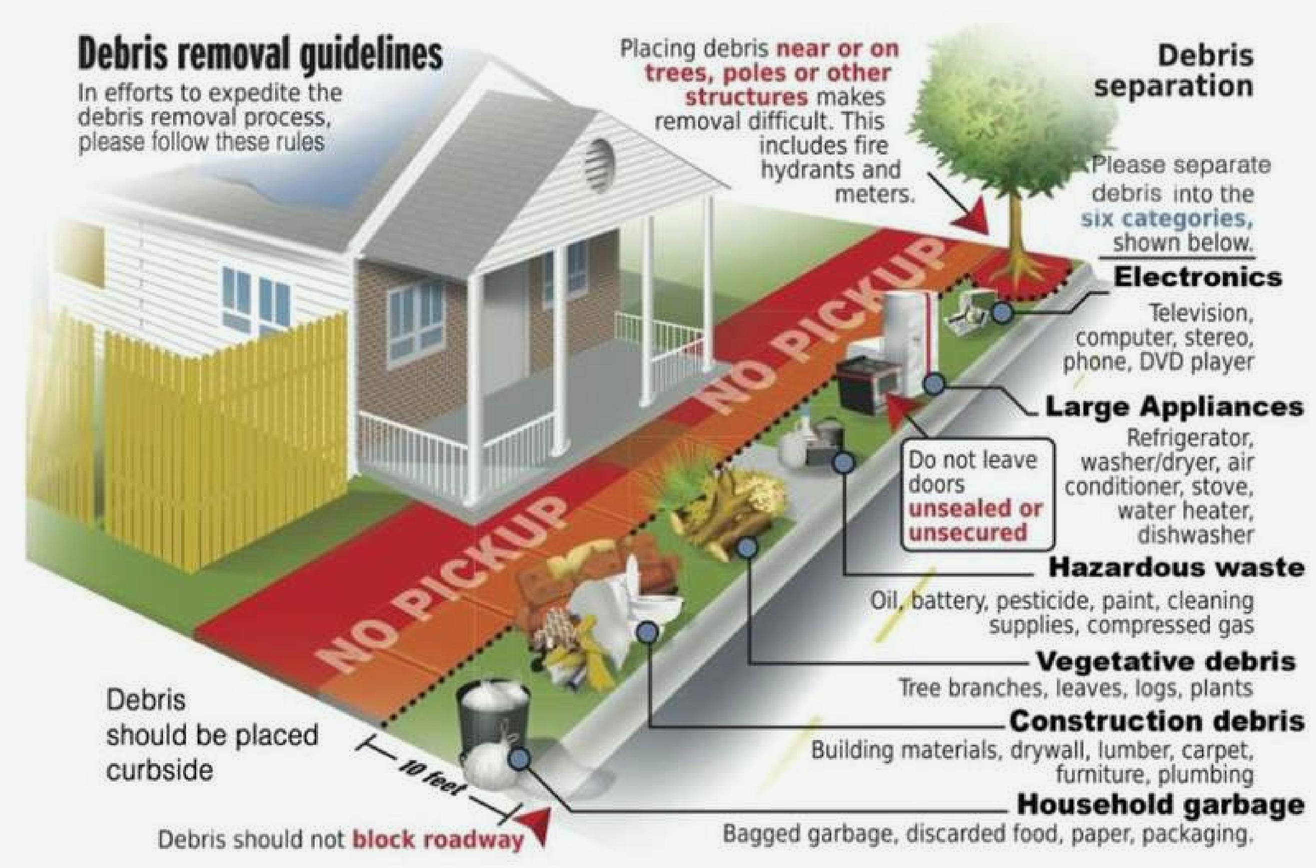
Promote Storm Debris Management as Part of Yearly Solid Waste Programs

A first step in debris management is to assess what reuse and recycling processes are already available and how they can be enhanced to handle storm debris. Solid waste collection is already divided into standard waste streams: household garbage, household hazardous waste, electronic waste, white goods/appliances, construction and demolition, vegetative yard waste, and recyclable metal/glass/plastic. Each waste stream already has an established collection and disposal process.

Fine-tuning Year-Round Waste Pick-up for Storm Debris

- Examine effectiveness of existing waste streams.
- Fix logistical and procedural problems within existing waste streams.
- Designate additional staging areas for larger volumes of storm debris next to the corresponding facility.
- Conduct a public information campaign. Note where year-round procedures are the same or different from post-storm procedures.
- Post-storm: deploy the same waste-stream specific collection methods, rather than mixed collection.
- Store collected materials at staging areas until they are processed.

Sample Visual and Written Directions for Sorting Debris (FEMA)



Waste Stream Specific Uses

Vegetative Debris

Downed trees and limbs in the right of way are typically the first debris to be picked up, as well as the largest volume. Collected debris should go to specialized sites that sort large stumps, trunks, branches, and leaves. On-site processing can produce the following products for local use:

- Branches for Mulch, Animal Bedding, and Erosion Control
- Branches for Wood Pellets
- Leaves for Compost
- Trunks for Firewood
- Stumps for Stream and Wetland Restoration Projects

Construction and Demolition Debris (C&D)

Typically the second largest volume of debris is from buildings that have been damaged by fallen trees and severe weather. Staging sites specifically for construction and demolition debris (C&D) waste may collect all materials in one pile for future sorting. Uses of C&D waste include:

- Lumber for reuse: clean and pressure-treated wood separated out for salvage
- Clean wood scraps for mulch and fiberboard (pressure-treated scraps require special disposal)
- Concrete, stone, and brick to gravel and fill
- Gypsum drywall for manufacture of new drywall, cement, fertilizer, soil amendments, and compost
- Asphalt and asphalt shingles for pavement
- Architectural salvage: doors and door frames, windows and window frames, millwork, and fixtures. Exceptions apply for hazardous material like lead paint.

Household Hazardous Waste[2]

Special collection events should occur during the post-storm clean-up. Ideally household hazardous waste collection would include at least one round of well-advertised curbside pick-up and additional collection tables at transfer stations. Debris of this type includes lead paint, asbestos, CFCs, pesticides, and other harmful chemicals.

Appliance Recycling Programs

Join a year-round appliance recycling program and leverage this program to collect appliances after a storm. For example, Responsible Appliance Disposal (RAD) is a program partnership program between the EPA and utility/manufacturing/retail partners who do the recycling. RAD recycles appliances with current best practices. Through RAD partners, over one billion pounds of waste has been diverted from landfills. RAD affiliates, particularly state governments, promote the program.[3]

Electronics Recycling

Similar to appliance recycling, several electronics recycling companies exist. These companies break down electronics in order to reuse or resell the components and base materials. As with hazardous waste, most municipalities collect electronics at special collection events. The electronics recycler used for regular collection events may be a good partner to hire for curb-side electronics collection after storm events.

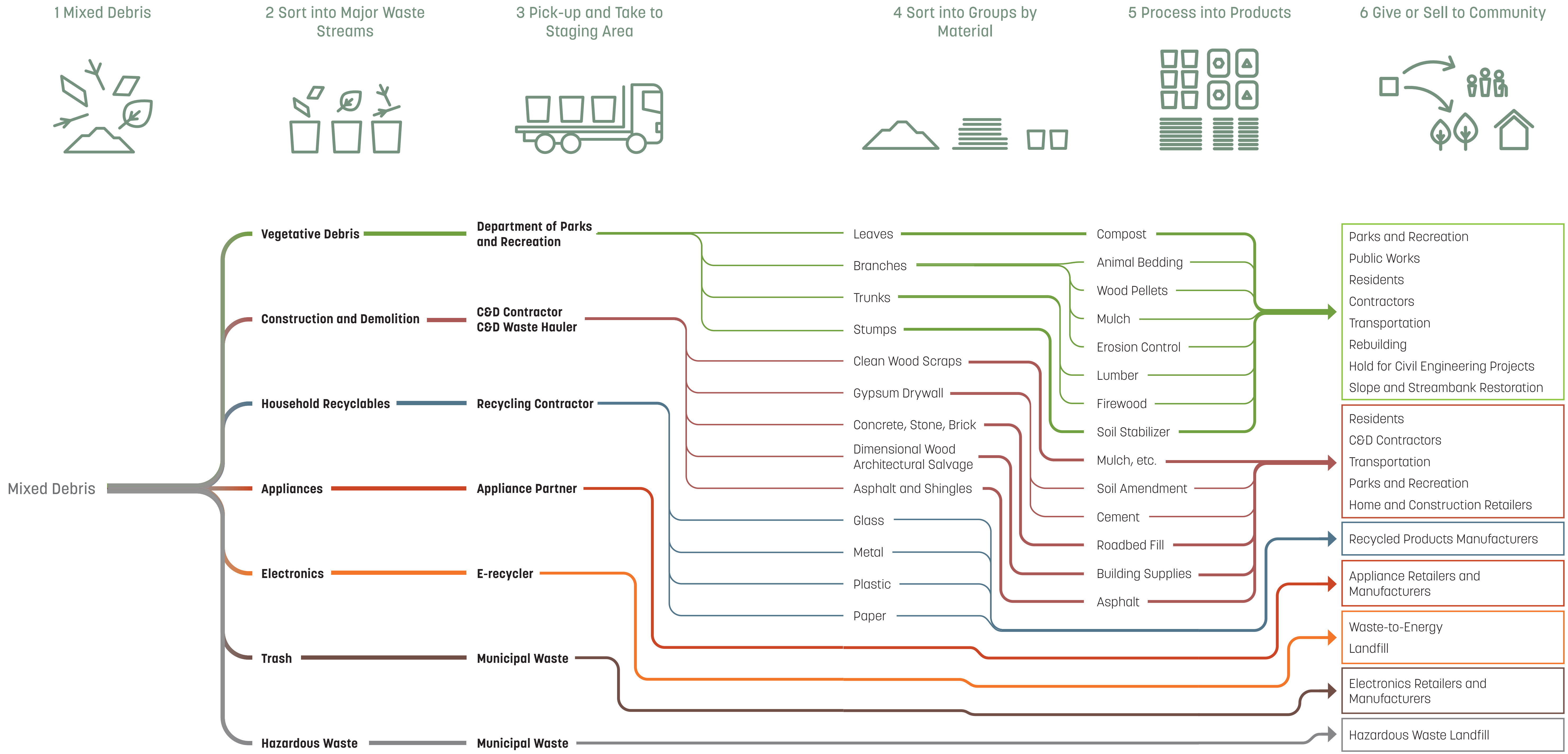
Household Recyclables: Paper, Plastic, Metal, and Glass

Memphis already has a facility to sort mixed plastic, metal, paper, and glass recyclables for market. To take advantage of this post-disaster, remind people to follow recycling and trash separation. Consider opening an additional staging location for people to bring mixed recyclables for future sorting. For towns that have a transfer station rather than curbside pick-up, hire additional staff to help sort waste and recycling.

Household Waste

Follow typical collection procedures. Consider setting out additional dumpsters on each street, to reduce the curb-side collection needs. The only major alternative to a landfill is sending waste to a waste-to-energy plant.

Resource Recovery System



6.2.2 Invest in Debris Separation Processes and Facilities

Preparation includes training workers, setting up staging areas, and coordinating shared equipment use

Workforce and Volunteer Training

Given the volume of debris generated by storm events, it is unrealistic to expect citizens and waste haulers to undertake all of the debris sorting necessary for recycling. More people and equipment are needed to handle the volume efficiently. Paid or volunteer sorters can be identified and trained before storm events. These sorters would be deployed to sort as well as to assist local people in managing their debris.

The advantage to this kind of training and investment is that they can be operational year round for general construction debris recycling. Construction and Demolition waste makes up approximately 40% of the US waste stream. Some cities have created C&D recycling requirements that ensure the use of recycling facilities. A less prescriptive approach is to make the recycling facilities cheaper to encourage contractors to use them. This could be done through the sale of processed materials, recycling grants and subsidies, or increased dumping fees at landfills for C&D waste.

A regional system supports shared use of staging areas and processing equipment. By working together, cities and towns can afford debris collection and processing equipment. Post storm event, staging areas are shared and equipment is rotated between municipalities.

Support Fast Clean-ups with Staging Areas

Fast clean-ups are essential to stop the spread of mold and disease, particularly after a flood. Toxic material like lead paint, asbestos, CFCs, mercury, and industrial chemicals should be disposed of through normal hazardous waste streams as quickly as possible and should not be salvaged. To accommodate quick debris removal from neighborhood streets, create staging areas where haulers can set aside loads of materials that will be recycled at some point in the future. Over the next several weeks or months, these materials can be sorted and processed onsite or trucked to processing areas.

Share Equipment Across the Region

Recycled debris (such as mulch) could be a good source of income for towns and cities. Having the equipment and training to process debris means that cities and towns can keep and sell the material, rather than paying outside contractors to haul it away.

Jurisdictions in the Mid-South should invest in material specific equipment for staging areas to speed up sorting and processing and store an aggregate sorter and rock chipper at staging areas for concrete, brick, and stone. Jurisdictions should also invest in storing containers or sheds so that processed materials can be separated and sold. A Regional Debris Management Plan could help in equipment investments, because the equipment could be moved between local staging areas in the weeks and months after debris collection. Examples of portable equipment are shown on the right. These can be shared by multiple towns and used as needed or on rotation. See 5.6 Snow and Ice for more information on equipment sharing.

5.6

Staging Area

Land set aside to accommodate large amounts of unsorted debris until it can be sorted, processed, or moved.

Gravel Crusher

A crushing machine breaks up construction debris into gravel that can be used as fill.

Sorting Dumpsters

Sorting dumpsters are useful for staging materials until they can be processed. They are also portable and compact.

Wood Chipper

Industrial portable wood chippers can handle everything from telephone poles to rail road ties. They create several sizes of wood chips for different purposes and could be shared between towns.

6.2.3 Develop a Debris Management Planning Group and Plan

Planning for debris removal before storm events is the best way to improve efficiency and order after an event. A nation-wide best practice is to create a Debris Management Planning Group (Planning Group) that develops and implements a Debris Management Plan (DMP). The Planning Group should consist of a representative from each department that manages waste removal and public assets: from utility managers to the Parks and Recreation Department. The Tennessee Department of Solid Waste is requiring each city and town to develop DMPs over the next few years and has prepared substantial resources for their preparation.[4]

Debris Management Planning is most effective when adjacent cities and towns work together to combine resources and networks. An appropriate scale to begin with is the county level, such as Shelby County. Moving up in size may offer new opportunities, but given how costly it can be to transport debris, larger regions may actually become inefficient. The planning process would be similar to that of the Hazard Mitigation Plan recently revised by Shelby County Office of Preparedness that takes an aggregate view of all jurisdictions within its geographic boundary.

This recommendation advances the current work of many cities and towns from a local scope to a regional scope. Coordination improves response time and efficient use of resources. Sharing facilities, equipment, and personnel increases the scale of reuse and recycling efforts. By sharing resources, the Mid-South may be able to open recycling centers for specific waste-streams or increase the capacity of existing facilities.

Components of a Debris Management Plan (DMP)

Organizational Structure

Include the author of the plan, the agency overseeing the plan, and all parties involved in execution of the plan.

Map of Service Area

Sub-divide the service area into zones that can be pre-assigned based on department and contractor capacity.

Map of Debris Collection Facilities

Include street addresses, phone and email contact information, materials accepted, fees, typical operating hours, and post-storm operating hours.

Contracts with Debris Haulers

Specify the companies the have already been contracted to respond to storm events. Summarize the scope, timeline, and service area that is covered by the contract. Specify recycling, tracking, and reporting requirements.

Lists of Roads

List all public roads the DMP covers. Sort the roads by service area and classification. Specify the order by which roads should be cleared.

FEMA reimbursement is only for city/county maintained roads and must have documentation. Roads not eligible for reimbursement are state and federal roads, private, and gated community roads.

List of Contacts

The list should include phone numbers and email addresses for the offices of the debris manager, mayor, public works, job-order contractors, additional contractors, and towns with mutual aid agreements.

Mutual Aid Agreements

Specify how long and in what order resources will be shared as well as how costs will be divided.

Coordination Methods Across Jurisdictions

Specify who is in charge and what methods will be used to coordinate during and after storm events.

Health and Safety Requirements

Specify which health and safety requirements apply to public, private, and volunteer workers.

Environmental and Regulatory Requirements

Identify the regulations that apply to storm debris and clean-up. Highlight key environmental factors such as toxic debris types (lead paint, asbestos, etc.) and sensitive situations, such as land adjacent to streams and wetlands. Provide a summary of the requirements as well as contact information for the regulatory agency.

Environmental and Historic Review Checklist

Environment and Historic Preservation (EHP) forms must be completed in order to qualify for FEMA reimbursements. Include these forms in the DMP.

Debris Tracking Requirements

Explain documentation of debris volumes, types, and disposal. Include contact information for help with documentation as well.

Public Communication Strategy

Including waste stream separation, which agencies and companies will collect each stream, how and in what order materials will be collected, hotline to report debris, hazards posed by debris, and right of entry for debris removal on private land.

Document Appendix

- Current contracts with on-call contractors
- Contracts associated with mutual aid agreements
- Sample contracts for new contractors
- Regulatory forms
- Debris tracking forms
- Public communication documents

Implementation

Developing, funding, and operating post-disaster debris recovery systems involves foresight and resources. This section provides information on the costs associated with debris management, implementation strategies, potential partners, and funding sources.

Capital and Maintenance Cost

Capital costs for debris removal include initial investment in a dedicated Debris Manager and the Debris Management Planning Group. The Debris Management Plan (DMP) proposed by the group will likely include the purchase of additional collection vehicles, sorting facilities, and sorting equipment. The DMP will also include personnel costs related to additional operation and oversight during clean-ups. In addition, there is a cost associated with the public outreach required for successful implementation.

Grants and public funding may be accessible for implementing waste and debris management programs. A Regional DMP is likely to be better poised to argue for grants and public funding due to its larger scale.

To increase community support, partner with school districts and local media outlets. Schools should include proper waste disposal as part of civic and science classes and environmental programming. Local television, radio, and newspapers should include debris recovery as part of their storm coverage.

Process

1 Planning	Select agency to begin Debris Management Plan (DMP) and identify partners. Develop a governing structure for the DMP. Designate a primary manager. Write DMP.
2 Funding	Solicit grants and government funding to implement DMP. Partner with private businesses that can assist with clean up (e.g., appliance collection).
3 Preparation & Execution	Engage debris haulers and recyclers pre-disaster. Set up base construction and demolition facilities with capacity to expand for storm debris. Purchase sorting and processing equipment for public facilities. Publicize new services, including necessary on-site sorting, pre-disaster and post-disaster. Execute plan contracts, aid agreements, facilities, and equipment. Track total amount of debris collected and amount recycled or reused for record keeping.

(Above) Memphis Department of Public Works leaf clean up.

1 Planning

In the short term, municipal-level departments can begin operating their own recycling centers that welcome material donations and sell products. For example, local parks and or public works departments can designate an area near their maintenance facilities for public vegetation debris collection.[5] Within that area, there would be separate spaces for woody and herbaceous materials. The woody materials would be shredded by city/county staff to create mulch and erosion control material. The herbaceous materials would be piled to make compost. City/county agencies could then use the products on public land for free as well as sell it back to citizens for a profit.

The step beyond individual local programs is to create a comprehensive Debris Management Plan (DMP). Ideally, the DMP would be coordinated across town lines to coordinate response procedures and maximize effectiveness. The steps to creating a DMP are listed in the Process Chart.

In the long-term, a Debris Management Plan is overseen by a Debris Manager, most likely someone working in a solid waste professional role. The Debris Manager coordinates with a Planning Committee composed of allied professions including municipal Solid Waste and Public Works Departments, emergency management, purchasing, administration, finance, parks and recreation, public safety, public awareness, GIS, and planning.

The Planning Committee and Debris Manager are then responsible for

- Updating the DMP and communicating updates to everyone implicated.
- Preparing debris staging locations.
- Setting up mutual aid agreements with other municipalities or counties.
- Conducting training exercises.
- Developing public information campaigns for citizens and businesses.

Partners

There is support available in the form of public assistance, volunteer groups, and private sector recycling programs.

Local Government Partners

The **Public Works** department of each town involved in the plan should provide an understanding of how general waste and storm debris are handled. They will likely know which equipment would improve the system, personnel needs, and which contractors are reliable.

Parks and Recreation departments can help determine which areas are available for vegetative debris. They also know which end products would be most useful for use in parks and should be involved in purchasing material processing and debris handling equipment such as mulchers and crushers.

The **Department of Transportation** for each state can be partners to help clear stone-type building debris. DOTs can store this material on unused property, where it can be processed into gravel and fines for roadbed fill.

Material Specific Partners

Material or product specific partnerships with private companies can help develop the DMP. Recycling companies, such as scrap metal recyclers, may be able to make a pre-disaster financial commitment to buy sorted debris. For example, a scrap metal recycler could commit to purchasing a certain volume of metal debris, which would allow the municipality to pay for the sorting and hauling of metals. Alternatively, the municipality may sign on a scrap metal recycler to help with metal debris removal from streets and/or staging areas.

Architectural salvage companies can be engaged to collect architectural debris that is still usable. This includes doors, hardware, decorative wood panels, moulding, and tiles. These same companies can be allies in the rebuilding process.

The DMP should encourage deconstruction rather than demolition of unusable structures. The DMP should include a list of local deconstruction companies and perhaps offer subsidies for their use.

Public Agency Partners

The **State of Tennessee Department of Environmental Conservation** manages statewide planning for solid waste and materials management.

The **State of Tennessee Division of Solid Waste Management** has resources for debris management plans.

The **Materials Management Program** has a planning tool designed to help local governments to develop Debris Management Plans. The tool is designed to make sure plans are developed in accordance with FEMA and the State of Tennessee codes and was developed by TDEC, TDOT, FEMA. In addition, each region is assigned a contact person to assist with DMP development.

DeSoto County Emergency Management Agency develops emergency preparedness plans in conjunction with town, city, state, federal, and private partners.

The **Mississippi Emergency Management Agency** coordinates between local and federal entities. In particular, MEMA helps manage applications for federal Public Assistance via MississippiPA.org.[6]

Volunteer Groups

After a severe weather event, there is often an outpouring of volunteers who wish to assist in clean-up. Part of the DMP should address the best ways for volunteer groups to contribute to clean up. The DMP should designate a volunteer coordinator as the point person for all volunteer groups. The communication section of the DMP should include directions for volunteer groups.

Volunteers who come as part of a group can be trained to sort debris either in neighborhoods or at staging areas.

Aspirational Targets

- Develop a Mid-South Regional Debris Management Planning Group and Plan
- Designate at least two sets of regional staging areas for each waste stream
- By 2025, recycle 90% vegetation and 75% C&D debris from storms

(Above) Americorps volunteers clearing storm debris in Weir, Mississippi. Source: George Armstrong/FEMA.

Keep America Beautiful (KAB) helps setup and operate community volunteer groups that operate year-round. Several cities and towns within the Mid-South already have KAB-type groups and affiliates. Organizations such as Memphis City Beautiful can help train volunteers in advance of storms so that they are ready to help as soon as possible.

2 Funding

FEMA Public Assistance funding is available when a state or county has a Presidential Disaster Declaration. Such a declaration is triggered when the damages per person exceed a predetermined amount: $1.50 for states and $3.78 for counties.[7]

The **Tennessee Department of Transportation** offers Public Assistance Program grants to local governments so that they can create debris management plans and pre-event contracts for removal. This funding could help with the establishment of a Debris Management Plan.[8]

Keep America Beautiful offers funding for environmentally responsible post-disaster clean up.

The Tennessee Department of Solid Waste also has grants available that may help fund the development and execution of a DMP. In particular, parts of a DMP may qualify for an Education and Outreach Grant and Recycling Equipment Grant, each of which may request up to $50,000.

Typical Cost/Benefit Factors

The cost of dumping storm debris runs in the millions to hundreds of millions of dollars depending on the severity of the storm. Recycling is almost always more cost effective than dumping, particularly for construction and demolition debris, as well as vegetative debris. These two waste streams are relatively simple to separate into raw materials and to process into usable products. Vegetation is 100% recyclable and construction debris is usually 90% recyclable. Demolition debris is around 70% recyclable.

Buildings and vegetation usually make up the bulk of storm debris. At a minimum, towns should invest the effort in separating and collecting these two waste streams because they create cost savings.

Factors that make recycling more expensive relate to the condition of the debris and the availability of recycling markets.

Debris created by strong winds tends to be high in vegetation and building materials, making it relatively easy and cost effective to recycle.

Events such as earthquakes and tornadoes generate easy to recycle building debris. Special equipment may be required to move the debris, raising the cost of cleanup. Recycling this debris would help recuperate some cost and have rebuilding material on hand.

Flood debris can be difficult to recycle for two reasons. First, material needs to be cleared out of neighborhoods quickly to prevent mold, fungus, and disease. Second, the debris may have been altered by the flood water. Fabrics and wood may become moldy, papers and cardboard soaked, etc. In this case, large staging areas for debris are helpful because they allow for the quick removal of mixed materials which can be sorted after they have dried out at the staging site.

3 Preparation and Execution

Debris management requires a network of staging areas, processing facilities, resale outlets, and landfills. At a minimum, a region as large as the Mid-South should have at least two staging, processing, and resale locations.

Staging & Processing

Sites for staging, processing, and landfills have similar requirements:

- Flat land areas that are greater than five acres
- Land is either already public property or can be easily obtained
- Located off of major and arterial roads that can accommodate large volumes of trucks
- Located at least a half mile away from ecologically sensitive areas such as wetland and streams
- Located near each other for ease of location and moving materials between sites
- Located several miles from home and schools to reduce the risk of accidents
- Located down-wind of inhabited areas, in the even that smoke, dust, or odors are produced

Distributing Processed Materials

Large volume resale for contractors and public works departments should be adjacent to the processing facility. Resale sites designed for the general public can be located within neighborhoods. In the case of vegetative debris, each town should set up a wood and compost staging / processing / storing facility. Prime locations for this include maintenance facilities in public parks or public works maintenance warehouses.

(Top) Debris staging on Hilton Head Island at Honey Head, one of two debris fields, after Hurricane Matthew in 2016.
Source: The Island Packet.

(Bottom) Debris on St. Thomas sits in sorted piles (metal and vegetation) months after Hurricanes Irma and Maria in 2017.
Source: The Washington Post via Duluth News Tribune, 2018.

Case Studies

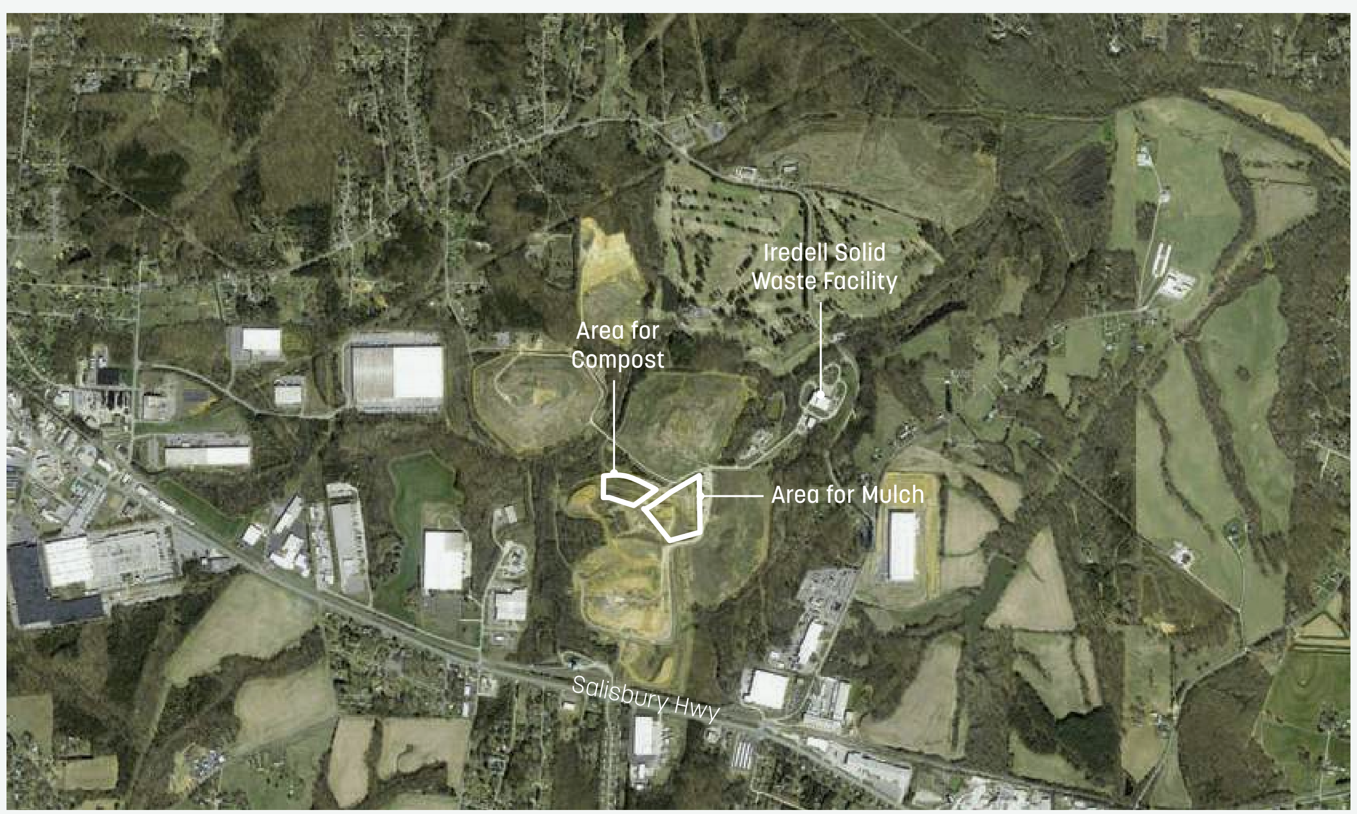
Emergency Debris Management Plan, Iredell County, NC

Emergency Debris Management Plan (EDMP) of Iredell County was established in 2012.[9] The EDMP assigns responsibility for directing post-disaster debris management operations to the Solid Waste Director as the 'Debris Manager.' The Debris Manager's responsibility includes dividing Iredell County into Debris Management Sites. During post-disaster recovery, the Emergency Management Coordinator will also work directly with the Debris Manager for coordinating all debris removal and disposal operations.

The plan also outlines responsibilities for a Public Information Officer, a Financial Officer, and a Damage Assessment Officer. The Debris Manager works closely with state and federal agencies in accordance with guidelines set forth by these agencies.

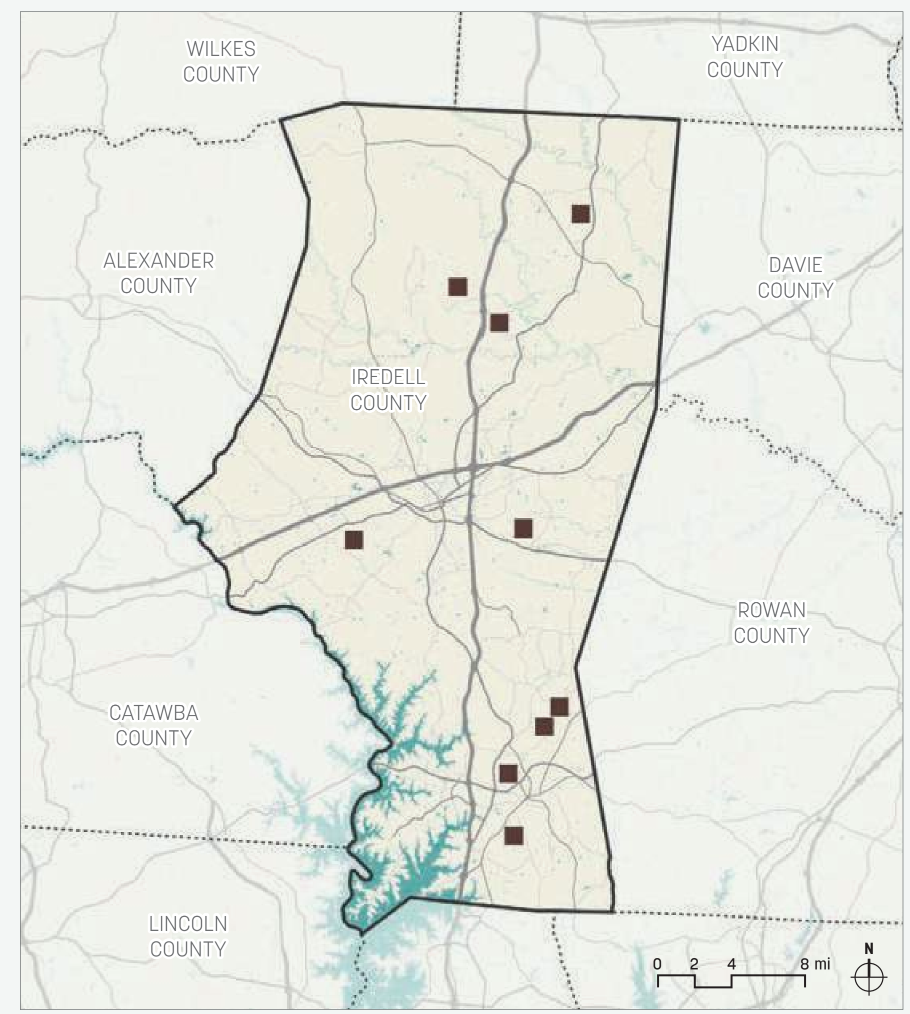
All municipalities within Iredell County are encouraged to participate in a common resource sharing agreement to facilitate exchange and cooperation during debris cleanup activities.

Cleanup activities are managed by volunteer crews and equipment from local municipalities, the North Carolina Department of Transportation (NCDOT), mutual aid providers, as well as through private contracts. Ongoing monitoring and evaluation of debris removal operations keeps the Debris Manager and the Emergency Management Coordinator updated of progress. As debris is collected, final disposal sites are selected. Included in this selection process are alternative sites for recycling vegetative debris to minimize the waste stream into landfills. Biomass facilities, paper mills, overseas energy facilities, farms, and other facilities are considered for recycling and may be managed in coordination with FEMA and other external agencies.



(Above) Satellite image of the Iredell Solid Waste Facility and one of its compost and mulch recycling sites.

(Left) A truck loads vegetative debris in Statesville, Iredell County, NC.



(Left) Iredell County Debris Site Map. Adapted from the Iredell County Emergency Debris Management Plan, 2012.

Endnotes

1 In the Mid-South, natural disasters typically result in tree wood debris.

2 Shelby County has discontinued collection of household batteries at hazardous waste facilities but continues to take car batteries.

3 Responsible Appliance Disposal," Environmental Protection Agency online, https://ww.epa.gov/rad.

4 "Debris Management," *Tennessee Department of Environment and Conservation* online, https://www.tn.gov/environment/program-areas/solid-waste/2015-2025-solid-waste-management-plan/disaster-debris-management.html.

5 In Memphis, maintenance is not a responsibility of the parks department (Division of Parks and Neighborhoods), but is done by General Services, Property Maintenance.

6 "About," MEMA/Mississippi Public Assistance, https://mississippipa.org/.

7 "Disaster Recovery," Mississippi Emergency Management Agency online, http://www.msema.org/about/disaster-recovery/.

8 "Education and Outreach Grant," Tennessee Department of Environment and Conservation online, https://www.tn.gov/environment/about-tdec/grants/grants-materials-management-grants/grants-education-and-outreach-grant.html.

9 Iredell County, Emergency Debris Management Plan, (2012), https://www.co.iredell.nc.us/DocumentCenter/View/582/Emergency-Debris-Management-Plan-PDF.

Resources

Material Reuse and Recycling

The Building Materials Reuse Association (BMRA), https://bmra.org/.

The Construction and Demolition Recycling Association, https://cdrecycling.org/.

U.S. Environmental Protection Agency Responsible Appliance Disposal Partners Program, https://www.epa.gov/rad.

Funding Resources

Tennessee Division of Solid Waste Management Grants, https://www.tn.gov/environment/program-areas/solid-waste/materials-management-program/grants-administration.html.

Debris Removal Planning

EPA, Planning for Natural Disaster Debris, (2019), https://www.epa.gov/sites/production/files/2019-05/documents/final_pndd_guidance_0.pdf.

Tennessee Department of Solid Waste Debris Removal Planning Tool, (2017), https://www.tn.gov/content/dam/tn/environment/solid-waste/documents/sw_debris-planning-tool-2017.pdf.

Tennessee Department of Solid Waste Debris Removal Contact for Southwestern Tennessee: 615-253-9929.

FEMA, Public Assistance: Debris Management Plan Workshop Student Handbook, (2019), https://www.fema.gov/pdf/government/grant/pa/dmpw_handbook.pdf.

Tennessee Department of Environment and Conservation, 2015-2025 Solid Waste and Materials Management Plan, (2015), https://www.tn.gov/content/dam/tn/environment/solid-waste/documents/sw_2025-plan-final.pdf.

6.3 Temporary Housing

Prototype Rapid, Temporary Post-Disaster Housing Solutions

Key Benefits

1	**Provides rapid, inexpensive housing to displaced residents after a disaster**
2	**Fosters public awareness and involvement in post-disaster planning**
3	**Increases emergency management preparedness**

Limitations

1	**Demands an investment of time and resources in planning**
2	**Requires land and/or warehouses for prototypes**

Overview

After a disaster, it is not uncommon for residents to wait months or years to return to home or find new permanent housing. Water damage, lack of utilities, and structural issues all require time and labor to fix. In addition, the high demand for repairs often causes a shortage of construction workers and materials. Balancing the need for immediate shelter with the reality of the long wait for resettlement is a challenging task for emergency managers.

Existing Shelby County guidelines outlined in the Basic Emergency Operations Plan address hosting people in existing facilities and the distribution of emergency kits. This recommendation proposes developing physical prototypes for emergency and interim housing to increase regional resiliency after natural disasters strike. It prepares emergency managers, city planners, and residents for what to expect if they should be displaced by a disaster.

(Right) NYC Emergency Housing Prototype (Garrison Architects)

Models of Temporary Housing

Immediately following a disaster, temporary shelters are deployed to quickly provide safety, warmth, and basic necessitates to displaced people. Temporary shelters include spaces such as tents on a local park or beds in a school gym. These suffice for a few days or weeks if needed, but they do not allow residents to begin to resume life as usual.

By contrast, Interim Housing Units (IHUs) allow life in a community to resume. Residents have space and the resources to be largely self-sufficient, live as families, and are able to go to work or school. IHUs fill the gap between emergency shelters and permanent re-housing. Several models of IHUs have been tested around the world, made from materials as diverse as cardboard tubes, fabric, shipping containers, and local mud. Some are completely pre-fabricated and delivered to the site, while others are constructed almost entirely on-site from local materials and building techniques.

In the past, FEMA has provided IHUs in the form of trailers, most notably after the 2005 Hurricanes Katrina and Rita. These trailers developed issues, including toxic materials and lack of supply sold to the public.[1] FEMA continues to update housing options, but they are not a universal solution.

As a result, it is increasingly important for local and regional emergency managers to develop a plan for housing displaced residents.

Post-Disaster Housing-Type Timeline

Immediate: Emergency Shelters

Emergency shelters in existing gyms, conventions centers, hotels, etc.

Days: Tents

Semi-private living spaces and support facilities for those who cannot return expediently

1-18 Months: Standard IHUs

Transition to standard intermediate housing where families can live independently, while homes are repaired, rebuilt, and relocated

Several Years: Innovative IHUs

Shelters or houses with 1.5-50 year lifespans for long-term housing (like the NYC Prototype and the IKEA Better Shelter)

6.3.1 Emergency and Temporary Shelter

Existing Building Adaptation

Most often, temporary shelters are housed in existing buildings, such as gyms, schools, or other public buildings.

In this case, it is most important to identify and obtain in advance supplies for emergency overnight guests. For example, Shelby County may choose to keep a repository of 1,000 cots in a county warehouse to be shared by several towns. Each town should be involved in selecting the cots and sharing the cost.

Temporary Structures

Several companies offer large tents for emergency and non-emergency events. In the case of an emergency, when evacuees are sheltered in the typical community assembly rooms (gyms, etc.), large emergency tents can be ideal places to host social services. Tents should be located in close proximity to the majority of the evacuees.

Focus Around Existing Services

In order to offer the most support services possible, shelters should be clustered around service centers. When planning where to locate emergency shelters, first look for spaces that have direct access to vital resources, such as food shelters, childcare, counseling, and municipal information.

Additional Services

Investments in outreach to local communities both before and during emergency events helps prepare communities for a smoother recovery. Sample outreach might include sign-up events for the ReadyTN App or visits from Mobile Command Units.

(Left) Mobile command units, such as this one in Memphis, are an effective investment in emergency preparedness.

Design and Site Considerations

1. Protection from the elements
2. Located outside of the floodplain
3. Access routes are outside of the floodplain
4. In a population center
5. Near existing social service providers
6. Near an emergency stockpile of food and water
7. Near medical facilities
8. Access to electricity generator or other energy source (solar, wind, micro-grid, etc.)

Planning Measures

1. Create on-site or easily accessible storage and stock with emergency supplies.
2. Store food and water that is shelf stable for several years. Cycle through provisions as they near expiration dates by donating to food pantries.
3. Store cots, privacy screens, tents, or emergency kits.
4. Create public awareness materials about the location of emergency shelters, accessible routes, and services provided.

(Right) ReadyTN is an app developed by TEMA to keep residents up to date on emergency situations and resources available. (TEMA)

(Left) New York State has several emergency stockpiles, including this one in Hamburg (NY.gov)

6.3.2 Interim Housing Units

Cities on the forefront of emergency preparedness are creating their own Interim Housing Units. The advantages are clear: regional specificity, stricter design guidelines, known construction quality and materials, practice with prototypes, and locally controlled distribution and use. Developing a prototype can be a community process that engages people in questions about their priorities for function, design, location, and cost. As an example, New York City used a design contest to frame the issues of IHUs and successfully build a prototype. Special considerations for the City included high density, protection from the cold, sustainable systems, and ADA compliance. The result of their work is a guidebook outlining the who, what, where, when, and how of IHUs. See the case study at the end of this section for more details. Successful IHUs are usually inexpensive, easy, fast, and convenient to install, connect residents to local services, connect to transportation, jobs, school, and markets, remain functional for more than 18 months, and reflect the culture and building practices of the local place.

Site Considerations

When choosing a location and layout for Intermediate Housing Units, the goal is to make people comfortable and safe enough to resume their typical daily routines while they work towards permanent housing. To that end, sites must be close to jobs, schools, retail, recreation space, support services, and utilities.

Ideal sites have:

- Typical street features (trees, on-street parking, etc.)
- Good pedestrian access and routes through the site
- Close proximity to emergency recovery points of distribution
- Close proximity to stores providing basic food and goods
- Ready transportation routes to schools, jobs, and services
- Functioning, high capacity utility hook-ups (water, sewer, electricity, gas)
- Pre-approved zoning for emergency housing

Design Considerations

Communities differ in their available materials, construction skills, architectural traditions and social and climactic needs. Common design considerations for Intermediate Housing Units include:

- Compliance with local zoning ordinances including FARs, setback, and open space requirements
- Percentage and location of units with full ADA compliance for wheelchair use
- Percentage and distribution of single-family and multi-unit housing.
- Time to manufacture and deploy each unit.
- Degree of pre-fabrication versus on-site assembly
- Degree of user-customization (paint, finishes, layout, bedrooms, etc)
- Degree of dependence on on-site municipal utilities (water, sewer, electricity, and gas)
- Potential to convert to a permanent unit
- Potential to deconstruct and recycle materials
- Potential to store and reuse locally
- Potential incorporation of vernacular architecture

Best Practices

Able to Become Permanent

Ideal IHUs are durable enough to be used indefinitely or become permanent dwellings with some modification. Units should be easy to fix, connect to permanent infrastructure, secure onto a foundation, and move to new sites.

Self-sufficient

Units that can operate on their own and avoid the labor and coordination involved with utility hook-ups. Built-in utilities can include:

- Solar electricity for lights, outlets, and USB plugs
- Back-up generator
- Cooking gas-tank or electric stove
- Rain collection for greywater and filtration for drinking water
- Composting toilet

Customizable

Research has shown that a significant factor in determining whether or not temporary units are successful is the degree to which they can be customized. Examples of common customization elements include:

- Combination and division rooms
- Conversion of living space into extra bedrooms
- Combination units to house large families
- Customizable finishes

Building Methods

Stackable Shipping containers

An emerging trend is to refurbish old shipping containers into living spaces. Due to their ubiquity in shipping, the containers are easy to bring to sights with rail road or truck access. However, containers have several disadvantages, including a long lead-time, inability to store onsite pre-disaster, and specialized unloading equipment.

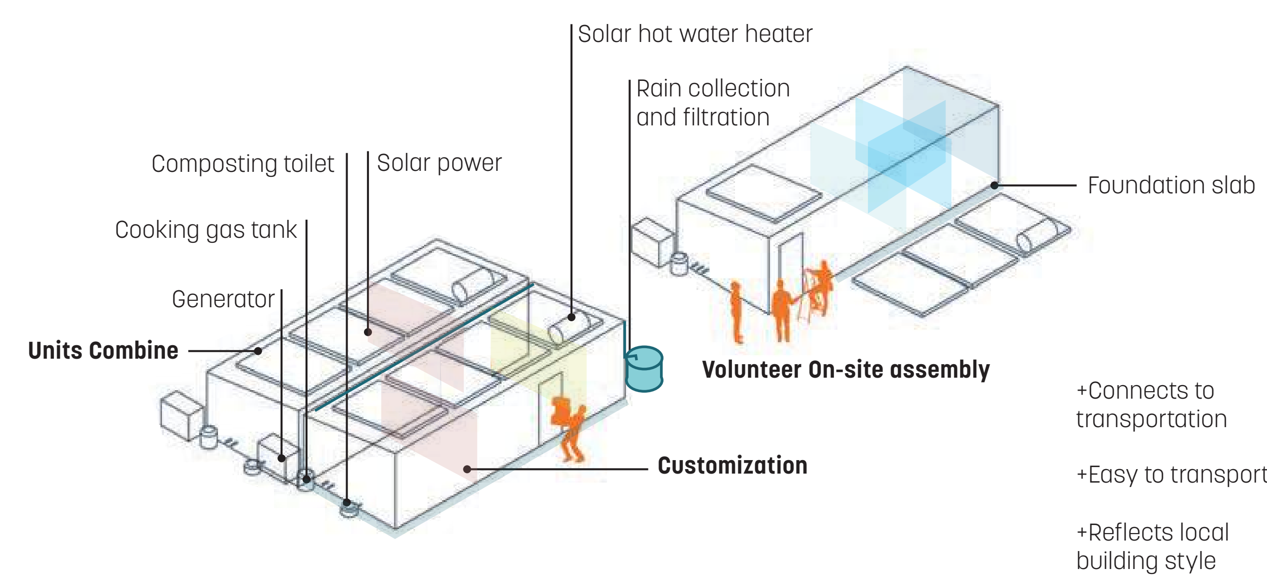
Manufactured Homes

Manufactured homes are common throughout the US building sector and are not limited to emergency housing. These homes are usually delivered on over-sized trailers and parked in place. They have a long lead time, cannot be stored onsite because of size, and can be vulnerable to wind, flooding, and tornadoes.

Onsite Assembly

Housing that requires assembly typically arrives onsite in kits with all or most of the materials included. Ideal kits require little specialized labor and can be assembled by volunteers. Kits have the significant advantage of being available off the shelf (short lead time) or can be stored at a local warehouse for speedy deployment.

General IHU Schematic



Implementation

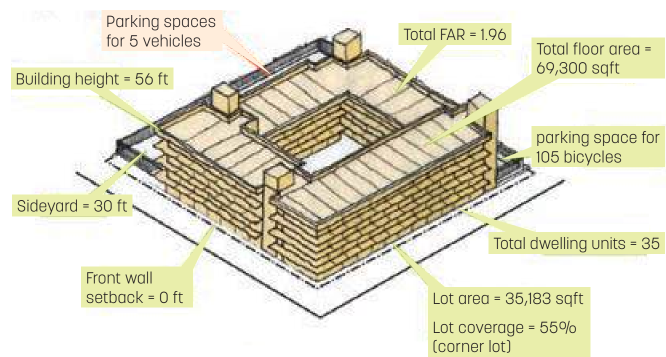
Prototyping emergency shelters can be a rewarding process that engages residents, designers, emergency managers, and several other local government departments. Design competitions are one way to solicit ideas while also generating publicity. Given the specific design parameters and rapid manufacturing, regions can develop prototypes within a year or two.

Capital and Maintenance Cost

The cost to the Mid-South to develop prototypes include:

- One full-time or several part-time project managers
- Time and coordination with housing, zoning, building code, and emergency management professionals
- Costs associated with creating the RFP
- Construction, delivery, installation, and operations of the prototypes
- Study groups to use and evaluate the prototype
- Production of a guidebook: creation and deployment
- Ongoing coordination with towns and cities in the Mid-South
- One or several retainer contracts with manufacturers

Zoning Compliance Chart Example



Requirements	Permitted in R6A	Proposed
Max. FAR	3.0	1.96
Max. Floor Area	105,300 sqft	69,300 sqft
Max. Building Height	70 ft	56 ft
Max. Lot Coverage	80%	55%
Min. Required Side Yard	30 ft	30 ft
Max front wall setback for narrow street	15 ft	0 ft
Permitted number of dwelling units	155	35
Parking Ratio (50%)	18	5
Bike Parking (1 per 2 units)	18	105

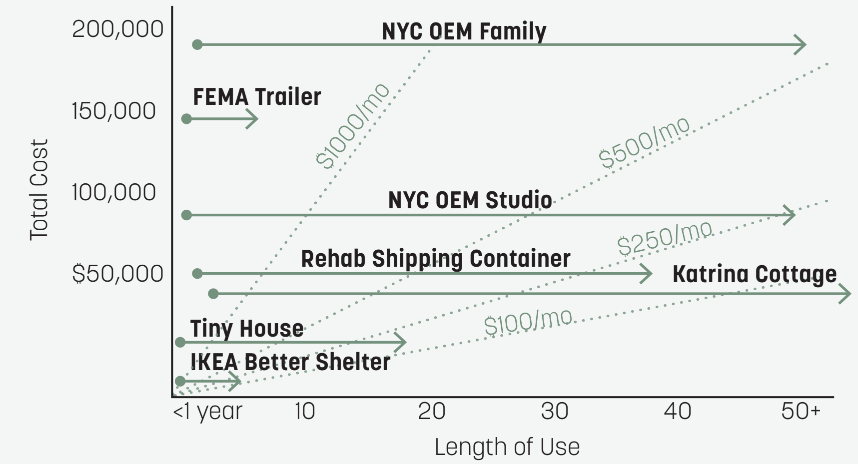
(Above) Adapted from Regulation Compliance chart for IHUs from the NYC OEM Playbook,[5] 44.

Process

1 Planning	Collect best practices examples from recent disaster recovery efforts Work with community groups to learn local priorities and preferences Identify site for deployment
2 Design and Permitting	Draft an RFP for prototype design, manufacture, and construction (this may be in the form of a design competition) Coordinate with local zoning and land-use regulations
3 Prototype and Trial Period	Hire contractors to complete the work Conduct emergency trials for deployment
4 Feedback and Guidebook	Solicit feedback from volunteer temporary residents Record best practices and lessons learned Make a guidebook specific to obtaining, deploying, and operating post-disaster housing. Share information with local planners and the public through demonstrations, websites, and other pre-disaster public information campaigns.

Typical Costs

Factors that affect the cost of emergency housing vary across the globe. In general, agencies should chose housing whose cost seems appropriate for the length of use. This is intuitively logical: housing that will last for 18 months should cost much less than housing that could last 50 years. A good rule of thumb for the US is to develop intermediate housing options that cost between $100 and $500 per month of anticipated use.



	Most Expensive	Moderate	Least Expensive
Assembly	Fully Manufactured	Assembled on-site	Constructed On-site
Labor Cost	Factory and Professionals	Professionals and Volunteer	Volunteer Labor
Utilities	Self-sufficient utilities	Local utility hook ups	No utilities
Materials	Steel, Particle Board, wood, glass	Plastic, wood, other	Paper, cardboard, mud
Finish	Fully Finished	On-site finishing	No finish

Cost of Temporary Emergency Shelters.

The cost to house evacuees in temporary shelters can be minimal if supplies are on hand or have been donated from volunteer agencies. Necessary supplies include cots or mattresses, extra blankets, hygiene products, food, surveillance, and facility personnel.

Cost of Intermediate Housing Units

The price for IHUs varies greatly across the world based on factors including materials, labor source, and climate. In general, the goal should be to have an IHU's costs match the length of time it is used. That is to say, IHUs that will only last for a few months should be less expensive than those that last for years. Factors contributing to costs are shown above.

At the most expensive end of this range is the prototype from New York City, in part because buildings there must use steel construction. Typical low cost shipping container homes begin at $15,000. Larger, more embellished containers cost between $50,000 and $200,000. After the 2005 hurricanes, architects developed the moderate cost /easy to build Katrina Cottage, at about $42,000 in 2008 dollars.[2] The cheapest substantial unit on the market is the IKEA Better Shelter which costs $1,250, but this is not currently deployed in the US (as detailed in the case study at the end of this section).

Manufactured and/or tiny homes are increasingly becoming a solution for fast, affordable housing. These homes are meant to be permanent, but they still provide an example of what an IHU could cost, or a way to transition IHUs to permanent housing. At A Tiny Home for Good, 300 square foot homes cost $28,500.[3] These homes are being built through donations and volunteers to house people transitioning out of homelessness.

Temporary Emergency Shelters and Interim Housing vary considerably in their need to comply with regulations. The emergency nature of TESs means there is not time to have them go through a permitting process. Since they usually last no more than a few weeks, regulations do not often become an issue.

Regulatory and Legal Considerations

People occupy IHUs for months and years after a disaster. As such, they must comply with all local building, zoning, and environmental codes. A best practice to enable compliance is to include members from these agencies in the development of prototypes and the IHU Guidebook. This collaboration should ensure that regulations are outlined in RFPs to manufacturers and construction companies.

Prototyping Goal: By 2022

Create design specifications and siting guide. Pick site and send out RFP.

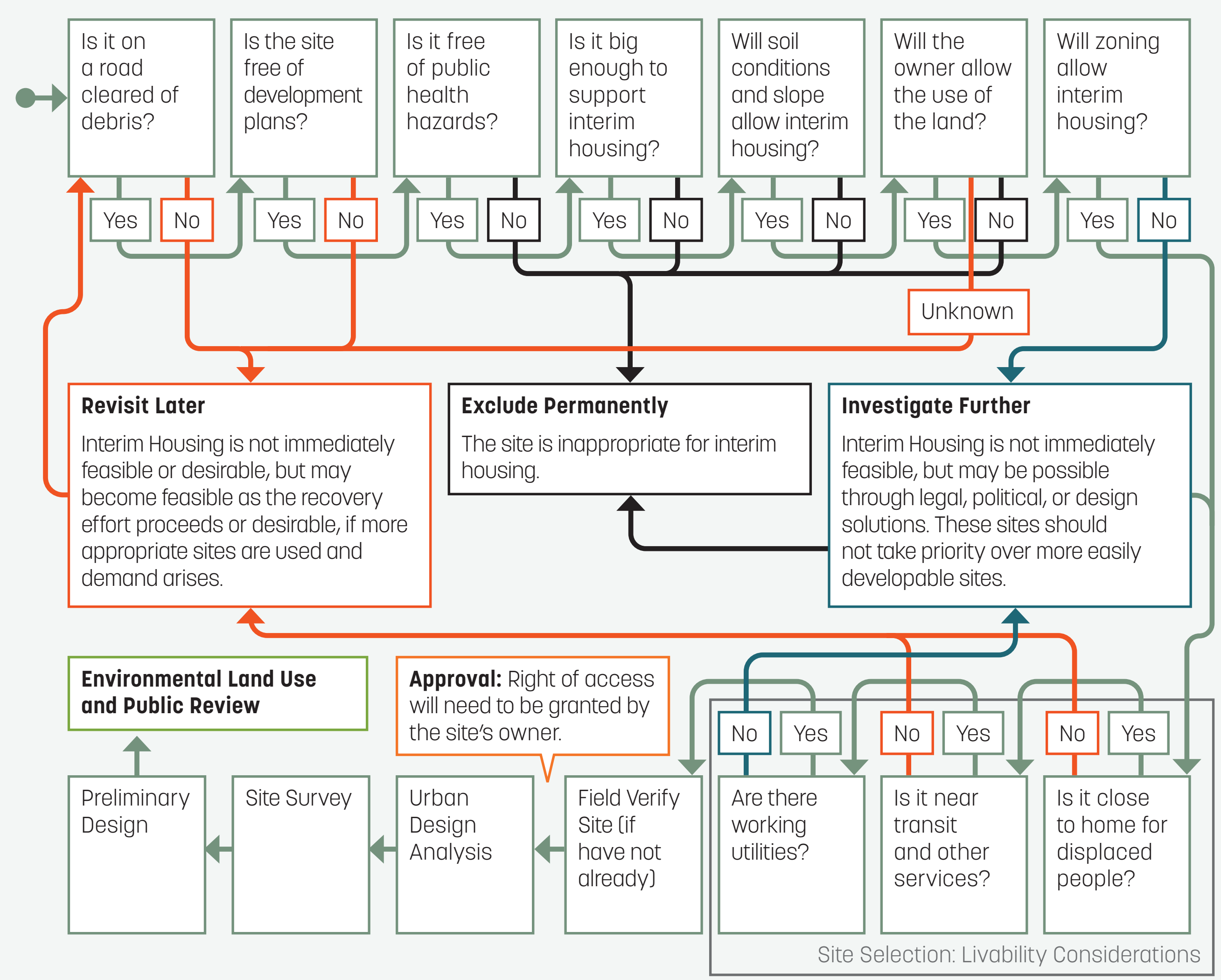
Choose 1-3 prototype manufacturer(s) to create prototypes.

Test prototype with info gallery and volunteer users.

Create a playbook, a plan for deployment, and a standing contract with manufacturer.

Prototype Development Site Selection and Preliminary Design

Adapted from the NYC OEM Playbook[6]



Regulations and building codes commonly include:

- Prohibition of disturbing wetlands, ecologically sensitive areas, and endangered species habitats
- Prohibition of building within the 100-year floodplain
- Land use zones
- FAR requirements

Some regulations may be less essential for IHUs, given their temporary nature and post-disaster location. For example, utility connections may be impossible or prohibitively expensive in an impacted neighborhood. If the IHU has its own electricity, water, and compost systems, the existing Universal Building Code may not apply. If land for IHUs is in short supply and there is a high need for housing within a given community, the typical FAR may need to be increased. Eventually, The Unified Development Code (UDC) should be amended to include exceptions and provisions for IHUs in order to streamline the process.

It is essential that all parties involved in IHUs understand their temporary nature in order to avoid unmet expectations in terms of quality, size, performance, and regulatory compliance.

Potential Prototype Partners

Developing emergency shelter prototypes can be an exercise in civic engagement as well as a productive training event. The federal and state emergency management agencies can provide local and national expertise on best practices. They also have full knowledge of the applicable codes and regulations for emergency housing.

Municipal stakeholders, including the department of housing, transportation, planning, and environmental protection will likely be willing to act as consultants for creating an RFP, guidelines, and design criteria. Cities, including New York, have found the US Army Corps of Engineers to be a valuable partner in developing the plans for prototypes.

As seen in the Katrina Cottage example and the NYC What If competition, many architects and designers are interested in developing plans that meet local needs.

Funding and Post-Disaster Assistance

The **Tennessee Housing Development Authority** funds a housing search website that could be used to connect people with IHUs. The site, TNHousingSearch.org, lists rentals across the state and reaches out to landlords after a disaster to add as many units as possible to the list. When IHUs are available, they could be listed on the site alongside traditional rental units.

If a disaster is declared at the federal level, funding may be available from several national programs. The **National Flood Insurance Program** offers funding to rebuild and residents may qualify for tax credits. The **Small Business Administration** provides recovery loans for businesses. **FEMA** operates several programs including funding for rental units for up to 18 months and low-interest rebuilding loans.[4]

When all other venues have been exhausted, FEMA also provides actual intermediate housing units. It is advisable that the Mid-South not rely on this as the primary source of interim housing for several reasons. First, FEMA will only offer such housing if a Presidential Disaster is declared. Second, if there are multiple disasters within several months or years of each other, FEMA may not have any available for the Mid-South. Third, the quality of these units can be an issue if residents need to live in them for longer than expected. Finally, the units are not specific to the Mid-South's needs in the way that a locally designed IHU would be. When possible, the Mid-South should seek out funding and support from FEMA and USACE to develop prototypes, rather than relying on the existing federal IHU stock.

Case Studies

Urban Post-Disaster Housing Prototype Program, New York City, NY

What If New York City was a project that developed design specifications for Interim Housing Units (IHUs) that could be deployed rapidly after a hurricane. The Project began in 2007 as a design competition and resulted in the construction of a full-scale prototype. In addition, the Project created a post-disaster playbook and Interim Housing Performance Specifications (IHPS) that any manufacturer can reference if they are interested in producing interim units.[7 8]

The NYC Office of Emergency Management (OEM) ran the competition with funding from the Rockefeller Foundation and numerous public agencies. Agencies included the New York City departments of Building and Fire, the New York departments of Environmental Protection, Transportation, and Health and Mental Hygiene. Federal partners included Housing and Urban Development (HUD), Federal Emergency Management (FEMA), and the Army Corps of Engineers (USACE). USACE managed the design and construction of the physical prototype.

The Urban Design Playbook for Interim Housing

The Playbook for Interim Housing is a valuable resource not only for NYC, but also for other American cities seeking guidance on post-disaster housing preparations.

Playbook Topics

- The purpose of Interim Housing
- The order of post-disaster housing options
- The goals of Interim housing
- A typical timeline for deployment
- How to choose a site
- How to layout housing units on a site
- Best practices for unit density and efficiency
- Permitting requirements and potential requirements
- How to create self-sufficient units with onsite water, sewer, and electricity
- Plan, section, and axonometric diagrams

Intermediate Housing is a Last Resort

Despite the focus on interim housing, the Playbook clearly states that Interim Housing Units should be a last resort. According to the playbook, prior to deploying IHUs, the City should identify and use all undamaged and vacant properties in the following order:

1. Vacant, undamaged rental units
2. Vacant, undamaged residential units
3. Rental and residential units that can be quickly repaired
4. Retro-fit available non-residential buildings
5. Finally, when the above options are exhausted, construct IHUs

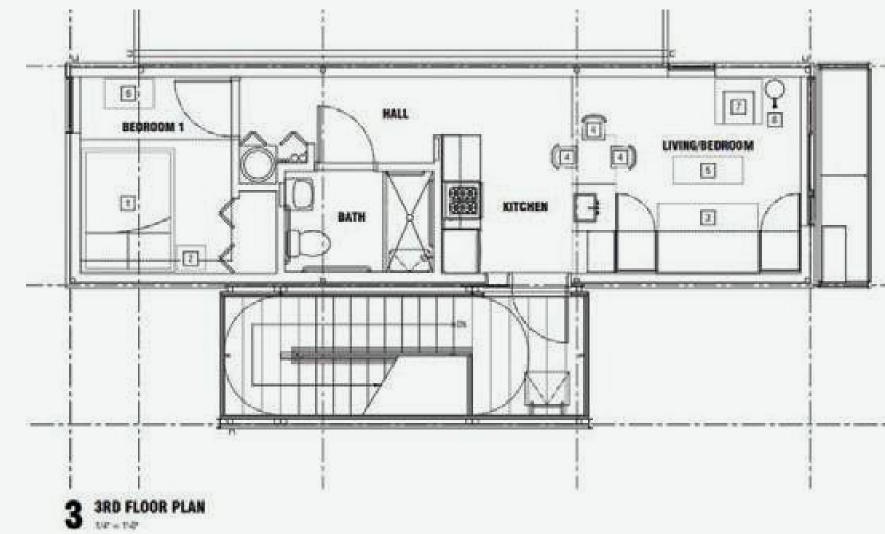
In recent years FEMA has adopted a similar strategy, only deploying trailer IHUs after all local and financial resources have been expended.

The Prototype

NYC OEM built a prototype to study costs, deployment, regulatory requirements, and coordination between agencies. After construction, different people lived in the units to gage how functional, comfortable, and safe they were. A 2016 prototype contained two units and a gallery to showcase the project. For cost comparison, the IHU costs about the same as a traditional affordable housing unit.

NYC OEM Prototype Facts:[10]

- Time for manufacture and delivery: 2.5 month
- Time to place onsite: 13.5 hours
- Onsite prep time: 2 weeks
- Number of units that could be produced annually in the US: 20,000
- Post-Disaster Bulk Orders Cost: $185-$200 per square foot
- Cost-one bed unit: $89,000-$96,000
- Cost-three-bed unit: $389,000-$410,000
- Lifespan: up to 50 years or more



(Left Page) Prototype exterior (NYC.GOV)

(Above Right) Prototype 3rd Floor Plan[9] (NYC and USACE)

(Right) Prototype interior (NYC OEM).

IKEA Better Shelter, Various Locations

IKEA has created a temporary shelter that is easy to ship, durable, and inexpensive. The "Better Shelter" is made with IKEA's expertise in flat-packed, easy to assemble furniture. The organization that manages the sales, distribution, and training is called BetterShelter.org and has extensive materials about the product on their website (www.bettershelter.org).

Better Shelter is built to meet the Sphere emergency settlement standards.[11] Sphere standards for shelters include 37.6 square feet for each person and a minimum ceiling height of 6 feet. Additional Sphere standards apply to camp layout, including 484 square feet per person, firebreaks every 1,000 feet, slopes less than 5%, and adequate drainage.[12]

The shelter comes in two flat cardboard boxes with picture-based directions and the tools required for assembly. The boxes are designed to fit in a 40' High cube shipping container, with 48 shelters in one container. Minimum orders are for 96 shelters, i.e., two shipping containers.[13]

Better Shelter is in use at refugee camps in Greece, Iraq, Ethiopia, Nepal, and elsewhere around the world. The organization does not currently have any installations in the US.

(Above) Better Shelter Axon. Source: Ikea Foundation/ Graphic News

(Below) Refugee camp on the Island of Lesbos, Greece. Each Better Shelter Comes in 2 Boxes (1 Shown). Source: Better Shelter

(Below) Better Shelters are assembled onsite by four people in Lesbos, Greece. Source: Better Shelter

Better Shelter boasts the following advantages[14]

- Cost of $1,250
- Can be stored in boxes for up to three years
- Temperature range of 41 to 104 degrees Fahrenheit
- Assembly in four hours by four lay people
- Can be moved, disassembled, or mounted on new foundation
- Hard plastic walls (rather than tarp or fabric)
- Original walls last for three years
- Components can be replaced with other materials, extending the lifespan indefinitely
- 188 square foot interior (10.8′ wide, 18.5′ long and 6 to 9.25′ high).
- Comfortably sleeps up to five people
- Solar power provides 4 hours of electricity for lighting or USB charging
- Better Shelter conducts training for people who will oversee assembly
- Lockable door

(Note: does not include floor)

(Above) Interior of a Better Shelter (Better Shelter)

(Right) Photograph of refugee camp on the Island of Lesbos, Greece. Source: Better Shelter

Endnotes

1 "Vacant FEMA Trailers from Katrina given to Indian tribes in need of housing," *The Associated Press*, July 06, 2011, http://blog.al.com/wire/2011/07/vacant_fema_trailers_from_katr.html.

2 *The post-disaster temporary dwelling: Fundamentals of provision, design and construction*, Housing and Building Research (HBRC) Journal, (2014) 10, pp.10-24.

3 "10 tiny house villages for the homeless across the U.S.," *Curbed Vox Media* online, July 18, 2017, https://www.curbed.com/maps/tiny-houses-for-the-homeless-villages.

4 "FEMA Individuals and Households Program (IHP) - Housing Assistance," DisasterAssistance.gov, last updated December 12, 2018, https://www.disasterassistance.gov/get-assistance/forms-of-assistance/4471.

5 "Urban Design Playbook for Interim Housing," NYC Emergency Management and NYC Department of Urban Planning, (2012): 44, https://www1.nyc.gov/assets/whatifnyc/downloads/pdf/urban_design_playbook_interim_housing.pdf.

6 Ibid: 3

7 "NYC Urban Post-Disaster Housing Prototype: Overview," *New York City Government* online, https://www1.nyc.gov/site/whatifnyc/about/overview.page.

8 "NYC Urban Post-Disaster Housing Prototype: Frequently Asked Questions," *New York City Government* online, https://www1.nyc.gov/site/whatifnyc/about/frequently-asked-questions.page.

9 *Prototype for Urban Interim Housing Units: 95% Construction Document*, US Army Corps of Engineers, NYC Office of Emergency Management, and NYC Department of Design and Construction, (July 01, 2013), https://www1.nyc.gov/assets/whatifnyc/downloads/pdf/oem_prototype_dwg_set.pdf.

10 "NYC Urban Post-Disaster Housing Prototype: Frequently Asked Questions," *New York City Government* online, https://www1.nyc.gov/site/whatifnyc/about/frequently-asked-questions.page.

11 See Sphere Association, *The Sphere Handbook*, 4th ed., (2018) https://spherestandards.org/wp-content/uploads/Sphere-Handbook-2018-EN.pdf.

12 *"UNHCR Emergency Handbook Camp planning standards (planned settlements),"* version 1.6, United Nations High Commissioner for Human Rights (UNHCR), (January 11, 2018), https://emergency.unhcr.org.

13 "Features," *Better Shelter* online: BetterShelter.org, http://bettershelter.org/product/.

14 Oliver Wainwright, "Why Ikeas' flatpack refugee shelter won design of the year," *The Guardian* online, Last modified January 27, 2017. https://www.theguardian.com/artanddesign/2017/jan/27/why-ikea-flatpack-refugee-shelter-won-design-of-the-year.

Resources

"Commonwealth of Massachusetts Disaster Housing Plan. Massachusetts Emergency Management Agency (MEMA), July, 2015. Available at: https://www.mass.gov/files/2017-07/2015-ma-disaster-housing-plan-final.pdf.

7 Governance

7.1 Resilience Database

Maintain Up-to-Date Resilience Data and Projections

Key Benefits

1	**Empowers a broad range of stakeholders and cross-sectoral partnerships**
2	**Promotes cohesive and engaged communities through access to critical information**
3	**Fosters long-term and integrated planning efforts of governments and other partners**

Limitations

1	**Can be an expensive and complex process to build open platforms and share data across multiple agencies and departments**

Overview

Collecting, organizing, managing, and disseminating data is a complex process and can often be costly, but it adds critical value to resilience planning efforts. This section outlines the key role data and data-sharing plays in resilience planning and provides some framework for implementing effective data management schemes that have allowed many cities throughout the US to leverage data in much more effective manners.

(Right) Building a database can help to connect critical infrastructural elements with other factors involved in resilience planning. Source: PIIA

Data as Infrastructure for Resilience

Data is a form of infrastructure. The majority of today's resilience planning initiatives require cross-sectoral collaboration – most of which is done through digital platforms and sharing of data. Because data underlies much of the resilience planning effort, its quality and effectiveness is of the utmost importance. Data's effectiveness also lies in the openness of its use. Much of the recent advancement in data collection, processing, and mapping has become open-source, allowing for greater collaborative efforts to be undertaken. This allows the public and private sector to operate with higher degrees of transparency and empowers local communities to use information to address local problems within a systemic framework supported by open data. Access to information provides opportunities for more communication about risk and resilience. It also facilitates engagement by providing some framework from which to understand climate, environmental, socio-economic, and demographic pressures as relatable phenomena. This provides communities with a higher degree of understanding of their predicament and may help open up avenues to improve this.

Smart Resilient Urban Development

Actors engaged in urban development utilize a variety of data. In promoting more-resilient typologies and sensitive designs, the availability of data pertaining to these factors is essential for planners, architects, and developers. The availability of open data can also allow for more engagement in research and development by civil society actors and local university researchers. Data is a major component of 'Smart Cities' initiatives across the US, allowing for more effective collaboration and coordination through data platforms across a broad array of stakeholders and government.

Engagement and Risk Communication

Making data available to the public is a major step forward in empowering communities with access to information. However, data literacy is an important consideration in the empowerment of local communities as there may not be many with the means to access the data in meaningful ways. Local communities should establish a data literacy program in partnership with local educational institutions and libraries and provide links to learning resources through Internet platforms like government websites.

Spatial and Analytical Scale

While many resilience plans look at local conditions where infrastructural investments may be devised in detail, a critical part of resilience planning includes a regional framing of large-scale systems. Many large-scale systems have important relationships that are illustrated through regional mapping. For instance, population changes within a region can indicate new pressures on infrastructure and hydrological systems leading to changes in commuting patterns or new trajectories of water flow and flood hazard. Data used at these scales may not be as fine-grained or as detailed as other types of data used at local scales. However, this kind of spatial data is important in the analysis of the impact of hazards, areas under threat, the potential vulnerability of certain communities relative to these threats, and potential areas for directed focus for policy or the implementation of mitigation projects. For example, it would be a mistake to use areas identified for stream restoration at a high level as channel delineations for local construction documents.

Quality, Usability, Metadata, and Data Management

There are a few important considerations in building data infrastructure: the quality of the data, usability, recording of metadata, and management standards and practices.

Quality

The importance of quality is related to a few factors: timeliness, accuracy, and its source. Timeliness refers to how relevant data is with reference to a desired time scale or the difference in time from when it was recorded to the desired time for purposes of comparison or relevance to a current situation. Depending on the type of data the interval of recording is important. For instance, population data may be acceptable to compare across a yearly scale, while economic data may be more appropriate to measure across a quarterly scale. Depending on the intended use of the data, timeliness is key to its usefulness. Accuracy is another important factor related to the source of the data. Data is a translated form of information, meaning it was recorded based on certain inputs and merely represents those inputs. Accuracy is related to timeliness, but must also record its source input and how it was recorded. For instance, satellite information

is a key source input from which many other data sources are extracted, however, this comes with inaccuracies due to image resolution, or the fact that different spatial information are recorded in a variety of formats from points, to lines, polygons and rasters.

Usability

Usability refers to the clarity of the data, but also the format. Clarity refers to the reasonableness with which a user can interface with the data. Data should provide clear labels and be navigable. Data for use across departments, especially open data, requires a format that is easily read by major platforms. These are important considerations in determining the platform and sharing of data and could require further reformatting to translate complex or difficult-to-use data types into usable types.

Metadata

Metadata is a set of information about a particular dataset. It is important to have documentation of a range of information such as how the data was created, sources of the data, and any relevant information about the source. This allows for users to identify particular weaknesses and strengths in a dataset and allows a user to track down sources of data. Indicating relevant processes by which data was made that can be useful in cross-checking overlaid data and reviewing the appropriateness of such references also aids in data analysis.

Data Management

The management of the data is essential in establishing many of the aforementioned standards that provides accessibility to users. In many cases, data management is a task done by a data manager. A data manager will typically organize and standardize data according to established parameters. They will also help to set up and maintain a working platform from which data users can reference, download, and sometimes upload, data. Maintaining an effective data management staff can be an important precondition for establishing open data platforms as elaborated upon in the following section.

Open Data

Open data is key to enabling effective resilience planning. Resilience planning requires cross-sectoral input and engagement with an array of stakeholders, risk analysis, collaborative problem solving, and risk analysis.

The term "open data" has a very specific definition within the data sharing and management context. It must be legally open, meaning that it must be in the public domain with minimal restrictions. Open data must also be accessible, meaning that it must be made available in digital formats that can be read widely by most data software and made available on an open and free platform without restriction.

Creating an open data platform requires robust data infrastructure noted above. But this also allows for the crowdsourcing of data. Through crowdsourcing and participatory mapping, major sources of local risk exposure may potentially be identified at a much higher accuracy and fidelity than many larger-scale organizations can provide alone. For instance, Open StreetMap[1] is an open platform that allows volunteers to input data resulting in a repository of crowdsourced spatial data within a structured database. Partnerships with open data platforms or the private sector can help to initiate the planning processes necessary for building and maintaining open data platforms for resilience purposes.

OpenStreetMap

OpenStreetMap is a collaborative platform that provides an open map of the world. Data is provided by volunteers and utilized by many individuals and organizations around the world.

Recommended Datasets for Resilience Planning

Datasets	Potential Sources	Chapter References
Infrastructural and Building Assets		
Power Infrastructure (electric grid, substations, power plants, etc.)	US Department of Energy, Local Energy Companies	5.1, 5.3, 5.4, 5,5
Power Outage Locations	Local Power Companies	3.3, 5.1, 5.3, 5.4, 5,5
Waste and Wastewater Infrastructure (sewer system, pump stations, etc.)	State Environmental Agencies, Local Public Works Departments	5.1, 5.2
Stormwater Infrastructure Details	Local Public Works Departments	5.1, 5.2
Transit Infrastructure (trains, bus network, etc.)	Local Governments, Local Transit Corporations	3.3, 5.1
Critical Emergency Facilities (fire stations, police stations, hospitals, shelters, etc.)	Local Governments	3.1, 3.2, 3.3, 5.1, 5.4, 5,5
Evacuation Routes	Emergency Management Authorities	3.3, 5.1
Food Distribution System Key Hubs and Routes	Emergency Management Authorities	3.3, 5.1
Building Footprints	County Departments	2.1, 2.2, 2.3, 3.1, 3.2, 3.3
Logistics Hubs (train yards, inland ports, etc.)	Port Authority, Local Governments	5.1
Highways and Roads	US Department of Transportation, Local Department of Transportation, US Highway Administration	5.1
Hydrocarbon Infrastructure	US Department of Energy	5.1
Community Facilities (libraries, community centers, cooling centers, etc.)	Office of Sustainability	3.1, 3.2, 3.3, 5.1
Ecology and Environmental Assets		
Conservation Priority and Critical Ecological Areas	Environmental Non-profits, US Environmental Protection Agency	1.1, 1.2, 2.1, 2.2, 4.1, 6.1
Impervious Surfaces	US Geological Survey Landcover Institute	1.1, 2.1, 2.2, 4.1
Tree Data (conditions, types, etc.)	Local Power Companies	2.4, 5.3, 5.7, 6.2
Watershed and Topographic Data (LIDAR)	US Geological Survey	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 4.1, 4.3
Waterbodies (rivers, canals, wetlands, ponds, etc.)	National Wetlands Inventory National Fish and Wildlife Service, US Geological Survey	1.1, 1.2, 2.1, 2.2, 4.1, 4.3
Aquifer Recharge Areas	CAESAR, US Geological Survey	2.1, 2.2, 4.1
Parks, Trails, and Open Spaces	Local Parks and Recreation Departments	2.1, 2.2, 2.4, 4.1
Soils	US Department of Agriculture	1.1, 1.2, 2.1, 2.2, 2.4, 4.1

Datasets	Potential Sources	Chapter References
Demographics and Socio-spatial Indicators		
Growth Projections	Local Governments	2.2, 2.3, 4.1, 4.2, 4.3, 6.1, 7.2
Census Datasets	US Census Bureau	4.2, 7.2, 7.3, 6.1, 6.3, 7.2
Household Survey Data	American Community Survey	7.2, 7.3, 7.4, 6.1, 7.2
Economic Indicators	Boyd Center for Business and Economic Research, US Department of Labor, State Departments of Labor and Workforce Development	4.2, 7.3, 7.4, 7.5
Administrative		
Annual School Closures	Local School Districts	3.3
Jurisdictional and Legislative Boundaries	State Governments	
Zoning and Regulations	County and Local Governments	2.1, 2.2, 2.3, 3.3, 4.1, 6.1
Land Use Coverage	County and Local Governments	2.1, 2.2, 4.1
Parcels and Assessment Information	Local Tax Assessor's Data	2.1, 2.2, 2.3, 4.1, 6.1
Public-interest Properties (Land Trust, Landbank, government-owned, etc.)	Local, State, and Federal Governments, Land Trusts, Environmental Non-profits	2.1, 2.2, 2.4, 4.1, 6.3
Risks		
Heat Island	US Environmental Protection Agency	3.3, 3.4
Earthquake Vulnerability	Central United States Earthquake Consortium	3.2
Recorded Flooding Areas	Crowdsource, Local Governments	1.1, 1.2, 3.1, 4.1, 4.3, 5.2
Contaminated and other Sensitive Sites	Environmental Protection Agency	1.1, 1.2, 2.1, 2.2, 4.1, 4.3, 5.2, 6.1
Floodplain and Flood Hazard Zone	Federal Emergency Management Authority	1.1, 1.2, 2.1, 2.2, 3.1, 3.3, 4.1, 4.3, 5.1, 5.2, 6.1, 6.3
Impaired Waterways	Local Environmental Non-profits	1.1, 1.2, 2.1, 2.2, 4.1, 5.2
Water Quality Indicators	Local Environmental Non-profits, State and Federal Environmental Agencies	1.1, 1.2, 2.1, 2.2, 5.2

Implementation

There are a few activities that can be pursued to improve the regional capacity to leverage data for resilience planning, improve cooperation, empower a broad range of stakeholders, and promote the engagement of communities. Many cities throughout the US and the world are implementing programs and initiatives for a wide variety of reasons, including the potential to engage a wider swath of society in data-informed decision-making. Many cities have partnered with organizations such as universities, NGOs, and community groups. A few potential lead agents in the Mid-South could be a combination of: regional organizations, local university institutions, or a range of private IT-sector specialists.

Outlined below are four key starting points for improving resilience data management in the region: share data across agencies and departments within the region, implement a data literacy education program, leverage crowdsourced and open data, and look to best practices in resilience data management from around the nation and world. While there are many examples, the real challenge is cross-agency collaboration, where the implementation process must adapt to local conditions in achieving the goals laid out for effective resilience data management.

Share Data Across Agencies and Departments within the Region

Sharing data has many useful applications that can support academic research, promote intergovernmental cooperation, and enhance commercial and economic development across the region. This may require some formal procedures to be put in place to enable sharing. Many agencies and departments may have their own methods and standards for data management. To overcome these sorts of barriers, a program and platform may be necessary to facilitate institutional change to data management.

OneNYC

The New York City Office of Emergency Management implemented a citywide data sharing initiative[2] that helped to break down agency silos as it related to the creation and exchange of information. The city developed a 3D dataset of underground infrastructure composed of data from several different agencies.

Implement a Data Literacy Education Program

Implementing a data literacy education program could enable local communities to access and build information on local assets, assess the health and well-being of its community members, identify strengths and weaknesses, and empower them to address opportunities and threats. This provides an informed framework for communities to organize, advocate, and fund local projects with the aid of robust data. Existing educational infrastructures are prime platforms for this kind of program: libraries, schools, community centers could all be centers for hosting classes and showcasing the power of data-driven analysis and decision-making. See 7.2 Outreach for more complimentary recommendations.

7.2

100 Resilient Cities: Atlanta

Within Atlanta's 100 Resilient Cities action plan, funds from the city have been earmarked to build and launch a data platform and data literacy education program. To promote the use of its data platform, the City is providing these educational program free of charge to community members. Additionally, the City plans to partner with Commercial Improvement Districts to develop tools for monitoring and planning.

Leverage Crowdsourced and Open Data

Resilience planners should utilize technology to provide crowdsource platforms for the region's emergency services and other relevant social media. Additionally, planners should integrate crowdsourced infrastructural data such as power outages, traffic, and other reporting platforms and align these inputs with local operations. The data collected can also inform future planning of infrastructure projects.

UNISDR Roadmap for Open Data Infrastructure

The United Nations Office for Disaster Risk Reduction, as part of the International Strategy for Disaster Reduction (UNISDR), has developed the Roadmap for Open Data Infrastructure,[3] a ten-step implementation checklist to help local governments develop a data framework and open data policies for building disaster resilience.

Look to Best Practices in Resilience Data Management

In recent years, cities around the world have been developing robust data management platforms as a critical infrastructure to support decision-making to improve regional resilience. In addition to OneNYC, or the 100 Resilient Cities campaign, there are many more cities improving their data framework in related ways.

Cities Alliance Data Toolkit

Funded by the Cities Alliance and as part of the Future Cities Africa Initiative, a Data Toolkit was created to inform city officials on data management for resilient city planning. The toolkit identifies ways to establish an effective process for data management as well as ways in which data could be utilized to support a resiliency framework for decision-making related to infrastructure building and economic development.[4]

World Bank Open Data Readiness Assessment

The World Bank Open Data Readiness Assessment (ODRA)[5] is a tool that allows governments or agencies to be assessed for its potential or capacity to implement an Open Data program. The User Guide provided alongside example assessments outlines a process through which to conduct the assessment with important considerations to legality, data ownership, and management. Although its focus is on national-level agencies, the process outlined is relevant to local-level implementation as well.

Endnotes

1 For more information see *Open StreetMap* online, https://www.openstreetmap.org/.

2 For more information see *OneNYC* online, https://onenyc.cityofnewyork.us/.

3 Mark Harvey, Nuha Eltinay, Sarah Barnes, Rebecca Guerriero and Mathylde Caffa, *Open Data Infrastructure for City Resilience: A Roadmap Showcase and Guide*, (UNISDR, 2018), last modified 2018, https://www.unisdr.org/campaign/resilientcities/assets/documents/guidelines/ODIR%20Publication%20Final_16042018_opt.pdf.

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7.2 Outreach

Expand Resilience-Related Public Outreach and Engagement Efforts

Overview

The Mid-South Region has many online resources available to educate residents about how to make a plan in the event of an emergency. In addition, these relatively static resources are supplemented by community engagement events, social media posts, and traditional media releases that help raise community awareness about the various natural threats facing the region and where to go to find resources before, during, and after an event. In spite of this, at many community outreach events that were part of the Mid-South Regional Resilience Planning process, several residents voiced confusion about where to get advance planning and preparedness information and how to be alerted to imminent threats. This section provides an overview of some of the static resources available to residents of the Mid-South Region, as well as some of the alert systems currently in place. This section also includes recommendations to improve this robust set of resources. Most of these recommendations relate to emergency preparedness and alerts for vulnerable populations.

It is worth noting that most of the resources available to Mid-South residents are furnished by Shelby County and City of Memphis in Tennessee, or DeSoto County in Mississippi. Fayette County in Tennessee and Marshall County in Mississippi offer few resources specific to their residents. Given the regional nature of the environmental threats facing the Mid-South, the resources offered by Shelby County, City of Memphis, and DeSoto County are still highly relevant for residents of Marshall County and Fayette County. It is likely unnecessary for these lower-density jurisdictions to bolster their preparedness or planning offerings. Instead, it is likely to be most beneficial for their respective emergency management offices to coordinate alerts with Shelby County, City of Memphis, and DeSoto County, and direct residents to online resources made available by these nearby jurisdictions and the federal government.

(Right) Public service announcements on bus stops tell New York City residents where to find resources to prepare for an emergency.

7.2.1 Preparedness and Planning

Local Initiatives

Ready Shelby

Ready Shelby is a collaborative initiative between the Shelby County municipalities. The Ready Shelby website offers information related to preparedness and planning in the event of a natural disaster. Published guides offer information on what to do in the event of severe weather, power outages, winter storms, tornadoes, extreme cold/heat, floods, and earthquakes.

Ready Shelby coordinates with Ready Faithful, a group of area religious leaders that offer community assistance during natural disasters, to offer support in developing emergency preparedness plans. Ready Shelby also coordinates with Ready Neighbors through the City of Memphis' Neighborhood Relations Office. Though neighborhoods are more loosely affiliated than religious congregations, establishing block captains and district leaders can help formalize chains of communication to reach more residents.

Finally, the Ready Shelby website offers lists of resources with links to appropriate websites. In the future, a brief description of those resources on the links page could enhance the user experience.

Some of the resources are geared towards vulnerable populations, including a Sesame Street Workshop designed for families with children. Additional published resources directed at other vulnerable populations would add to the robustness of the Ready Shelby resources. The Center for Disease Control and Prevention and the Federal Emergency Management Agency offer some guidelines to help populations who are deemed vulnerable based on socioeconomic status, housing tenancy, mobility, and health. For a more in-depth understanding of vulnerable
7.3 populations in the Mid-South Region, see Section 7.3.

I'm Ready
ReadyShelby.org

DeSoto County Fire and Emergency Management Agency

DeSoto County's Fire and Emergency Management Agency offers similar resources to Ready Shelby, directed at residents of DeSoto County. Resources for individuals and families on planning in the event of an earthquake, hurricane, tornado, severe thunderstorm, winter storm, or hazardous materials and facility accident are available on their website.

Marshall County and Fayette County Emergency Management Agencies

Both Marshall County and Fayette County offer limited information about emergency planning or preparedness on their Emergency Management Agency websites. However, due to the proximity of Shelby County and DeSoto County, residents may be able to rely on information provided elsewhere. To facilitate this, the Marshall County EMA website could direct viewers to the DeSoto County Fire and Emergency Management Agency website, and the Fayette County EMA website could direct viewers to the Ready Shelby website.

State Programs

Tennessee Emergency Management Agency - Ready TN

!TN

The Tennessee Emergency Management Agency (TEMA) provides a mobile app that offers Tennessee residents information about emergency preparedness, response, and recovery. During an emergency, app users can receive alerts and warnings, find open shelters linked to the American Red Cross, view traffic information along roadways or evacuation routes, or get updates from TEMA social media accounts. The app provides planning guides for disasters, including specific information for kids, pets, seniors, and individuals with functional disabilities. Specific information about what to do in the event of droughts, earthquakes, extreme temperatures, wildfires, floods, geologic disasters, severe weather, tornadoes, and dam/levee failures is also available in the app.

(Left) DeSoto County's Fire and Emergency Management Agency website offers residents information about planning and preparing for an emergency event.

Mississippi Emergency Management Agency

Mississippi's Emergency Management Agency (MEMA) offers similar preparedness and planning resources as TEMA. A publicly-available smartphone app provides information on current emergencies, preparedness tools, and other information. The MEMA website offers similar information. Preparedness information addresses hazards such as hurricanes, tornadoes, earthquakes, floods, winter weather, and radiological events. More general information about disaster preparedness is also available, including a disaster kit supply list, and preparedness for vulnerable individuals with vision, auditory, or mobility impairments.

National Programs

StormReady

StormReady is a program managed by the National Weather Service. It helps guide local governments and organizations towards emergency preparedness. In order to be recognized as a StormReady community, a community must: establish a 24-hour warning point and emergency operations center, have more than one way to receive severe weather warnings and forecasts and to alert the public, create a system that monitors weather conditions locally, promote the importance of public readiness through community seminars, and develop a formal hazardous weather plan, which includes training severe weather spotters and holding emergency exercises.

Participation in this program counts towards the National Flood Insurance Program's Community Rating System, offering flood insurance premium discounts to residents of participating communities (see Section 4.3 for more information). In the Mid-South, 4.3
Shelby County, Fayette County, DeSoto County, the City of Memphis, Memphis International Airport, and several local institutions participate in StormReady. Marshall County in Mississippi does not yet participate, but participation would help improve emergency preparedness.

Weather Ready Nation

Weather Ready Nation is an amabassador-style initiative run by the National Oceanographic and Atmospheric Association (NOAA). Ambassadors sign up to lead by example in implementing resilience best practices. They receive information and resources from NOAA but face lower participation requirements than the Storm Ready program. Today, no communities in the Mid-South participate in the Weather Ready Nation program, but it could be a first step towards emergency preparedness for Marshall County or local municipalities or organizations who are not yet ready to commit to the StormReady program.

7.2.2 Raising Awareness

Public Outreach Campaigns

Public outreach campaigns can help direct people and organizations to existing resources offered by Ready Shelby and the DeSoto Fire and Emergency Management Agency, or to educational events offered by communities through their participation in StormReady or Weather Ready Nation. These can take many shapes and forms, from the standalone event or notice, to the recurring program. A diverse series of formats and outlets will be the most effective way to reach the most people. A recent example of this is the Severe Weather and Flood Awareness Week presented by the Memphis National Weather Service.[1]

Engagement Events

Engagement events offer the most opportunity to educate Mid-South residents about the threats facing the region and what they can do to prepare. In the past, WHBQ Fox 13 has hosted an annual Mid-South Weather Camp for kids that offers demonstrations of weather events and information on how to prepare and behave during an emergency.[2]

Media

Traditional and social media public outreach campaigns can direct people to preparedness resources. Planning for an event goes a long way to improving resilience during and after an event, but many in the region may not know that planning and preparedness resources are available. Newspaper, radio, or television advertisements and announcements or social media blasts many reach people in relatively passive ways. Shelby County's Emergency Management/Homeland Security maintains a Facebook page with limited posts (3-6 times per month). Encouraging residents to "follow" the page on Facebook would help increase awareness about preparedness efforts and drive traffic to planning resources on the Ready Shelby website. Libraries, community centers, and other places that serve vulnerable populations should post hardcopies of these notices to expand their reach.

Public Art

Public spaces and trails, particularly those adjacent to areas susceptible to flooding, could host public art that raises awareness about regional threats, historic events, local ecology or geology, and existing preparedness resources. The unique form that these outreach campaigns take can reduce the risk that the notices are "lost in the noise" of other outreach campaigns.

Public Advertisements

Public service announcements posted in public spaces can be a very effective way to direct people to resources. Billboards, advertisements on buses and at bus stops, and notices in libraries, community centers, or healthcare facility lobbies reach significant numbers of people each day. Care should be given to maximize the reach of these advertisements; Spanish and potentially Vietnamese translations of the most pertinent information will reach most non-English speakers in the region as those are the two most common languages spoken at home after English. Very visual advertisements will reach children, other non-English speakers, and those with limited reading proficiency.

ListServs

Many public and private organizations maintain e-mail ListServs for their communities. These can also reach significant populations. They can be particularly effective at communicating targeted information to specific groups. A local PTO can provide preparedness information relevant to families with children, or a community health group can provide relevant preparedness information to those who require health or mobility assistance in the event of an emergency.

In all cases, the more platforms and diversity of platforms that a message can be transmitted across, the more people it will reach. Ideally, these efforts are enhanced by word-of-mouth communications, with an exponential effect for each method of raising awareness.

Emergency Alerts

Media

Traditional media outlets such as newspapers, radio stations, and television networks have historically notified Mid-South residents about upcoming severe weather events. Television networks and radio stations also typically provide "breaking news updates" by interrupting regularly-scheduled programming with timely alerts. Social media outlets have started to follow suit. Shelby County's Emergency Management/ Homeland Security hosts a Twitter feed with real-time updates about local emergencies. Though the volume of posts may be too great to recommend that casual users "follow" the feed (posting approximately 30 times per month), it serves as a great resource for residents to pro-actively find updated information.

Sirens

Not all residents have access to traditional or social media outlets, or may find themselves without access in the moments before, during, or after an emergency. Sirens offer a passive alert system that notifies everyone within a prescribed vicinity. Today, Shelby County offers siren alerts to notify of upcoming tornadoes. DeSoto County offers siren alerts for tornadoes, and a more general emergency alert that directs residents to check other resources for information regarding an imminent emergency. To reduce confusion and improve the functionality of siren alerts, all communities in the Mid-South should follow the same siren protocols, including one sounding pattern that directs people to tune into local media for more information.

Implementation

Complete Resource Library

To complete the resource library available to individuals seeking guidance on creating an emergency preparedness plan, additional information should be provided to address the specific needs of vulnerable populations, identified in 7.3 Vulnerable Populations. In order to do this, the first step is identifying which local groups or organizations are best equipped to advise on this topic. The second step is to coordinate a meeting to discuss the unique needs of each group during an emergency and begin to identify resources to meet those needs. The third step is to identify any gaps in local resources and notify relevant parties who may be able to address the gaps. The final step is to document the available resources and make that information available on the Ready Shelby and the DeSoto County Fire and Emergency Management Agency websites.

7.3

Coordinate Emergency Alerts

Regionally, the emergency alert systems do not function as a unit. Each system of alerts is managed autonomously by each jurisdiction. To reduce confusion, siren alerts should be made consistent across the region. Additionally, coordination of traditional media and social media alerts and broadcasts could increase the quantity of people reached in the shortest amount of time and reduce possible confusion during region-wide alerts. The Memphis Area Association of Governments could help facilitate this coordination.

Case Study

Sea Change Exhibition, Boston, MA

Sea Change was a curated exhibition designed to share the results of a research initiative to explore the effects of rising seas and the changing climate in Boston, Massachusetts. Hosted in an open community exhibition space in a flood-prone neighborhood of the city, the exhibition employed high-tech and high-touch communication tools to show future flood areas and describe the impact to daily life for people living and working there.

A digital screen offered an interactive tool for viewers to see different future flooding scenarios in Boston. Informational boards shared maps, charts, diagrams, and personal stories to communicate the information in ways that speak to a wide variety of audiences.

Outside the exhibition hall, installation art "grounded" the ideas of sea level rise, marking areas that would be underwater during high tides in the future. This component of the exhibition was visible to passers-by, a way to reach passive audiences. Meeting people where they are, bold visuals, and connections to daily life are all tested ways of reaching casual audiences.

(Left) Image of future high tide levels in Boston's Seaport neighborhood.

Endnotes

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7.3 Vulnerable Communities

Identify Resilience Strategies for Vulnerable Communities

Overview

Vulnerability to environmental hazards refers to a group or communities potential for loss, while resilience refers to the capacity to recover from loss. There are socially created vulnerabilities and physiographic vulnerabilities. Socially created vulnerabilities relate to a community's experience with hazards including their ability to respond to, recover from, and adapt to hazards. Factors of vulnerability (and resilience) are also influenced by economic, demographic, and physical dimensions that include:

- Socioeconomic Status
- Housing Stock and Tenancy
- Age, Gender and Family
- Race and Ethnicity
- Health
- Language
- Mobility

Physiographic vulnerabilities relate to geography and the particularities of a physical location with regard to risk of an environmental hazard. This may include the proximity and elevation in relationship to a floodplain, or exposure to areas of extreme heat where tree canopies, green space, and other features may help to mitigate such exposure.

While both may be difficult to quantify given their dimensions, a loose geography of vulnerability can be constructed through analysis of these particular factors. Prioritizing resilience investments in vulnerable communities can go a long way in mitigating the far-end of the damage for populations who may struggle based on socially-created conditions. Broad strategies have been identified to aid in the mitigation of potential damage a hazard may cause and help vulnerable communities recover.

(Right) Flooding is one of the most devastating disasters that can affect vulnerable populations

Vulnerable Communities

Social vulnerability refers to the inability to "anticipate, cope with, resist, and recover from the impact of a discrete and identifiable disaster in nature or society." [1]

A measure of a community's resilience to disaster is its attentiveness to its most vulnerable populations. Disasters may affect certain populations with greater severity than others. Vulnerability is not a fixed category but is defined by circumstance. Many factors of vulnerability are influenced by social conditions. A lack of income, for instance, can be a barrier in access to secure locations for housing based on land value, transportation costs, and other factors based on other human decisions. To mitigate the negative effects – particularly the vulnerabilities caused by such conditions – social interventions are also useful. For instance, the elderly and disabled are more likely to lack the means to generate income, especially in the case where they may not have others to provide for them. To remedy the vulnerability of lack of income and ability, social security provides a safety-net for those whose abilities diminish naturally with age or who have been otherwise disabled through other circumstances.

Physiographic vulnerabilities may correlate to social vulnerabilities based on geography and physical susceptibility to the dangers presented by a disaster or hazard. This may be the nearness to a stream or location within the floodplain which places communities within such geography at a much higher risk than those outside. To mitigate the effects of this type of vulnerability, both social and physical interventions may be needed. Yet, social vulnerabilities remain one of the most prominent and complex set of factors affecting the risk and resilience of communities. It is for this reason, both physical and social interventions should prioritize vulnerable communities in order to help those at most risk.

There are six key dimensions of vulnerability to consider in prioritizing areas for investment. These are listed in the table to the right. Each are paired with key data points in order to define a loose geography of vulnerability and identify broad strategies that can aid in the mitigation of potential damage a hazard may cause to these vulnerable communities.

Vulnerability Dimensions and Data Sources

Vulnerability Dimension	Data Source
Socioeconomic Status	
Income Under Median (<$50k)	2010 Census
Mortgage Holders	2016 ACS Data
Workers in Transportation and Warehousing	2010 Census Data
Unemployed	2010 Census
Housing Stock and Tenancy	
Living in Mobile Home	2010 Census
Renters	2016 ACS Data
Age, Gender and Family	
Age Under 18	2016 ACS Data
Age Over 65	2016 ACS Data
Single Women Households with Children	2010 Census
Race and Ethnicity	
Non-White Population	2010 Census
Health	
No Health Insurance	2010 Census
Disability	2016 ACS Data
Mobility	
Limited or No English	2016 ACS Data
No Car	2016 ACS Data

Socioeconomic Status

Population Income Under Median (<$50k), 2010 Census Data
Population with Mortgage, 2010 Census Data
Workers in Transportation Services, 2010 Census Data
Unemployed Population, 2010 Census Data

One of the greatest indicators of vulnerability and resilience in a community is the socioeconomic status of its population. The level of income can make a major difference in the ability to prepare or make repairs during or after a disaster. Likewise, debt, like that associated with mortgage holders, may hinder the resilience of a community to 'bounce back,' particularly when the home for which the mortgage was taken has been damaged.

Those employed in jobs that depend on functioning infrastructure, such as transportation workers, are at risk where communities rely on high concentrations of infrastructure such as bridges, roads, etc., which may be damaged in a disaster. Memphis's workforce is dominated by those that work in trade, transportation and the utilities sector. In fact, the majority of the population works in these industries, with over 177,000 workers in the metropolitan area.[2] Around 58,000 are directly employed in transportation services. Additionally, those unemployed are at risk. Without a secure source of sustainable income, the loss of property or other assets can be devastating.

Socioeconomic dimensions also affect other vulnerability dimensions, such as choice of housing options. Poverty itself is correlated with lower rates of literacy and health insurance.[3 4] These factors can hinder reaction to, and recovery from, potentially dangerous environmental hazards. Lack of income or means can exacerbate other social vulnerabilities such as those associated with age (see Age, Gender and Family section). While the overall poverty rate in the Memphis metro region is 19%, 31% of children under the age of 18 are in poverty. This can affect the environment a child grows up in and reinforce other social vulnerabilities under which a child's family may be enduring.

Poverty also strongly correlates with race (see Race and Ethnicity section). While the overall poverty rate for non-Whites is around 30%, it is only 9% for the non-Hispanic White population.

Housing Stock and Tenancy

Population Living in Mobile Homes, 2010 Census Data
Renter Population, 2016 ACS Data

The quality of housing stock and tenancy are important in determining vulnerability. This dimension includes structures that may pose risks to evacuation or incur greater damage than other housing types. Those that live in mobile homes are at a greater risk to exposure of structural damage during storms and other disasters. Mobile homes are also more susceptible to wind damage and tornadoes versus many conventional housing types.[5]

Renters are also at high risk for displacement given the nature of tenancy and the preponderance of higher-density living in urban areas.[6] While the quality of rental housing in the Mid-South may be an issue, there is also less incentive for renters and owners of rental properties to invest in disaster mitigation measures as compared to homeowners. There is also a greater chance that renters will have had less exposure to information and community assistance in preparing for disasters and will likewise be less familiar about potential risks in the area.[7]

Age, Gender and Family

Population Age Under 18, 2010 Census Data
Population Age Over 65, 2010 Census Data
Single Women Households with Children, 2010 Data

Current research on vulnerable populations indicate children and elderly are most at risk.[8] It is more likely in disaster situations that children and the elderly require the help of others. The elderly are also more likely to have health issues putting them at risk both during and after a disaster. Chronic health problems may impair their ability to move around or limit their senses in other ways. This can have an effect on how they may follow directions. They may also be limited by their isolated living situation and the manner in which they use media, making it difficult to communicate directions and notices about disaster preparedness.

Single parents—particularly women—are at greater risk as they are often more likely to have a lower socioeconomic status in comparison to men and often must manage caring for children while maintaining a steady income.[9] 20% of households with children are headed by single women in the entire metropolitan area. That number is close to 42% for Shelby County alone. During situations of disaster preparedness, they may be at a disadvantage in access to resources, and following a disaster may face difficulty in the event that their home is damaged or they face other effects that place additional burden on these households.

Race and Ethnicity

Non-white Population, 2010 Census Data

Many non-white minorities are more likely to be at risk in times of disaster. The vulnerabilities associated with race and ethnicity have been studied extensively[10] and are mostly related to the history of disadvantageous policies and contemporary systemic issues associated with these histories. Generally speaking, non-whites are more likely to have been discriminated against in the past, have different cultural and social norms, or may be more spatially segregated from the non-Hispanic White population.

Population Breakdown by Race

Race	Population	% of Total Population
Non-Hispanic White	456,330	40.58%
Black	528,211	46.97%
Hispanic	61,347	5.45%
Asian, Native American and Other	78,766	7.00%
Total Population	**1,124,654**	**100.00%**
(Total Households	*474,470)*	

2010 Census Data

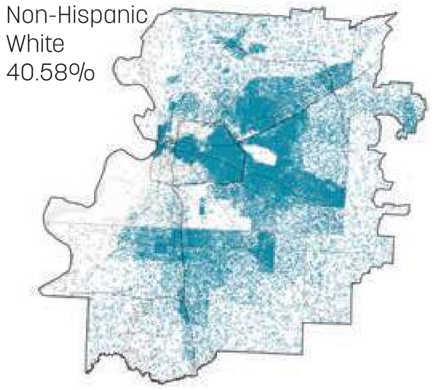
Poverty Rate by Race

Racial Identity	United States	Tennessee	Memphis Metropolitan Area
Non-Hispanic White	10.00%	12.50%	9.40%
Black	23.80%	26.30%	28.30%
Hispanic	21.00%	27.70%	30.10%
Asian, Native American and Other	45.20%	33.50%	32.20%
Overall	**14.00%**	**15.80%**	**19.40%**

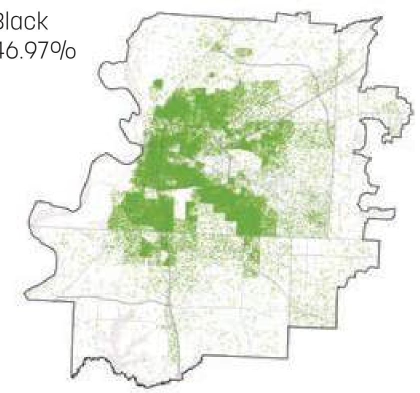
2016 ACS Data, 1-Y Estimates

The metropolitan area has a majority non-white population with clear spatial characteristics. These spatial characteristics have some correlation with other vulnerability dimensions associated with socioeconomic status. In the metropolitan area, 30% of the non-white population is in poverty.

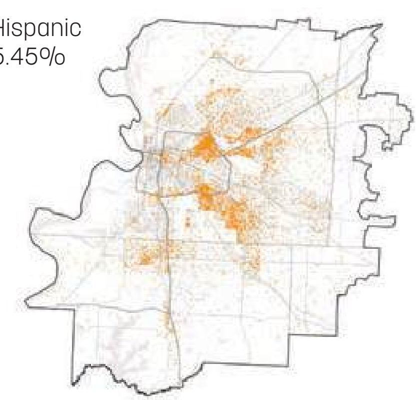
Non-Hispanic White 40.58%



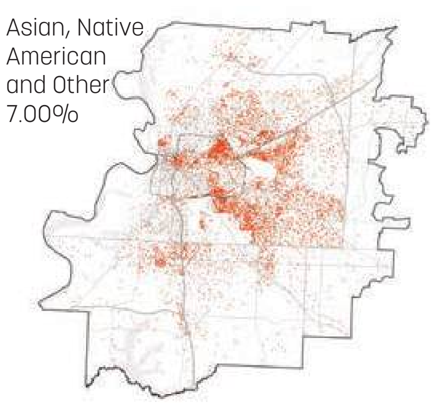
Black 46.97%



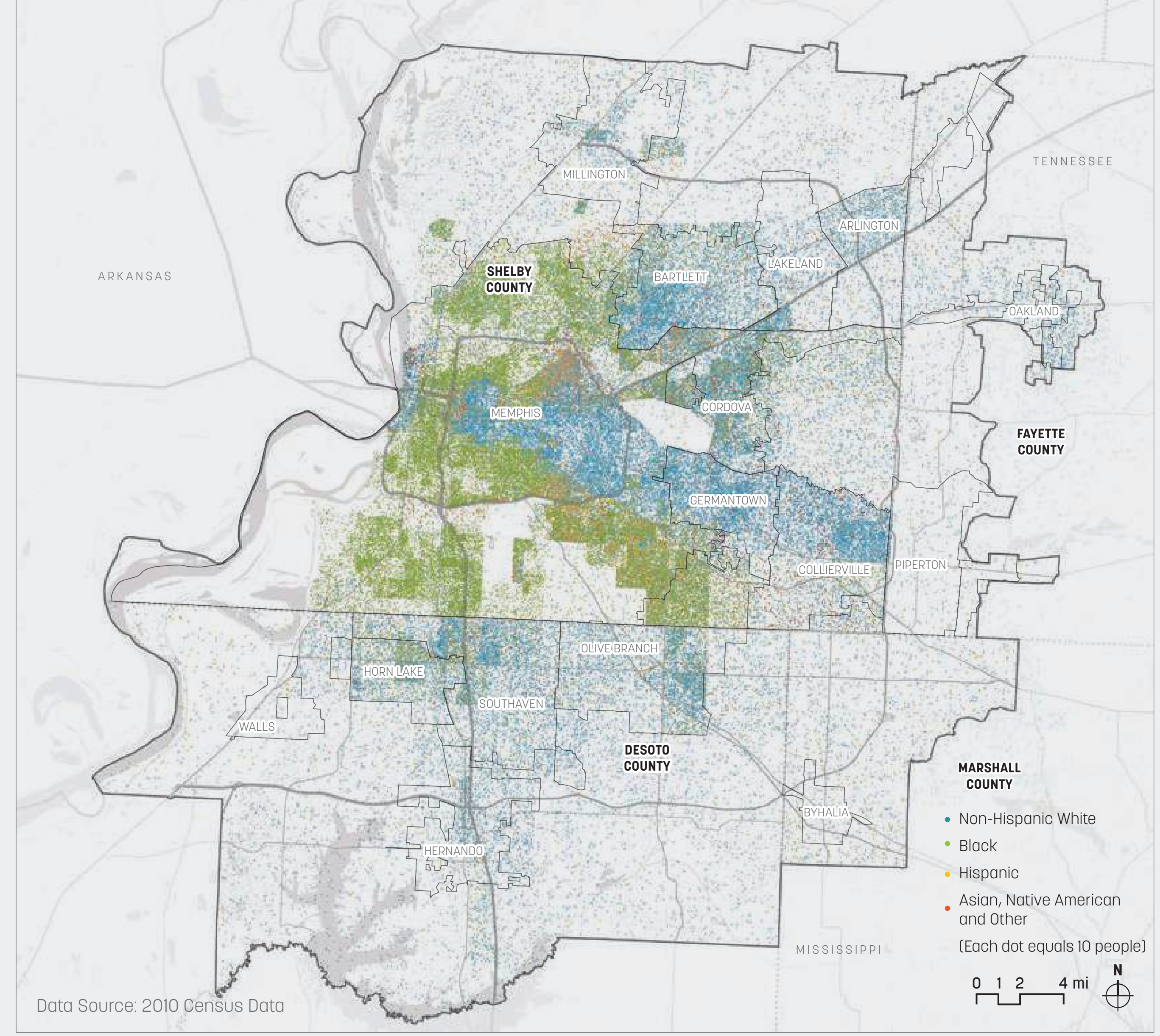
Hispanic 5.45%



Asian, Native American and Other 7.00%



Population Distribution by Race



Breaking that down: 28% of Blacks, 30% of Hispanics, and 32% of Asian, Native American and Other races are in poverty compared with only 9% of non-Hispanic Whites (see table on previous page).

In times of disaster, it may be difficult for certain groups in the population to seek and receive help. For instance, during hurricane Katrina, a large group of mostly black refugees attempted to enter Gretna, Louisiana, but were halted by armed police because the residents of Gretna did not wish to allow them to enter or help them.[11] It is difficult to plan for these potentialities, yet other dimensions of social vulnerability must be looked at where they intersect race.

Race is also correlated with different negative health conditions. There is a higher prevalence of heart disease, cancer, diabetes, and cerebrovascular diseases amongst Blacks as compared to the non-Hispanic White population. In confronting these diseases, the mortality rates also tend to be higher in the Black population as compared to others.

(Left) Mobile homes are often at greater risk due to the limitations of their structure as compared to many other types of housing

Health

Population without Health Insurance, 2010 Census Data
Population with Disability, 2010 Census Data

Disability is a crucial factor for both risk and resilience, particularly in times of a disaster where the disabled may require care or assistance in evacuation. This can place additional burdens on communities and families with few resources to aid their neighbors or family members with disabilities. Hazards and disasters can also cause damage to the environment, making mobility and access a key issue for many types of disabilities.

There are many health risks associated with disasters and hazards due to the impact on the environment such as contamination or temperature changes that have impacts on the body. For instance, extreme heat can exacerbate the effects of cardiovascular disease and kidney disease, as well as increase the incidence of strokes and dysrhythmia due to heat-related stress and constricted blood flow. Having health insurance has a major effect on a person's or household's resilience after a disaster. Many kinds of treatment can take a toll on the economic conditions of a family in the case that a family member does not have adequate insurance. Not having insurance can also dissuade those who may need to seek medical attention due to the perceived high costs and difficulties that may follow.

In addition to lack of health insurance, there are other factors of health to consider in terms of a community's vulnerability. The elderly population is more prone to health-related issues that may come with age, or make them more likely to be affected by stress and changing environmental conditions. Children also come with a set of conditions that require special treatment and should be seen by qualified pediatricians given the difference in care needed to address health issues in children as compared to adults.

Language

Population with Limited or No English Ability, 2016 ACS Data

Language can be a barrier to understanding key notifications and directions during a disaster emergency. It can also be a hindrance in terms of access to resources more generally. If a person, such as a head of household, is unable to comprehend or converse in English, the constrained ability to mobilize and react to notifications can amplify other forms of vulnerabilities associated with low socioeconomic status, family dynamics, and others. Around 5.70% of the overall population of Memphis are native Spanish speakers. 0.52% speak an African Language and 0.40% speak Vietnamese.

Mobility

Population with No Car, 2016 ACS Data

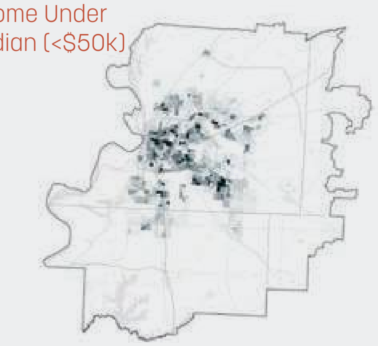
Not having a car can hinder a persons ability to react to a disaster in time and may require aid from neighbors and family members. For those without resources, they may be stranded in the event of an emergency evacuation. Reliance on public transit can also present problems if transit systems are negatively impacted by a disaster.

Mapping Dimensions of Vulnerability

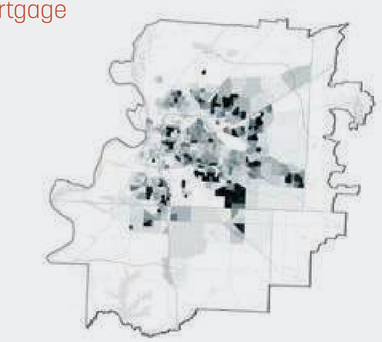
Concentrations of population based on each dimension.

Source: 2010 Census Data, 2016 American Community Survey Data

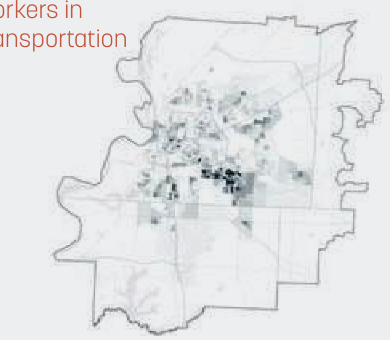
Income Under Median (<$50k)



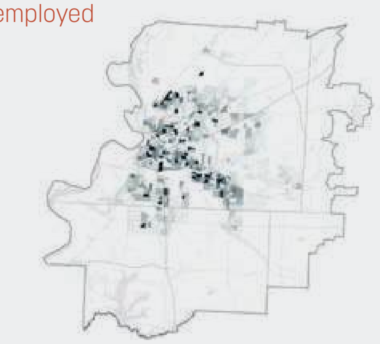
Mortgage



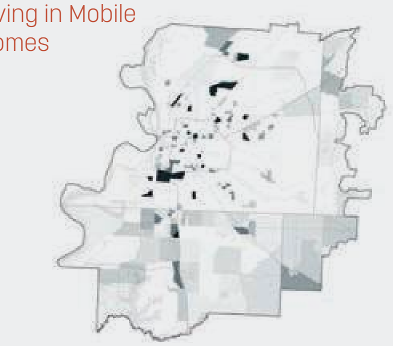
Workers in Transportation



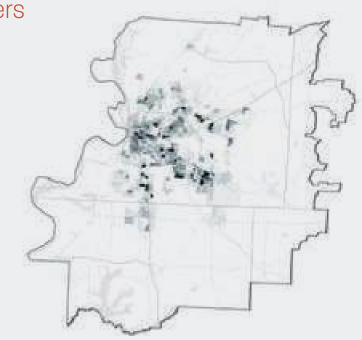
Unemployed



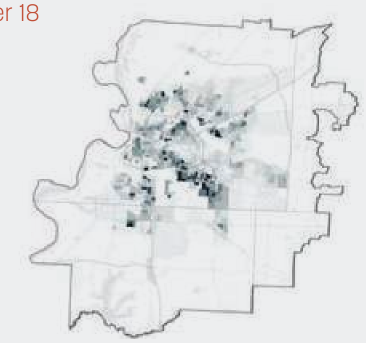
Living in Mobile Homes



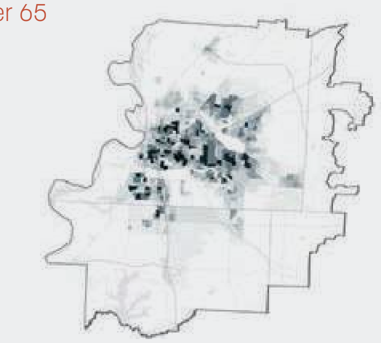
Renters



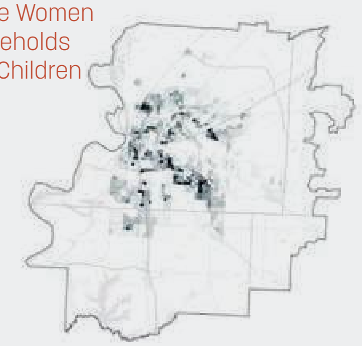
Under 18



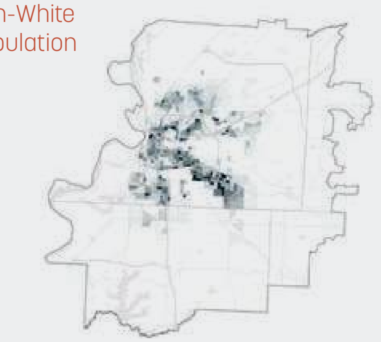
Over 65



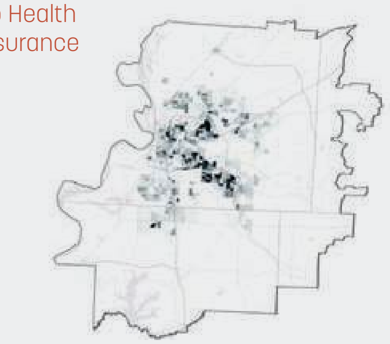
Single Women Households with Children



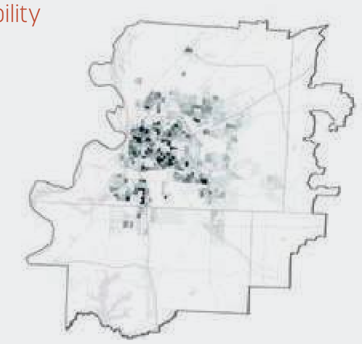
Non-White Population



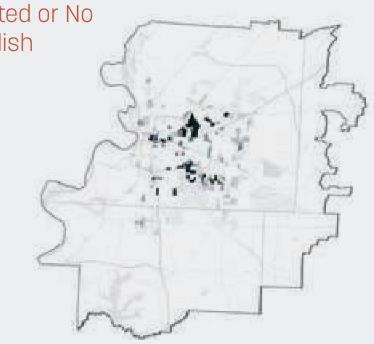
No Health Insurance



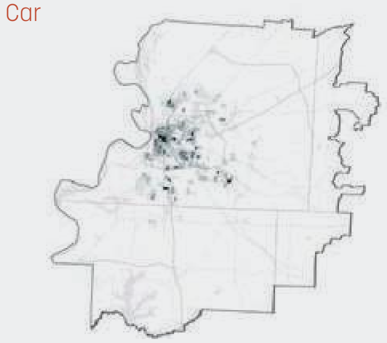
Disability



Limited or No English



No Car



Overall Vulnerability Map

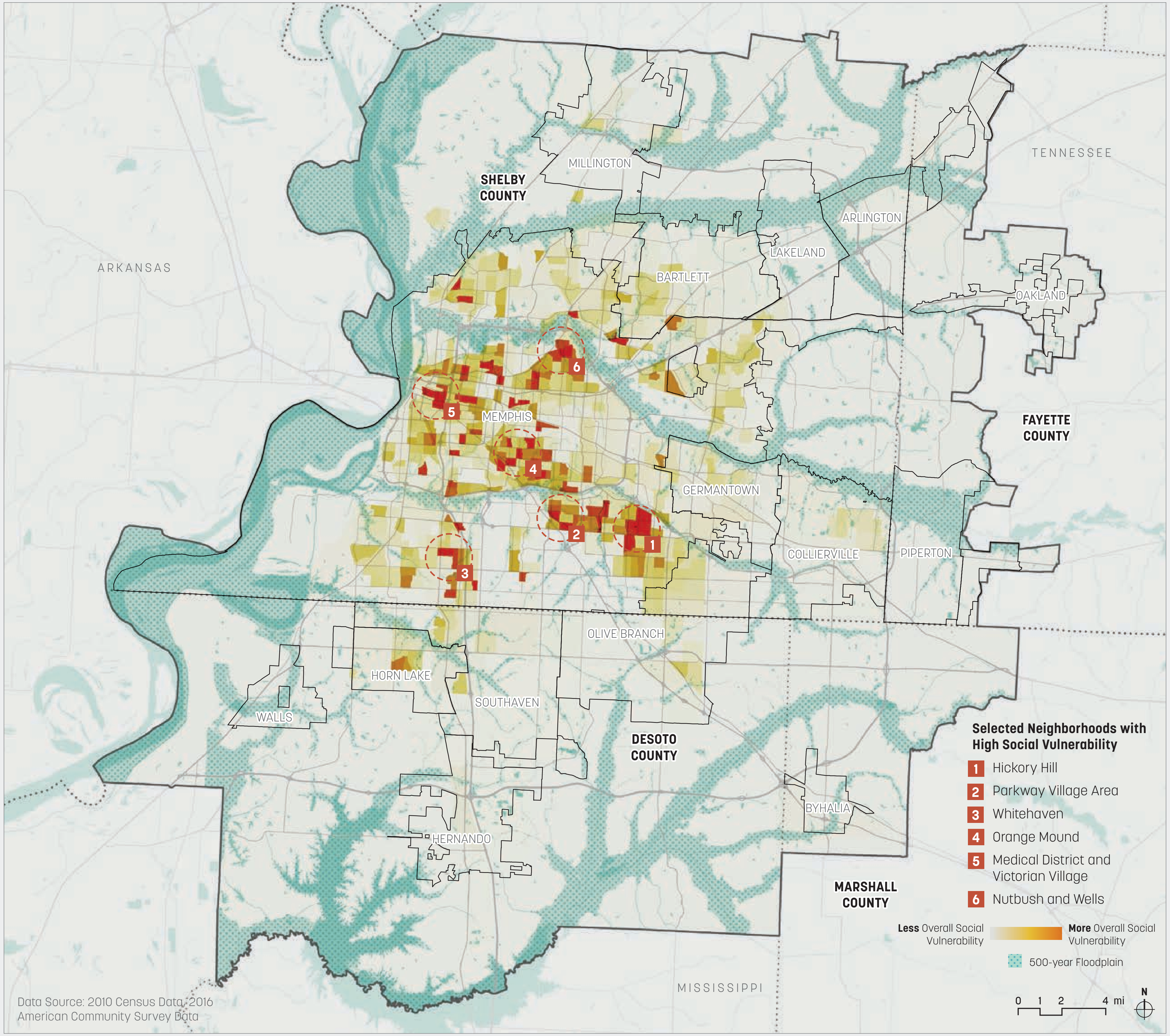
With an analysis of overlapping social vulnerability dimensions, there are a few key areas that begin to reveal a clustering of vulnerable demographics. In the map to the right, the darker colors reveal areas with more overlapping social vulnerability dimensions. Six neighborhoods were selected for further breakdown on the following page.

Throughout all of these six neighborhoods, a few key vulnerability dimensions stand out. On average 34.85% of the population in these areas were in poverty, almost twice the rate of the entire Memphis metropolitan area. The vast majority of racial and ethnic demographic representation is non-white (96% within these six neighborhoods) with the majority black at 71%. Lack of health insurance in these neighborhoods is also nearly twice the rate of the entire metropolitan region at 27%, along with a majority of renters present at 70%, also twice the rate of the overall metropolitan region.

Total Population Breakdown by Vulnerability Dimension

Vulnerability Dimension	Population	% of Total Population
Socioeconomic Status		
Income Under Median (<$50k)	213,944	19.02%
Mortgage Holders	579,904	51.56%
Workers in Transportation and Warehousing	57,988	5.16%
Unemployed	56,022	11.81%
Housing Stock and Tenancy		
Living in Mobile Home	23,709	2.11%
Renters	395,865	35.20%
Age, Gender and Family		
Age Under 18	297,620	26.46%
Age Over 65	116,666	10.37%
Single Women Households with Children	54,297	11.44%[1] 20.28%[2]
Race and Ethnicity		
Non-White Population	668,324	59.42%
Health		
No Health Insurance (Under 65)	160,473	15.92%
Disability	105,168	9.35%
Language		
Limited or No English	7,144	0.64%
Mobility		
No Car	34,475*	7.27%*

[1] Based on total number of households
[2] Ratio to total number of households with children
Combination of 2016 American Community Survey Data and 2010 Census Data

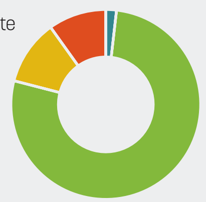


Selected Neighborhoods with High Social Vulnerability

1 Hickory Hill

Total Population: 16,784

- **1.81%** Non-Hispanic White
- **77.20%** Black
- **11.09%** Hispanic
- **9.89%** Asian, Native American and Other



Persons/mi²: 8,540 (2.6X Average)

Key Vulnerability Dimensions

39.24% of residents have a yearly income under the median ($50k), about 2.1 times the metropolitan rate.

11.22% of residents in the area work in transportation and warehousing sector, about 2.2 times the metropolitan rate.

81.23% of residents in the area are renters, about 2.3 times the metropolitan rate.

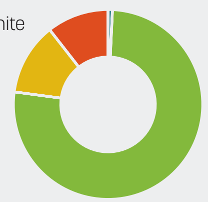
29.23% of residents under age 65 in the area do not have health insurance, about 1.8 times the metropolitan rate.

9.81% of households in the area do not have a car, about 1.4 times the metropolitan rate.

2 Parkway Village Area

Total Population: 13,380

- **0.75%** Non-Hispanic White
- **76.37%** Black
- **12.30%** Hispanic
- **10.58%** Asian, Native American and Other



Persons/mi²: 6,932 (2.1X Average)

Key Vulnerability Dimensions

7.47% of residents in the area work in transportation and warehousing sector, about 1.5 times the metropolitan rate.

60.85% of residents in the area are renters, about 1.7 times the metropolitan rate.

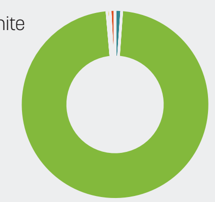
21.73% of households in the area are single-parent, about 1.9 times the metropolitan rate.

29.75% of residents under age 65 in the area do not have health insurance, about 1.8 times the metropolitan rate.

3 Whitehaven

Total Population: 6,437

- **1.13%** Non-Hispanic White
- **97.48%** Black
- **0.54%** Hispanic
- **0.84%** Asian, Native American and Other



Persons/mi²: 5,237 (1.6X Average)

Key Vulnerability Dimensions

30.88% of residents have a yearly income under the median ($50k), about 1.6 times the metropolitan rate.

74.27% of residents in the area are renters, about 2.1 times the metropolitan rate.

22.75% of households in the area do not have a car, about 3.1 times the metropolitan rate.

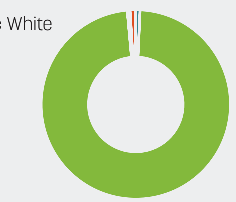
500-year Floodplain

See 579 for full breakdown of neighborhoods.

4 Orange Mound

Total Population: 7,779

- **0.72%** Non-Hispanic White
- **97.83%** Black
- **0.48%** Hispanic
- **0.98%** Asian, Native American and Other



Persons/mi²: 5,886 (1.8X Average)

Key Vulnerability Dimensions

32.11% of residents have a yearly income under the median ($50k), about 1.7 times the metropolitan rate.

53.28% of residents in the area are renters, about 1.5 times the metropolitan rate.

14.95% of residents in the area are over the age of 65, about 1.4 times the metropolitan rate.

16.17% of households in the area are single-women, about 1.4 times the metropolitan rate.

22.08% of residents under age 65 in the area do not have health insurance, about 1.4 times the metropolitan rate.

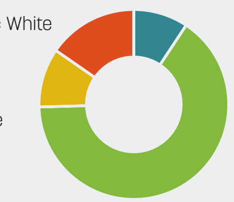
17.34% of residents have a disability, about 1.9 times the metropolitan rate.

19.59% of households in the area do not have a car, about 2.7 times the metropolitan rate.

5 Medical District and Victorian Village

Total Population: 4,333

- **9.30%** Non-Hispanic White
- **65.27%** Black
- **10.06%** Hispanic
- **15.37%** Asian, Native American and Other



Persons/mi²: 3,991 (1.2X Average)

Key Vulnerability Dimensions

56.75% of residents have a yearly income under the median ($50k), about 3.0 times the metropolitan rate.

92.29% of residents in the area are renters, about 2.6 times the metropolitan rate.

22.52% of residents under age 65 in the area do not have health insurance, about 1.4 times the metropolitan rate.

27.46% of residents have a disability, about 3.0 times the metropolitan rate.

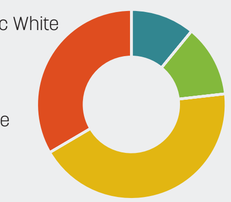
2.49% of residents are limited or cannot speak English, about 3.9 times the metropolitan rate.

43.60% of households in the area do not have a car, about 6.0 times the metropolitan rate.

6 Nutbush and Wells

Total Population: 8,467

- **10.96%** Non-Hispanic White
- **12.25%** Black
- **43.34%** Hispanic
- **33.45%** Asian, Native American and Other



Persons/mi²: 5,871 (1.8X Average)

Key Vulnerability Dimensions

26.51% of residents have a yearly income under the median ($50k), about 1.4 times the metropolitan rate.

55.45% of residents in the area are renters, about 1.6 times the metropolitan rate.

19.12% of households in the area are are single-woman, about 1.7 times the metropolitan rate.

64.30% of residents under age 65 in the area do not have health insurance, about 4.0 times the metropolitan rate.

6.90% of residents are limited or cannot speak English, about 10.7 times the metropolitan rate.

Implementation

1 Identify Vulnerable Communities

Identify traditionally disadvantaged populations and those likely to be disproportionately harmed by a disaster

Identification of potentially vulnerable communities should include thorough research into key dimensions of social vulnerability. Many of these have been outlined in this chapter and mapped to define a loose geography of vulnerability. These dimensions include:

- Housing Stock and Tenancy
- Age and Family Characteristics
- Wealth, Income and Employment
- Race and Ethnicity
- Health
- Language
- Mobility

An assessment of vulnerable communities to disaster should also include physiographic vulnerabilities such as:

- Location prone to specific disasters (such as flooding)
- Spatial indicators related to severe weather effects (impervious surfaces in relation to heat)

Tennessee has promoted the development of a Health Impact Assessment (HIA) at local levels to understand the distribution of negative health outcomes within a community. The Mid-South has completed a HIA[12] while Shelby County has undergone a similar assessment (Community Health Assessment).[13] Resilience planning will benefit from health-related data to develop a comprehensive understanding of social vulnerability. Using this information, a spatial distribution of vulnerability can then be produced. This may require additional data to determine where investments should be prioritized.

2 Reach Out and Connect

Involve vulnerable groups in planning initiatives while linking other relevant organizations and programs toward investment in vulnerable communities

A second step should include outreach to identified communities to assess, in greater detail, the challenges faced by the community as well as the latent potentials for improving resilience. In assessing the vulnerability of a community, input should be obtained directly from these communities through organized workshops and outreach to community leaders and organizations.

Jurisdictions in the Mid-South should work with organizations like the Red Cross, United Way, or faith-based organizations to identify other relevant organizations that may be of help in mobilizing and caring for vulnerable communities. Representatives could be chosen from among major advocacy organizations, such as the National Council on Disability and the AARP. These representatives can also be a liaison between relevant organizations involved in community safety and development.

Relevant programs in the area are also important sources of capital. Within the City of Memphis, the Division of Housing and Community Development currently supports a 2019 Strategic Community Investment Fund (SCIF) with specific programs such as the Emergency Solutions Grant Program, Community Housing Development Organization Program, Neighborhood Development Program, and the Tenant Based Rental Assistance program that can improve conditions of vulnerability.

See 7.2 Outreach for more information on outreach strategies. 7.2

3 Define Objectives and Implement Strategies

Identify and address the needs of vulnerable populations likely to arise from a disaster through a variety of approaches

There are three primary objectives with regard to investment in vulnerable communities:

- Improve Response to Disasters
- Enhance Coping and Adaptation Capacities
- Promote Methods of Recovery and Resilience

Each objective targets specific vulnerabilities based on conditions of time during and after a disaster. The threats and long-term consequences are different based on the dimension of time and may impact different populations based on a variety of factors. The strategies outlined below provide a short description of what the strategy is and how it may be achieved.

4 Monitor and Evaluate

Continue monitoring and evaluation of outcomes to ensure vulnerabilities are being addressed and underlying causes of vulnerability are improved

As strategies are implemented, monitoring of key indicators will help to evaluate the success of these measures. In preparing for a disaster, continued monitoring and evaluation will also promote readiness of related organizations and communities to respond. Each dimension of vulnerability may be monitored in relationship to strategies to assess necessary changes and additional strategies to prepare communities for a disaster and the potential of recovery when a disaster hits. This should also be done in coordination with federal, state and local governments and agencies tasked with environmental security and disaster response.

Earlier engagement processes and assessment information can also be valuable in future decision making for city investments. Proper resiliency planning should consider methods of integrating such engagement and assessment as part of a normal process of planning and evaluation.

Improve Response to Disasters

Improving response to disasters includes key strategies that target specific conditions of vulnerability during a disaster to mitigate the immediate impact a disaster may have on areas of highest risk.

A. Expansive and Accessible Notifications

Being able to effectively notify elderly users who may not frequently use mass media or those with language restrictions can be much more difficult when it comes to their exposure and ability to understand the message. To improve both reach and understanding for older populations and those that have limited or no English ability, the communication of the message must be clear. Physical dissemination methods, such as mailers, can include information such as proper steps to take in evacuation, bus pick-up spots and schedules, notices about cooling centers, emergency numbers, etc. This can be made available in large text and translated in multiple languages.

Utilizing as many media channels as possible to disseminate an emergency notification is the best method of increasing exposure, but this should also include clear, simultaneous translation into major languages, such as Spanish. Translations are key for non-English speakers, but there can also be icons and visual material for particular media types to help communicate the message for those that may speak uncommon languages. To effectively engage these communities, outreach is necessary to understand and address other culturally-appropriate methods of notification that traditional media may leave out.

While most disaster alert responsibilities fall onto local governments, many of these alerts are done in partnership with the private sector in some form or another. Most communications devices produced are also built to manage alert messages, requiring collaboration and protocols to be established for their effective delivery. However, many elderly may lack newer devices such as cell phones, or may not keep them visible for long periods throughout the day. Newer devices, such as those used in Personal Emergency Response Systems (PERS) may be useful in reaching the elderly where other forms of technology might not. A PERS is a system that allows individuals (older adults) to summon help during an emergency. While these systems are designed for use in the cases of personal emergencies, they hold promise for use as an extra layer of emergency notification through direct contact to targeted individuals. The use of these devices can also be coordinated with elderly care networks and local family and community caregivers, linking important medical and care information into a larger network that can work in post-disaster recovery situations.

B. Centralized Information for Social Organizations

One of the major issues in disaster planning is the coordination and compilation of data on households that are, or may be, affected by hazard conditions. Aid agencies are often hindered from providing coordinated assistance given the difference in standards for data collection and management which may limit the expediency with which an agency can give aid to those with the greatest need. Likewise, data often is not integrated into long-term development and planning.

Information should be shared between local government and community organizations as well as with state and federal aid agencies in order to effectively target those most in need and coordinate response during an emergency. Government agencies should work closely with local community organizations involved in social assistance. These can include community development organizations, social welfare and employment organizations, housing and development organizations, etc. Data on socioeconomic conditions and housing quality can help in assessing the need for aid, especially in the immediate post-disaster recovery period, but data coordination is needed in order to be able to share data properly between local organizations and government agencies. Particular reference to existing data management techniques within national and NGO aid organizations can help improve the translation and sharing of local data for the purposes of response and recovery.

See 7.1 Resilience Database for more information. 7.1

Existing Programs, Agencies, and Initiatives

- *LINC, Memphis Public Libraries and the United Way of the Mid-South*

C. Provide Transportation Options to Vulnerable Areas

The Shared-Use Mobility Center (SUMC) is working with the Memphis Area Transit Authority (MATA) to develop mobility-on-demand (MOD) projects. As the program researches communities in need of transit options, direction could be given to look into demand-response services for emergency preparedness for vulnerable communities – particularly those with little personal transportation options or communities that may have a population with difficulty evacuating.

Emergency planning should include mobilization of available resources including buses, vans, and other available vehicles to areas of most need based on factors such as geographic location and individual need and ability. Areas of highest risk should be prioritized. Establish a system (through the recommendation of B Centralized Information for Social Organizations) to identify and contact vulnerable residents, provide directions for their care and evacuation, and establish a chain of responsibility for their caregivers. Through notification mechanisms, deliver instructions on pick-up locations and what evacuees should bring.

Additionally, public-private partnerships have been pursued in the past with public-minded companies like Getaround.com, a car sharing platform. In times of emergency, cars already listed on the site could be made available by their owners free of charge. Those without transportation options, either due to lack of a personal vehicle, or at a loss, could find or use a vehicle as they need. Companies in an area could also register on the platform to make their trucks and other vehicles available for disaster response and recovery as well.

Existing Programs, Agencies, and Initiatives

- *Shared-Use Mobility Center (SUMC) Partnership with Memphis Area Transit Authority (MATA)*
  An ongoing project with training and consultation led by SUMC to build mobility-on-demand services through MATA.
- *Transportation Services such as Independent Transportation Network (ITN) Memphis, Delta Human Resources Agency (HRA), and Metropolitan Inter-Faith Association (MIFA)*
  These organizations provide assistance to the aged and disabled as well as a variety of other assistance programs.

D. Promote Healthcare Capacities to Manage Surges

Resilience planners can build upon existing networks and coalitions of medical services including the Shelby County Medical Reserve Corps to promote preparedness for communities in most need. Children are also some of the most vulnerable and in need of specialized care not obtainable at adult healthcare institutions. A 2012 code requires child care agencies to develop a multi-hazard plan, but larger coordination efforts are necessary.

The identification of pediatric physicians and resources able to deploy in an emergency surge should also be part of an overall coordinated plan within the health network. This may include the establishment of a resilient health information technology system that can better share medical information across hospital systems. This could be undertaken by health and medical system partners and state/local health departments such as those involved in the Mid-South Emergency Planning Coalition. Key partners could also include health insurance agencies as well as private-sector IT professionals and vendors.

Existing Programs, Agencies, and Initiatives

- *Child Care Agency Emergency Preparedness Plan (T.C.A. § 71-3-517)*
  According to this 2012 code, child care agencies are required to develop a multi-hazard plan to protect children in the event of emergencies.
- *Cities Readiness Initiative (CRI)*
  A federally funded program designed to enhance preparedness in many of the nation's largest cities including Memphis metropolitan area.
- *Mid-South Emergency Planning Coalition*
- *Shelby County Medical Reserve Corps (MRC)*

As the frequency and severity of potential hazards may increase with climate change, communities will have to adapt to these changing circumstances. It is important to improve physical and social infrastructures that can help vulnerable communities react to disasters and protect themselves during and after.

Dimensions of Vulnerability and Associated Strategies

Degree of Potential Impact of Strategy

○ Indirect Impact

● Direct Impact

Vulnerability Dimension

	Socioeconomic Status				Housing Stock and Tenancy		Age, Gender and Family			Race and Ethnicity	Health		Language	Mobility
	Income Under Median (<$50k)	Mortgage Holders	Workers in Transportation Services	Unemployed	Living in Mobile Homes	Renters	Age Under 18	Age Over 65	Single Women Households with Children	Non-white Population	No Health Insurance (Under 65)	Disability	Limited or No English	No Car
Improve Response to Disasters														
A Expansive and Accessible Notifications					○			●		○			●	
B Centralized Information for Social Organizations	○			○	○	○	○	○	●	●	●	●	●	●
C Provide Transportation Options to Vulnerable Areas					○			○				○		●
D Promote Healthcare Capacities to Manage Surges							●	●			●	●		
Enhance Coping and Adaptation Capacities														
E Prioritize Shelters and Community Centers					●	●	●	●	●	●			●	●
F Offer Grants to Community Facilities for Resilience Programs	●	●	●	●	●			●	●	○	○	○		
G Prioritize Stream Restoration and Flood Mitigation		○			○	○						○		
H Promote Green Infrastructure							●	●	●	○				
Promote Methods of Recovery and Resilience														
I Workforce and Social Welfare Programs	●	●	●	●		●	●	●	●	○				
J Improve Access to and Costs of Healthcare Services				○			○	○	○	○	●	●		
K Promote Housing Services and Affordability		●		●	●	●				○				
L Initiatives Supporting Working Parents	○						●		●	○				

Enhance Coping and Adaptation Capacities

E. Prioritize Shelters and Community Centers

Effective shelters must deal with a range of vulnerable populations including the homeless, vulnerable families, youth, and the elderly. Emergency shelters should support a flow of those vulnerable from a crisis situation to a situation of stability. Some may need immediate access to shelter, while other may need longer-term stays in emergency shelter. This may result in limited space to provide in situations of disaster.

To provide relief from existing shelters and the management of a wider range of vulnerable populations, other facilities can act as a shelter in times of disaster. Schools, libraries, faith-based buildings, and other public facilities may double as shelters during these times. It is important to stock these and other shelters with items that will help people to maintain independence such as hearing aid batteries, canes, and walkers in addition to accessible features, such as bathing, toileting, eating facilities, and bedding. The Shelby County Office of Preparedness also lists requirements and guidelines for the stocking and operation of shelters. (https://www.staysafeshelby.us/)

F. Offer Grants to Community Facilities for Resilience Programs

Engagement between local governments and their communities is key to developing a viable resiliency plan, but empowering local communities to improve their capacities to plan for themselves allows for more directed and effective response in the event of a disaster. Small grant funding could be made available for community centers and other community organizations in vulnerable neighborhoods to develop and implement resiliency programs.

In preparing to make funds available to empower these organizations, efforts to link this planning with other strategies (such as workforce development, housing and affordability strategies, improving access to healthcare, etc.) will be important in strengthening local capacity and adapting communities to become more resilient in the face of disaster.

Existing Programs, Agencies, and Initiatives

- *Memphis Division of Housing and Community Development Neighborhood Development Program*

G. Prioritize Stream Restoration and Flood Mitigation

One of the most effective ways of reducing flood damage in vulnerable communities is to assess areas where stream restoration and other forms of flood mitigation may be employed. Preventing damage through physical interventions may be the most effective means of building resilience in a community by mitigating longer-term damage that comes through immediate shocks. These can be prioritized in areas of higher social vulnerability as indicated on the chapter map. See Chapter 1 for more information on techniques and best practices for stream restoration and flood mitigation. 1

H. Promote Green Infrastructure

To adapt to persistent exposure to hazards or potential disasters, there are physical measures that can be taken that can also help communities adapt to the changing climate and higher exposure to some types of hazards. See 2.4 Open Space Strategies for more information. 2.4

Once a disaster is over, there is still much work to do ensuring that people may be able to move back into their homes, or to assist those that have been affected. Vulnerable populations in particular will likely need continued assistance. Although there is much work required after a disaster or hazard event, there are measures that can be taken to improve resilience by mitigating systemic aspects of social vulnerability.

Promote Methods of Recovery and Resilience

I. Workforce and Social Welfare Programs

The development of a resilient workforce is key to disaster recovery, particularly in healthcare, infrastructure, and education sectors. In terms of success of recovery efforts, a well-integrated and collaborative workforce is best suited to managing post-disaster recovery efforts. Interprofessional Education (IPE) programs are key to building resilient-minded professionals. IPEs develop transdisciplinary collaboration and capacity that helps coordination between important sectors involved in recovery efforts. Training and competency-based professional programs can be promoted at local community colleges and trade schools as well as through building partnerships with industry leaders in the region.

Existing social welfare programs at the community level can be integrated with workforce development. Opportunities for community infrastructure improvements and development projects can be combined with workforce training programs for those in the community. Local residents themselves can build skills while leveraging their local network to build capacity across neighborhoods and professions. Additionally, the promotion of incentives for companies to hire local, such as job credit programs, can be useful in building local skills. Rebates on permits and other city fees could be made based on jobs offered to local residents within vulnerable communities.

Overall, the strengthening of workforce agencies and establishing links between educational institutions, state funding, and federal social assistance in the development of skills is a viable method to focus a variety of resources on the most vulnerable communities. It may go a long way on moving the under- and unemployed into more sustainable jobs and build resilience in vulnerable 7.4 communities where the right competencies are generated. See 7.4 Economic Development for more information.

Existing Programs, Agencies, and Initiatives

- *Workforce Investment Network*
  Offers a variety of assistance and training programs for small businesses and job seekers.
- *JobLINC*
  Helps job seekers find local job opportunities, aid, and training. It can be accessed along with a variety of community services.

J. Improve Access to and Costs of Healthcare Services

Resilience planners should work with administrations within the region to promote strategies for employers in providing accessible and affordable healthcare. This may be done through the promotion of on-site clinics and visitations by providers where employees can access check-ins with convenience. Doing this may also reduce healthcare costs for both employer and employee through combining certain aspects of preventative care and evaluations into clusters of visitations. To accomplish this, it may be necessary to partner with local health providers or private-sector health providers that specialize in on-site clinics. The key factors of success lie in lower costs for early evaluative and preventative care for patients and the promotion of continued check-ins.

Many hazards can exacerbate the effects of chronic diseases. Another method that can make a difference at the metropolitan level is the promotion of wellness clinics for chronic diseases. Many chronic diseases can be prevented and some effects mitigated through building wellness capacities in vulnerable communities through classes, evaluations, and educational material.

Wellness clinics may also combine functions of shelters (or other general public-use functions) and can be implemented as 'pop-up' clinics in public-use facilities such as schools in after-hours, or parks and recreation facilities.

Existing Programs, Agencies, and Initiatives

- *Shelby County Health Department Chronic Disease Management Program*
- *Shelby County Health Department Community Health Assessment*
  The community health assessment is driven by a process called Mobilizing for Action through Planning & Partnerships (MAPP). This tool helps communities improve health and wellbeing through community-driven planning processes.
- *Healthy Parks Healthy Person (HPHP)*
- *DeSoto County Community Health Council*
- *Mid-South Food Bank*

K. Promote Housing Services and Affordability

Resilience planners should work with jurisdictions in the Mid-South to promote housing services and affordable methods of shelter during and after a disaster. For instance, coordination with resilience planning efforts in the Mid-South should be integrated into the operations of the Memphis Division of Housing and Community Development which already sees significant work related to disaster recovery and planning.

Coordinated resilience planning may also help identify opportunities for public-private partnerships that may help communities respond to disaster events through coordinated housing repair services and other forms of assistance. An example of such a partnership has occurred during a disaster response involving AirBnB. A few cities in the US have worked with AirBnB to connect those with housing needs to hosts in areas outside a hazard or disaster zone, offering their places for free. FEMA has shared its hazard layers with the company in the hopes that they may become a responsive partner in the event of a disaster in cities where they operate. The company has already established memorandums of understanding with Portland and San Francisco to coordinate disaster response. The resilience and recovery staff in San Francisco have also begun to coordinate with AirBnB to notify hosts about ways to retrofit their homes so that they are more resilient.

Existing Programs, Agencies, and Initiatives

- *Community Service Agency (CSA)*
  Emergency financial assistance.
- *Memphis/Shelby County Emergency Housing Partnership*
  Short-term rental assistance and information on supportive services.
- *Memphis Division of Housing and Community Development Down Payment Assistance Program*
  Provides services and assistance for prospective home buyers in the City of Memphis.

L. Initiatives Supporting Working Parents

Many of the potential vulnerabilities for single parents stem from the lack of time and amount of responsibility they have for their children. Working full-time and caring for a child alone can place strain on both the parent and child. Paying for childcare can heighten other vulnerability factors such as low-income status. For many low-income, working families with children, job-loss or even a short delay in receiving a paycheck can be devastating—a situation that may be more likely to happen or exacerbated by natural hazard. Under these circumstances it can also be difficult for children to learn and keep up with their peers, making it difficult to climb the socioeconomic ladder later on, adding to the vulnerable population. Supporting initiatives for working parents can reduce the strain of childcare and low-income status may allow for more free time and money to make a household more resilient in the face of losing property or other effects such as job-loss or payment delays.

One potential strategy to help mitigate some of the stress single parents undergo is to provide subsidies for childcare where single parents are managing full-time jobs. These subsidies can be supplied through partnership directly with childcare agencies and locations.

Job credits, similar to the proposed strategy Workforce and Social Welfare Programs, is also another method to promote employment for single-parents. Cities and counties could offer rebates for hiring single-parents. This may be even more beneficial where companies offer childcare services on-site.

To promote long-term resilience and development, children deserve attention as well. Increasing the exposure of children to books has a measurable effect on their learning. Work with libraries to promote free donations and exchanges for books in the homes for children in vulnerable communities. This sort of program could be managed by libraries themselves through mail-in services.

Existing Programs, Agencies, and Initiatives

- *Tennessee's Families First Program*
  Provides cash assistance to qualifying families.
- *Shelby County Community Services Agency*
  Provides food assistance to needy families in addition to the Supplemental Nutrition Assistance Program (SNAP).
- *LINC, Memphis Public Libraries and the United Way of the Mid-South*
  LINC maintains a large, comprehensive database of human services organizations, government agencies and volunteer groups. Services include Childcare, housing, mental health services, English language learning, etc.
- *BooksfromBirth.org*
  Offers low to no-cost service for book exchanges from local libraries for children.

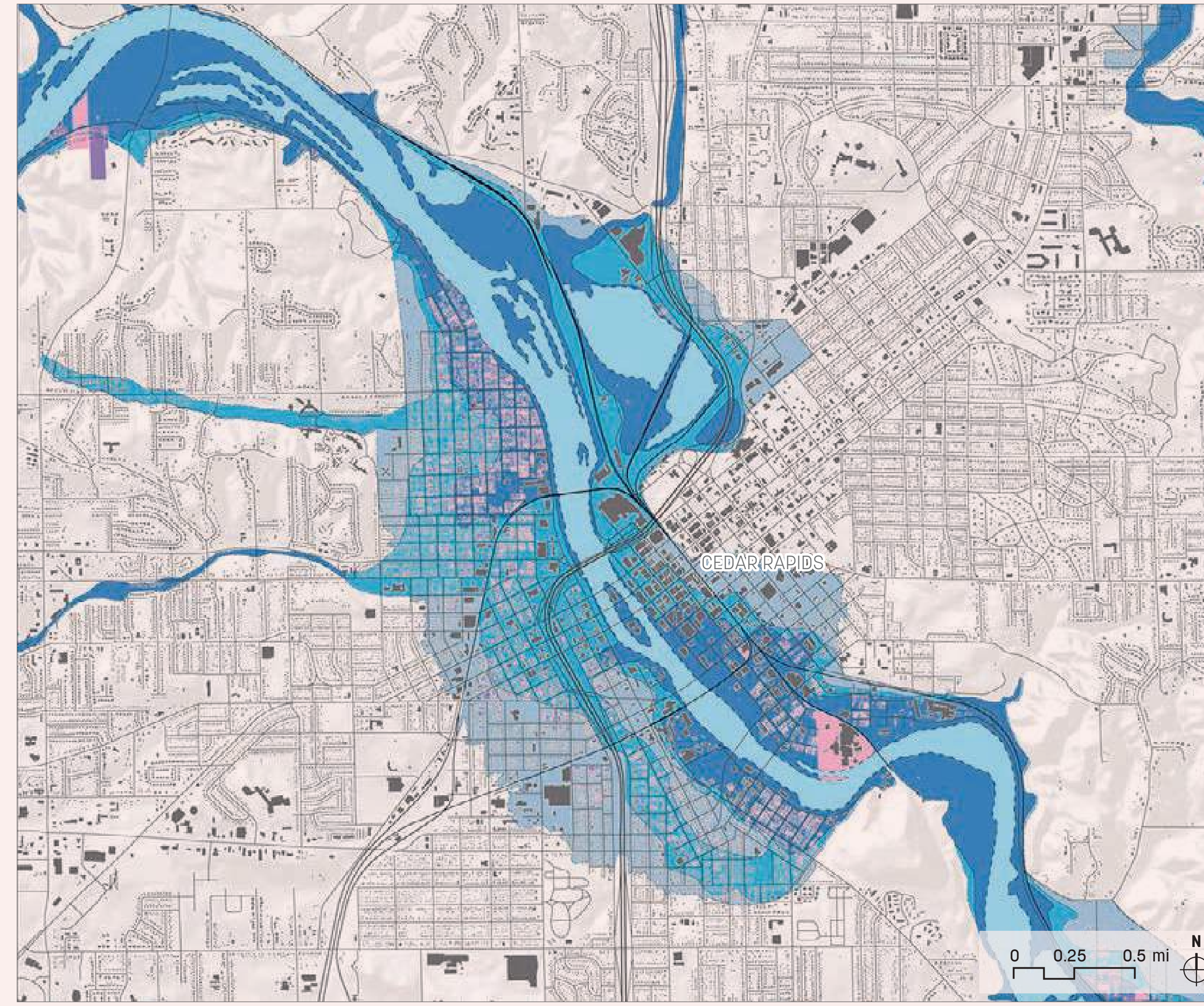
Case Study

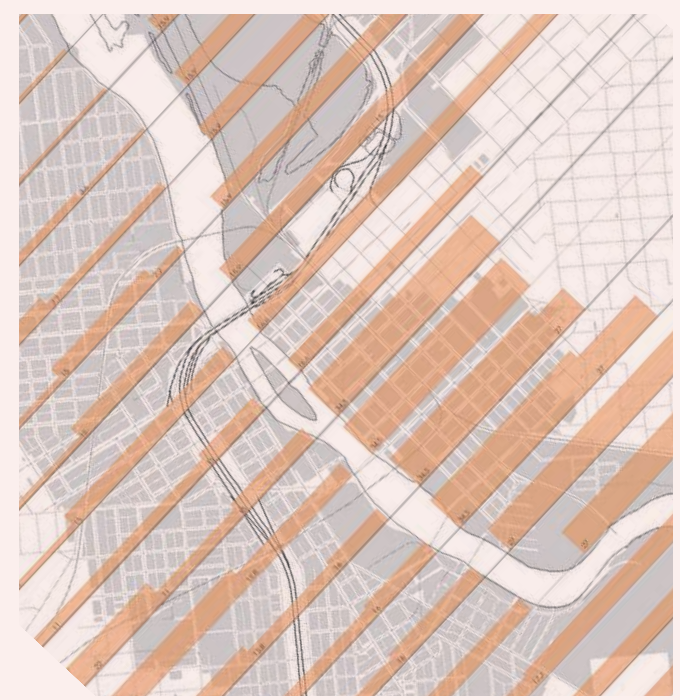
Resiliency Planning, Cedar Rapids, IA

In June 2008, Cedar Rapids, Iowa was hit by massive flooding of the De Moines River. 14% of the city was impacted with over 10,000 residents displaced and just under 6,000 properties affected. This cost around $376 million in damage to homes and a total of $1.3 billion total in recovery costs. The greatest impacts were felt in areas with high social vulnerability including minorities, the elderly, the disabled, female-headed households, and those in poverty. However, the city had acted in advance to engage local communities to develop a shared vision for the community's future.[14]

Using the existing engagement process, the community was able to come quickly together after the flood to plan for recovery. The plan was drawn from input from thousands of residents and included strategies to promote active lifestyles, ensure equitable development, build resilient and efficient buildings, and protect the city against future flooding by focusing rebuilding outside the floodplain.[15] Cedar Rapids was recognized for its planning efforts by the US Army Corps of Engineers, the American Planning Association, and the International Downtown Association. It's success has been measured by its proactive and sustained engagement with local neighborhoods to create consensus around a recovery plan that will build a safer environment for its citizens.[16]

(Above) Image of 2008 flooding event in Cedar Rapids





(Top) Floodplain map of Cedar Rapids, Iowa

(Left) Clip of social mapping in the floodplain by Iowa State University research team

(Above Right) Proposed flood mitigation measures along riverbank

Case Study

HIAs and Resiliency Planning, NJ

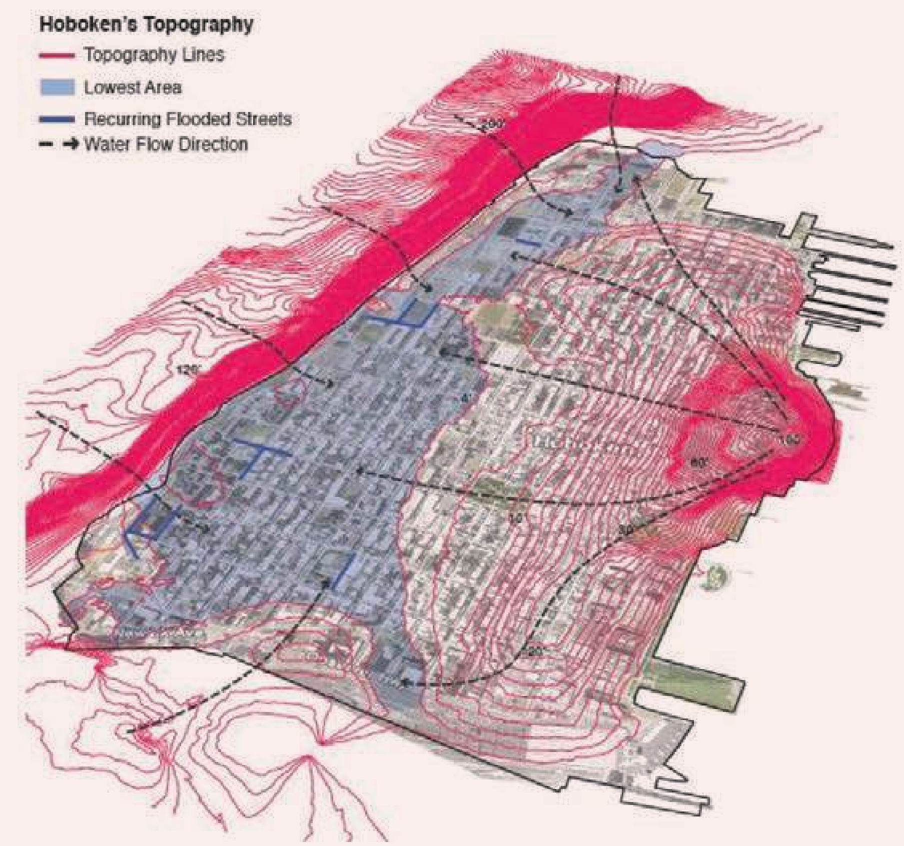
Rutgers University has led a project that looks to integrate the practice of preparing Health Impact Assessments (HIA)[17] with post-disaster decision-making. It will provide public sector decision makers in New Jersey with a tool to consider the positive and negative health impacts for major decisions.

Rutgers focused on two communities for the project: Mystic Island in Ocean County and Hoboken in Hudson County. The project will also create a toolkit for use by other municipalities in New Jersey in integrating HIA into their decision making processes and look to broadening the scope of this process to the US more generally.

The project in Mystic Island[18] is developed as an HIA that will inform officials on the potential health impacts of a decision whether to support a voluntary buyout program for residents in a flood-prone neighborhood. While some officials approve of a buyout, others worry about the impact on tax-revenue and economic impact of such a program. The HIA will help to determine physical and mental health impacts based on a range of scenarios from no buyout to full buyout while addressing the overall impacts to vulnerable populations, municipal finances, and the impact of future risks of flooding.

The project in Hoboken[19] focuses on an ongoing preparation of the stormwater management plan by utilizing a HIA to provide information on the health impact considerations of the ordinance and new infrastructure investments. It will address the persistent health risks of flooding and sewage overflow events while looking at the potential benefits and risks of green infrastructure strategies to be integrated into the stormwater management plan.

(Above) Image of Mystic Island community in Ocean County, NJ



(Left) The analysis done by Rutgers included physical characteristics overlaid with social vulnerabilities

(Right) Demographic analysis along multiple dimensions of vulnerability allowed for effective decision-making of where to prioritize investment in green infrastructure within the stormwater management plan.

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Appendix: Neighborhood Demographic and Social Vulnerability Dimension Breakdown

	Hickory Hil			Parkway Village Area			Whitehaven		
Vulnerability Dimension	**Area Total Pop.**	**% of Area**	**Factor of Total %**	**Area Total Pop.**	**% of Area**	**Factor of Total %**	**Area Total Pop.**	**% of Area**	**Factor of Total %**
Breakdown By Race									
Non-Hispanic White	304	1.81%	0.0	100	0.75%	0.02	73	1.13%	0.03
Black	12,958	**77.20%**	1.6	10,218	**76.37%**	1.63	6,275	**97.48%**	2.08
Hispanic	1,862	**11.09%**	2.0	1,646	**12.30%**	2.26	35	0.54%	0.10
Asian, Native American and Other	1,660	**9.89%**	1.4	1,416	**10.58%**	1.51	54	0.84%	0.12
Total Population	16,784	100.00%	1.0	13,380	100.00%	1.00	6,437	100.00%	1.00
Socioeconomic Status									
Total Under 50k	6,586	**39.24%**	2.1	3,160	23.62%	1.24	1,988	**30.88%**	1.62
Mortgage Holders	2,703	16.10%	0.3	4,161	**31.10%**	0.60	1,238	19.23%	0.37
Workers in Transp. and Warehousing	1,883	**11.22%**	2.2	999	7.47%	1.45	314	4.88%	0.95
Unemployed	1,324	7.89%	0.7	1,040	7.77%	0.66	356	5.53%	0.47
Housing Stock and Tenancy									
Living in Mobile Home	0	0.00%	0.0	0	0.00%	0.00	0	0.00%	0.00
Renters	13,634	**81.23%**	2.3	8,142	**60.85%**	1.73	4,781	**74.27%**	2.11
Age, Gender and Family									
Age Under 18	4,795	28.57%	1.1	4,322	**32.30%**	1.22	2,045	31.77%	1.20
Age Over 65	1,365	8.13%	0.8	476	3.56%	0.34	633	9.83%	0.95
Single Women Hh. with Children	1,717	**17.83%**	1.6	1,055	**21.73%**	1.90	581	9.03%	0.79
Race and Ethnicity									
Non-White Population	16,480	**98.19%**	1.7	13,280	**99.25%**	1.67	6,364	98.87%	1.66
Health									
No Health Insurace	4,507	**26.85%**	1.9	3,839	**28.69%**	2.01	766	11.90%	0.83
Disability	1,434	8.54%	0.9	886	6.62%	0.71	652	10.13%	1.08
Language									
Limited or No English	192	**1.14%**	1.8	246	**1.84%**	2.89	65	1.01%	1.59
Mobility									
No Car	945	**5.63%**	1.8	421	3.15%	1.03	618	**9.60%**	3.13

	Orange Mound			Medical District and Victorian Village			Nutbush and Wells			*Avg.*	Metro Area
Vulnerability Dimension	**Area Total Pop.**	**% of Area**	**Factor of Total %**	**Area Total Pop.**	**% of Area**	**Factor of Total %**	**Area Total Pop.**	**% of Area**	**Factor of Total %**	**Average %**	**Total % of All**
Breakdown By Race											
Non-Hispanic White	56	0.72%	0.02	403	9.30%	0.23	928	10.96%	0.27	4.11%	40.58%
Black	7,610	**97.83%**	2.08	2,828	**65.27%**	1.39	1,037	12.25%	0.26	71.07%	46.97%
Hispanic	37	0.48%	0.09	436	**10.06%**	1.84	3,670	**43.34%**	7.95	12.97%	5.45%
Asian, Native American and Other	76	0.98%	0.14	666	**15.37%**	2.19	2,832	**33.45%**	4.78	11.85%	7.00%
Total Population	7,779	100.00%	1.00	4,333	100.00%	1.00	8,467	100.00%	1.00		
Socioeconomic Status											
Total Under 50k	2,498	**32.11%**	1.69	2,459	**56.75%**	2.98	2,245	**26.51%**	1.39	**34.85%**	19.02%
Mortgage Holders	2,285	29.37%	0.57	60	1.38%	0.03	2,740	32.36%	0.63	21.59%	51.56%
Workers in Transp. and Warehousing	228	2.93%	0.57	145	3.35%	0.65	201	2.37%	0.46	5.37%	5.16%
Unemployed	739	9.50%	0.80	254	5.86%	0.50	733	8.66%	0.73	7.54%	11.81%
Housing Stock and Tenancy											
Living in Mobile Home	0	0.00%	0.00	0	0.00%	0.00	0	0.00%	0.00	0.00%	2.11%
Renters	4,145	**53.28%**	1.51	3,999	**92.29%**	2.62	4,695	**55.45%**	1.58	**69.56%**	35.20%
Age, Gender and Family											
Age Under 18	2,038	26.20%	0.99	497	11.47%	0.43	2,598	30.68%	1.16	26.83%	26.46%
Age Over 65	1,163	**14.95%**	1.44	527	12.16%	1.17	755	8.92%	0.86	9.59%	10.37%
Single Women Hh. with Children	613	**16.17%**	1.41	233	7.31%	0.64	589	**19.12%**	1.67	**15.20%**	11.44%[1] 20.28%[2]
Race and Ethnicity											
Non-White Population	7,723	**99.28%**	1.67	3,930	**90.70%**	1.53	7,539	**89.04%**	1.50	**95.89%**	59.42%
Health											
No Health Insurace	1,461	**18.78%**	1.32	857	**19.78%**	1.39	4,959	**58.57%**	4.10	**27.43%**	14.27%
Disability	1,349	**17.34%**	1.85	1,190	**27.46%**	2.94	735	8.68%	0.93	13.13%	9.35%
Language											
Limited or No English	0	0.00%	0.00	108	**2.49%**	3.92	584	**6.90%**	10.86	**2.23%**	0.64%
Mobility											
No Car	743	**9.55%**	3.12	1,390	**32.08%**	10.47	155	1.83%	0.60	**10.31%**	3.07%

[1] Based on total number of households
[2] Ratio to total number of households with children
Combination of 2016 American Community Survey Data and 2010 Census Data

7.4 Economic Development

Align Job-Training Programs with Resilience-related Workforce Needs

Overview

The implementation of key aspects within resilience planning will require specialized skill sets. The availability and development of the local workforce is an important part of providing new opportunities within a changing regional economy while building local capacities for resilience-related work. Within a changing economy, it is important to be responsive to both new market demands as well as regional planning measures related to resilience with the promotion of key sectors of the workforce through education and training.

Job-training and other educational components should build on key industries and target the development of potential gaps in basic services for both pre- and post-disaster resilience-related work. While it is difficult for local jurisdictions to shape economic factors, basic services such as education and job-training are a major area of investment local governments are capable of promoting. This section provides an outline for communities to assess existing workforce training needs and provides resources related to key sectors of growth within the development of resilient systems.

Promoting job training programs that address resilience-related workforce needs should include targeting regional demographic vulnerabilities
7.3 related to employment and skills-related development (see 7.3 Vulnerable Communities). Job-training programs can also be a valuable addition to other resilience planning efforts such as the implementation and maintenance of important infrastructure, both pre- and post-disaster (Chapters 5 and 6), or in the implementation of a variety of measures mentioned throughout this report ranging from building-scale systems engineering (Chapter 3) to watershed management strategies (Chapters 1 and 2).

Integrating job-training programs with resilience planning can align demands related to new investments made in the implementation of resilience planning with a skilled workforce.

(Right) Rescue workers in New Bern, NC in the aftermath of Hurricane Florence

Implementation

1 Assess Workforce Training Needs

Build an inventory of key industries and specific businesses that may be affected by various environmental hazards

Jurisdictions in the Mid-South should utilize resilience planning efforts related to the identification of critical community assets. Jurisdictions should identify important and potentially affected industries to assess the economic impact of environmental hazards. A general economic profile of each community should be built to inform a broad strategy where major economic sectors and economic priorities should also be identified. These may encompass a wide range of industries:

- Agriculture and landscaping
- Defense industries and military installations
- Energy and utilities
- Engineering, planning, and design
- Retail, restaurants, and consumer services
- Innovation industries such as biosciences and information technology
- Insurance and real estate
- Manufacturing
- Logistics and transportation
- Tourism

Businesses should also be classified based on the relative risk or opportunities each is exposed to based on the type of economic activity. This assessment will serve as the foundation for resilience-related workforce planning. Environmental hazards and other harmful shocks or stresses to the local economy are important to consider as the promotion of job-training programs can target industries that can mitigate potential stresses to the economy and address shortfalls in both emergency response as well as other resilience-related workforce needs, such as those directly involved in emergency response.

Relevant information on businesses may be obtained through working with the local chambers of commerce, business associations, districts, or other economic development organizations. The next section also outlines a list of existing, potential organizations and initiatives to look to for information. This information may include:

- Industry type and reliance on other sectors
- Products or services offered
- Size of buildings/establishment
- Number of employees
- Potential risks posed by hazards

It is also important to identify both positive and negative impacts to the local economy from exposure to environmental hazards. This can be complimented by brainstorming ways in which these impacts can be managed to support new workforce needs or where external investment is needed. Having a baseline assessment will help to develop a plan to direct both existing and future investments and initiatives in the development of workforce resources.

2 Strengthen Existing Job-training Programs

Work with local, state, and federal organizations and build on existing initiatives

Jurisdictions in the Mid-South should identify current educational programming from vocational to university-related curricula in the region. Look for ways to strengthen and link education and training to workforce development goals. This should include the identification of gaps in educational opportunities. Working with the local educational community can help to address these gaps.

Promote new pathways in job-training by linking education and training to new investments and the implementation of resilience planning needs. Resilience-related jobs cut across a full spectrum of skill levels. In addition to engineers, planners, designers, ecologists, economists, etc., resilience in the economy will require people to dig and plant newly restored stream corridors, construct and assemble the gray infrastructure to mitigate flooding, bury power lines, collect debris after a storm, and a variety of other tasks (See a breakdown of the Workforce Development Potential on page 589).

(Left) Workers are employed to gather debris from a recent storm.

Existing Initiatives

Workforce Innovation and Opportunity Act (WIOA)

The Workforce Innovation and Opportunity Act (WIOA) of 2014 brought about workforce development programs across the US. National and Local Workforce Development Boards (WDBs) were established as part of the Workforce Investment Act of 1994. These organizations are made up of local business leaders and plan to identify and support in-demand industry sectors and occupations.

Workforce Investment Network

The Workforce Investment Network (WIN) is a local WDB encompassing the Mid-South. It supports local economic development through educational and job-training resources such as through the Workforce Innovation and Opportunity Act (WIOA) Youth Program and the Work Opportunity Tax Credit (WOTC) Program which help to support both students and small businesses grow.

http://www.workforceinvestmentnetwork.com/

Three Rivers Planning and Development District

The Three Rivers Planning and Development District is a local WDB within the Mississippi Partnership for DeSoto County. It promotes community planning as well as civic, social, and economic development.

http://www.trpdd.com/

ACT's Work Ready Communities and ACT WorkKeys National Career Readiness Certificate

ACT's Work Ready Communities looks to connect local skills learning with employers throughout each state. The National Career Readiness Certificate provides applicants with a certification of skill proficiency.

https://www.workreadycommunities.org/index/about

State of Tennessee's Work Based Learning Grant

Grants are awarded to projects that help to promote community-led work-based learning opportunities for students to develop career experience within the region.

https://www.tn.gov/ecd/rural-development/work-based-learning-grant.html

Tennessee Pathways

Provides coordination between K-12 education, college, and career opportunities.

https://www.tn.gov/education/pathwaystn.html

HUD Section 3 Employment Program

This provision of the HUD Act of 1968 requires recipients of HUD financial assistance provide, to the extent possible, assistance to low-income persons in the form of job training and employment.

https://www.hud.gov/program_offices/fair_housing_equal_opp/section3/

(Left) Construction of a grassed filter strip on Watsonville Slough Farm to treat tailwater run-off and reduce erosion into adjacent Hanson Slough. The area includes 500 acres of restored wetland habitat.

Other Relevant Organizations

Tennessee Departments of Economic and Community Development, Education, Labor

Tennessee Board of Regents, Labor and Workforce Development

County Chambers of Commerce

Existing Resilience-related Job-training (WIOA Eligible Training Providers)

Health Tech Institute of Memphis

571 Vance Avenue Memphis, TN 38126
http://www.htim.edu/

Lab Four Professional Development Center

1255 Lynnfield Road Suite 160 Memphis, TN 38119
http://www.labfour.com/

Memphis Electrical Joint Apprenticeship and Training Committee

6211 Shelby Oaks Drive Memphis, TN 38134

University of Tennessee at Martin (Satellite)

13085 North Main Street Somerville, TN 38068
http://utm.edu/

3 Promote New Pathways

Small Business Incubators

Utilize existing programs to fund incubators and other economic development programs. City-owned assets can be utilized for these purposes. Hosting and supporting local small businesses may be beneficial to the region's larger industries but can be focused on promoting resilience-related trajectories including research, planning, technology, manufacturing, etc. Funding is available from both state and federal workforce development and educational grant programs, and additional support may be had by local companies through job-training and community investment (see Newport Case Study on page 586).

Leverage Future Investment Opportunities

Within the scope of resilience planning, shelters, community centers, libraries, and other important community buildings could be utilized as important resource centers for learning and job-training for resilience-related workforce needs. Many of these places serve the community in a variety of ways that build resilience. Linking these as part of a larger institutional network links local communities with the regional economy.

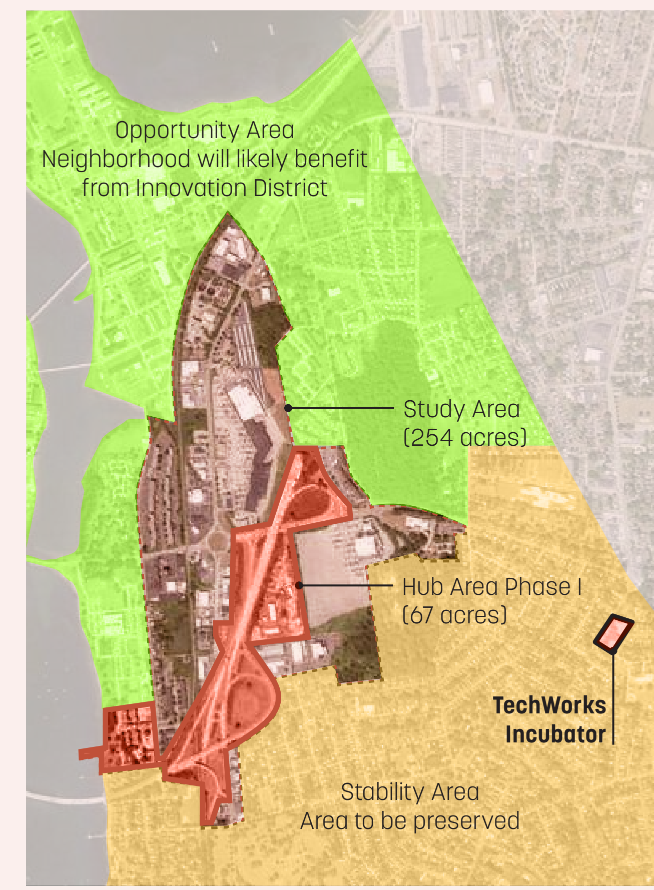
Case Study

Newport Innovation Hub, RI

In 2014, the City of Newport, RI worked with the Newport County Chamber of Commerce and the Economic Development Foundation of Rhode Island to develop urban investment strategy related to its resilience planning initiatives.[1]

The City received a grant of $1.6 million from the US Department of Commerce Economic Development Administration to convert a city-owned, vacant school into a technology business incubator called the Newport TechWorks.[2] Additionally, federal funds were used to reach LEED certification.

The incubator is designed to host entrepreneurs, small businesses, and researchers that can build on the region's technology and resilience industries. Through the sharing of resources, the hope is that the project will catalyze high-skill job creation.



(Top Right) A rendering of the Newport TechWorks Innovation Center which converted a vacant school into a technology business incubator.

(Bottom Right) A map illustrating the Innovation Hub Area and planned investment areas.

Endnotes

1 *Planning for a Climate-resilient Economy*, US Environmental Protection Agency, May 2016, https://www.epa.gov/sites/production/files/2016-05/documents/planning-framework-climate-resilient-economy-508.pdf.

2 For more information on this project, see: "Innovation Hub," *Engage Newport* online, https://engagenewport.com/projects/newport-innovation-hub; Flynn, Sean. "$1.7M Grant Will Allow City to Move Ahead With Business Incubator Project," *Newport Daily News*, September 22, 2014. "Technology Business Incubator and Accelerator," *Engage Newport* online, https://engagenewport.com/projects/newport-techworks.

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General Workforce Development

US Environmental Protection Agency. *Planning for a Climate-resilient Economy.* U May 2016. https://www.epa.gov/sites/production/files/2016-05/documents/planning-framework-climate-resilient-economy-508.pdf.

Job Training Resources

"Education and Job Resources." My Energy Gateway. Website. http://www.myenergygateway.org/.

"Professional Training." Solar Energy International. Website. https://www.solarenergy.org/.

Residential Energy Services Network. Website. http://www.resnet.us/professional/programs/training.

"Clean Cities Coalition Network." *US Department of Energy*. Website. https://cleancities.energy.gov/.

Energy & Environmental Building Alliance: Website. https://www.eeba.org/.

Find Courses, Energy. Website. https://www.findcourses.com/search/energy-training.

"Green Industry Education." *Heatspring.* Website. https://www.heatspring.com/.

"Training Resources," *Performance Systems Development*. Website. http://psdconsulting.com/training/.

Ulster BOCES Educational Resources. Website. https://www.ulsterboces.org/.

National Association of Workforce Boards. Website. https://www.nawb.org/solar_training_initiative.asp.

TN Department of Labor and Workforce Development. Website. https://www.jobs4tn.gov/.

Appendix: Workforce Development Potential

Related Recommendation		Workforce Development Potential	Skill Training Requirements	Impact	Viability
1 Waterways					
1.1	Mitigate flooding and improve stream health through bank stabilization, ecological restoration, and selective de-channelization	$$	Construction, Ecology, Education, Engineering	Direct	Long-term
1.2	Selectively construct hard infrastructure to protect vulnerable communities from river flooding	$$	Construction, Ecology, Education, Engineering, Manufacturing, Technology	Direct	Long-term
2 Watersheds					
2.1	Create large-scale water retention areas to mitigate downstream flooding	$$	Agriculture, Ecology, Engineering	Direct	Long-term
2.2	Protect critical watershed assets including aquifer recharge areas and wetlands	$	Ecology, Engineering, Information	Direct, Indirect	Long-term
2.3	Encourage Low Impact Development (LID) techniques to improve on-site stormwater management and protect sensitive drainage basins	$$	Construction, Ecology, Engineering, Energy, Information, Technology	Direct, Indirect	Long-term
2.4	Identify existing and planned parks, trails, and other open space that could be modified to provide additional flood mitigation value	$$$	Construction, Ecology, Education, Engineering, Health Care, Media	Direct, Indirect	Long-term
3 Buildings					
3.1	Implement building-scale flood mitigation techniques, including elevating key systems, acquiring temporary flood barriers, and installing non-return plumbing valves	$$	Construction, Education, Engineering, Technology	Direct	Long-term
3.2	Retrofit critical civic buildings to be earthquake resilient and provide seismic resilient design guidelines for new development	$$$	Construction, Education, Engineering, Technology	Direct, Indirect	Medium-term
3.3	Ensure that communities are adequately served with emergency shelter facilities that have backup power, waste, and water systems, emergency shelter space, heating and cooling, and are accessible by designated emergency access routes	$$$	Construction, Education, Engineering, Energy, Health Care, Information, Media, Technology, Transportation	Direct, Indirect	Medium-term
3.4	Encourage green roofs as a way to retain water, reduce energy use, and mitigate urban heat island effect	$$	Construction, Ecology, Engineering, Energy, Technology	Direct	Long-term
3.5	Subsidize green building retrofits for businesses and homeowners	$$	Construction, Education, Engineering, Energy, Technology	Direct	Long-term

Related Recommendation		Workforce Development Potential	Skill Training Requirements	Impact	Viability
4 Land Planning					
4.1	Incorporate site resilience factors into zoning and development approvals	$$	Construction, Ecology, Education, Engineering, Energy, Information, Technology	Indirect	Long-term
4.2	Encourage compact and infill development to reduce sprawl and limit the expansion of impervious cover	$	Construction, Ecology, Energy, Information, Transportation	Indirect	Long-term
4.3	Adopt floodplain development regulations that exceed the minimum requirements of the National Flood Insurance Program (NFIP)	$$	Ecology, Education, Information	Indirect	Long-term
5 Infrastructure					
5.1	Enhance and maintain the regional network of drainage conveyance infrastructure to meet current and future stormwater needs	$$	Construction, Ecology, Engineering, Information	Direct	Long-term
5.2	Selectively bury overhead electrical wires and require in-ground utilities in new subdivisions to reduce power disruptions due to wind and winter weather	$$	Construction, Engineering, Energy	Direct	Medium-term
5.3	Implement a smart grid with distributed automation switches to mitigate and contain future power outages	$$$	Engineering, Energy, Information, Technology	Direct	Long-term
5.4	Test pilot projects for community-based ownership models of energy and water systems	$$$	Engineering, Energy, Information, Technology	Direct	Long-term
5.5	Fund additional resources for post-storm snow and ice removal	$	Information, Transportation	Direct	Post-disaster
5.6	Modify street tree planting and maintenance programs to offset the urban heat island effect, increase biodiversity, and minimize falling branches that cause power outages	$	Ecology, Information	Direct	Long-term
6 Post-Disaster					
6.1	Implement a voluntary buyout program for damaged properties that have suffered from repetitive loss and/or are located on sites with high flood mitigation potential	$$$	Construction, Ecology, Engineering, Information	Indirect	Long-term
6.2	Recycle fallen trees, branches, and material from damaged or collapsed structures whenever feasible	$$	Construction, Ecology, Education, Engineering	Direct	Post-disaster
6.3	Prototype rapid, temporary post-disaster housing solutions	$$	Construction, Ecology, Education, Engineering, Manufacturing, Technology	Direct	Post-disaster

7.5 Capital Market Funding

Fund Disaster Mitigation and Recovery Through Private Capital Markets

Key Benefits

1. **Limits financial losses from natural disasters**
2. **Can help limit physical loss and damage**
3. **Reduces reliance on state and federal disaster recovery funding**
4. **Market caps are large enough to fully cover assets at risk**
5. **Funding can be released to municipalities faster than conventional disaster relief funds**

Limitations

1. **Demand for resilience financing exceeds supply**
2. **Resilience bonds are still under development**

Overview

Municipalities and individuals often carry insurance against natural disasters such as floods and earthquakes. However, not all assets affected in the event of a natural disaster are covered by these policies, and often the value of covered assets exceeds the insurance industry's ability to pay in the event of a major disaster. One reason for this is that big catastrophic risks of one type (flood, earthquake, fire, etc.) cannot be sufficiently diversified by insurance companies: concentrations of wealth and assets are too few, so insurance policies cannot adequately cover a major catastrophe in one market with policies against the same catastrophe in other geographic markets. Given the value of assets needing coverage, there is a need to extend the risk beyond what the insurance market can support, and one way to do that is in financial markets. Two major financial instruments have been developed for this purpose: the catastrophe bond and the resilience bond.

(Right) Rescue workers after a major earthquake in Mexico. Recovery efforts were paid for through a catastrophe bond.

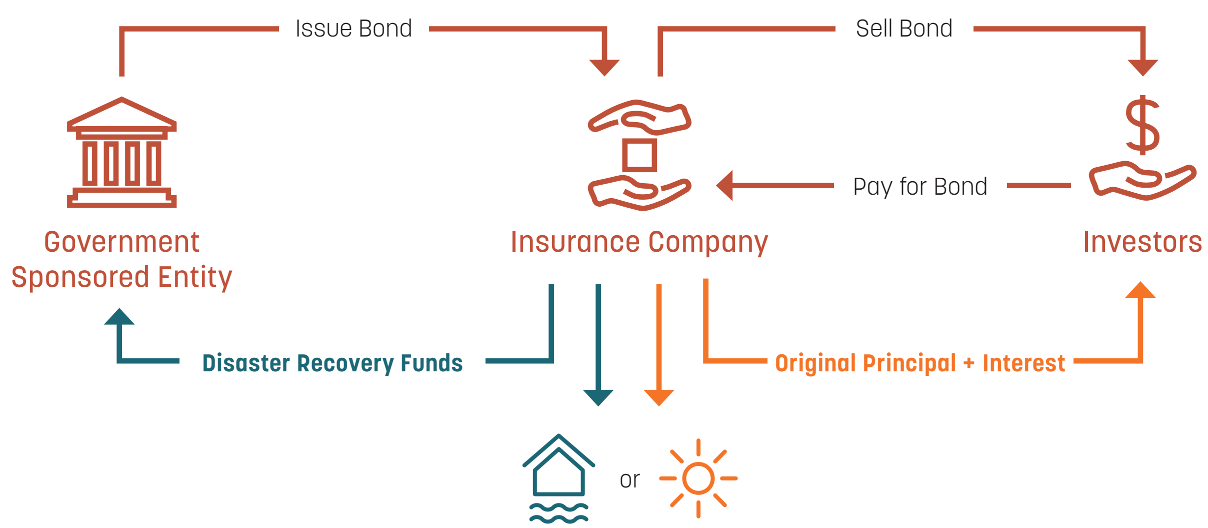
7.5.1 Issue Catastrophe Bonds

Catastrophe bonds are financial instruments that protect jurisdictions against the financial risk of a catastrophe. They are triggered after a catastrophe occurs and thus do not provide financing for pre-disaster mitigation. They are most suitable for catastrophes where physical interventions are impossible, or the cost benefit analysis does not support a physical intervention. In the Mid-South, a catastrophe bond linked to earthquakes offers a way to recover from major financial loss at a lower cost than retrofitting all existing structures.

A jurisdiction in need of insurance will identify the type of catastrophe to protect against and a threshold that triggers the payout of the bond, which could be the total dollar value of damage from a catastrophe, the magnitude of an earthquake, the amount of rainfall, water gauge readings, or extreme high or low temperatures for a specified duration, among others.

To issue a catastrophe bond, a jurisdiction will work with an insurance company to set up the financial instrument. It will have a specified term and geographic scope. The insurance company will sell the bond to investors, who receive their initial investment plus interest at the end of the term if the catastrophe does not occur. In the event of a catastrophe, investors lose their principal and the aggregate initial principal from all investors goes to the jurisdiction to pay for recovery from the catastrophe. Typically, investors of catastrophe bonds are large funds seeking to diversify risk, including pension funds, hedge funds, or other major institutional investors.

For jurisdictions, catastrophe bonds are better than simply buying insurance as the insurance market is unlikely to provide adequate coverage at a reasonable cost: often the cost of catastrophe insurance issued through an insurer equals the cost to self-insure over time. For investors, catastrophe bonds help diversify the risk-return distribution of an investment portfolio. Catastrophe bonds are tied to natural events that have a degree of independence from the political or economic factors that affect other financial instruments. As of April 2018, only 10 of the 300 market transactions have resulted in a loss of principal to investors since the first catastrophe bond was issued in 1997.[1]



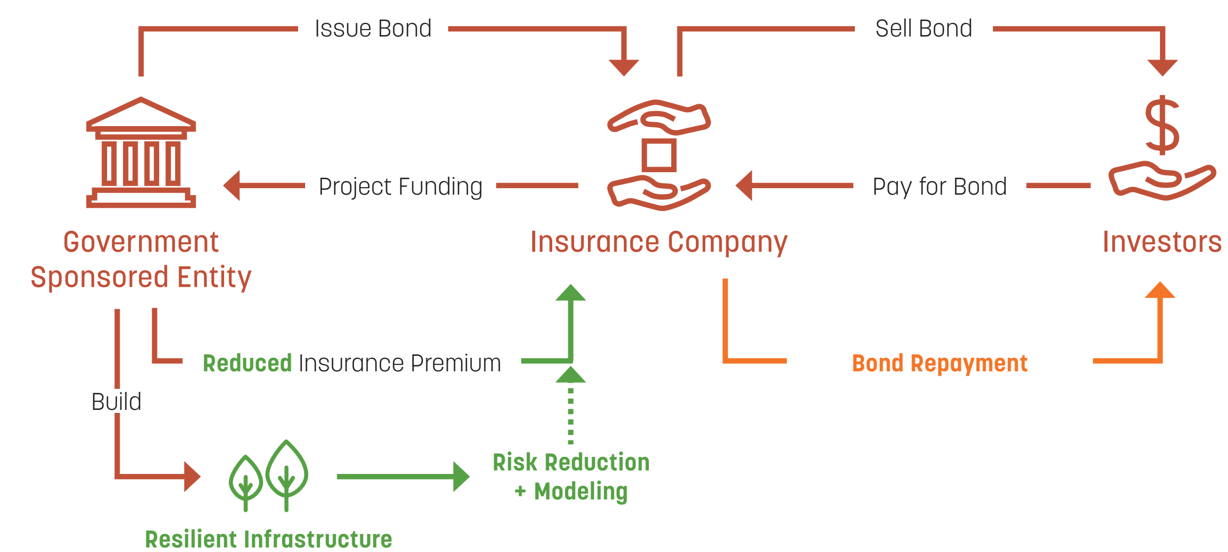
7.5.2 Issue Resilience Bonds

Resilience bonds are financial instruments that help fund capital improvements to protect against the physical and financial risk of a catastrophe. The physical improvements funded by the bond can be implemented before a catastrophe strikes, either preventing loss or making the impact less severe. They are most suitable in places where physical interventions can provide adequate protection of assets or reduction of risk. Resilience bonds link insurance coverage costs (potentially through catastrophe bonds) with capital improvements. While resilience bonds are often considered in the context of flood risk mitigation projects, they could also be used for any manner of risk mitigation that would reduce insurance premiums. An electric utility could make smart grid improvements to reduce wind related outages (and outage-related costs), or public building operators could make improvements to protect against earthquakes, thus reducing risk and therefore lowering insurance premiums.

A jurisdiction will identify a capital improvement, often in the form of hard or green infrastructure, that would make the jurisdiction more resilient against a natural disaster. Then the jurisdiction would work with an insurance company to issue a bond to cover all, or part, of the cost of the capital improvement project. Investors, typically in the form of large funds such as pension funds or hedge funds, would invest in a lower risk, lower return government bond product (as compared to the catastrophe bonds). The jurisdiction would use the initial bond principal payments to pay for the physical improvements. Once the physical protection is in place, jurisdiction insurance premiums would go down. The jurisdiction would then use these savings to pay back the bond investors. Once the bond was fully repaid, the jurisdiction would realize the annual savings from the insurance premium cost reduction.

Ultimately, it is less expensive to build physical protections against disasters than it is to pay for the financial recovery after a disaster, making resilience bonds more economically efficient than catastrophe bonds. Additionally, it can be difficult, if not impossible, to pay for disaster-related costs that are hard to measure or account for financially, including stress, health, loss of community, etc.

At this point, resilience bonds are still in their infancy. The Mid-South Region would be a pioneer, piloting the first resilience bond issuance.



Implementation

Effectively leveraging private markets to finance mitigation and resilience requires clarity around the area of greatest need (is it a physical project that will mitigate risk? A pool of funds to recover from an event?), an experienced insurance company or other third party intermediary to manage the process, and a reasonable balance of risk and return offered by the investment.

Catastrophe Bonds

1 Identify Need	Jurisdiction identifies a specific catastrophe, collection of assets, and time frame for protection
2 Find Insurance Partner	Jurisdiction creates a captive insurance company, or works with an existing insurance company, to issue a bond
3 Sell Bonds to Investors	Insurance company sells bond or other instrument to investors
4(a) Catastrophe	Catastrophic occurs; municipality receives investor principals to pay for recovery. Investors lose their principal.
4(b) No Catastrophe	Catastrophic event does not occur within the identified time frame; investors are paid back their principal, with interest.

Resilience Bonds

1 Identify Need	Jurisdiction identifies a specific catastrophe, collection of assets, and level of protection
2 Identify Risk-Reducing Capital Improvement	Jurisdiction identifies and designs resilient infrastructure, including cost estimates for the improvements
3 Find Insurance Partner	Jurisdiction creates a captive insurance company, or works with an existing insurance company, to issue a bond
4 Construct Capital Improvement	Jurisdiction constructs resilient infrastructure using the bond principal
5 Repay Bond	Jurisdiction repays the bond principal plus interest using savings from reduced insurance premiums due to lowered risk

Case Study

Catastrophe Bonds and Mexico City Earthquake,[2,3] Mexico

In August of 2017, the Mexican government worked with the World Bank to issue a $360 million catastrophe bond that would provide financial protection against losses incurred due to hurricanes or earthquakes. Mexico is one of the world's most vulnerable countries with regard to natural disasters, with 71% of the country's GDP considered to be at risk from two or more of the following disasters: hurricanes, floods, earthquakes, and volcanic eruptions.

On September 7, 2017 an earthquake struck the Mexico City area. By mid-November, the Mexican government had received a $150 million payout from the catastrophe bond. One reason for the timeliness of the receipt of funds was due to the structure of the catastrophe bond. The bond payout was triggered because an earthquake of a certain magnitude affected a specific area. Parametric modeling prior to the catastrophe estimated the value of the damage should such an event occur, and that value becomes the value of the payout, regardless of actual damage sustained.

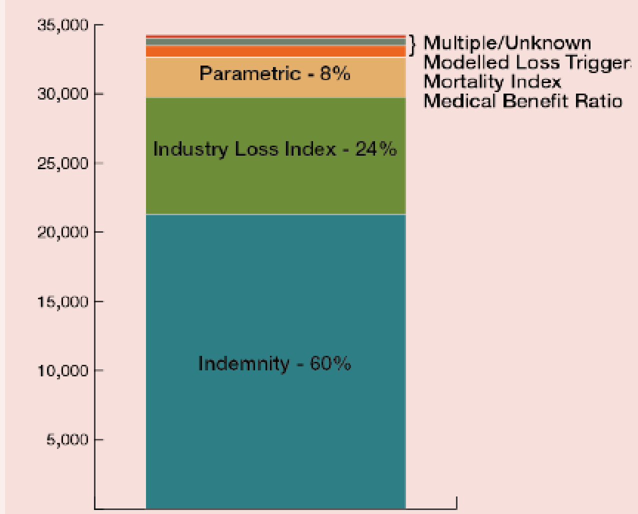
Investor interest in catastrophe bonds continues to grow as more products are introduced to the marketplace. Five months after the earthquake, Mexico renewed the catastrophe bond with the World Bank with coverage up to $260 million. As of spring 2018, 78% of catastrophe bond investors were dedicated insurance linked securities and catastrophe bond specialists. Approximately 97% of all catastrophe bonds have returned principal and interest to investors.

Catastrophe Bond Trigger Types

Catastrophe bond payouts can be triggered in a number of ways, depending on how the bond was originally set up. The most common type is an indemnity bond, where payouts are triggered by the actual losses from a catastrophe. This ensures financial coverage for assets actually lost, but the payout is not made until actual losses have been tallied, which can cause a delay between the catastrophe and receipt of recovery funds.

Parametric bonds, as used in Mexico, are growing in popularity but still remain a relatively small percentage of catastrophe bonds overall. They pay out based on modeled losses from a catastrophe of a specified severity in a particular location, regardless of the actual total value of the damage. While this could result in a gap between actual loss and covered loss, the payout is much quicker.

Risk Capital Outstanding By Trigger Types



Endnotes

1 *Mexico Confirms $150m Cat Bond Payout for Quake*. Artemis, October 11, 2018. http://www.artemis.bm/blog/2017/10/11/mexico-confirms-150m-cat-bond-payout-for-quake/.

2 *World Bank Bonds to Provide $360 Million in Catastrophe Protection for Mexico*. The World Bank, August 4, 2017. Available at: https://www.worldbank.org/en/news/press-release/2017/08/04/bonos-del-banco-mundial-proporcionaran-a-mexico-us360-millones-en-proteccion-ante-catastrofes.

3 "Catastrophe Bond and ILS risk capital outstanding by trigger type." *Artemis*. Last accessed September 19, 2018. http://www.artemis.bm/deal_directory/cat_bonds_ils_by_trigger.html.

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APPENDIX

Appendix

Appendix: List of Frequently Used Acronyms

ACEEE	American Council for an Energy-Efficient Economy
ARAP	Aquatic Resource Alteration Permit
ARRA	American Recovery and Reinvestment Act
ASCE	American Society Of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
BFE	Base Flood Elevation
CDBG	Community Development Block Grant
CDE	Community Development Entity
CDFI	Community Development Financial Institutions
CFPP	Critical Facilities Protection Plan
CRA	Community Redevelopment Agency
CRS	Community Ratings System
CWSRF	Clean Water State Revolving Fund
DCV	Demand-Controlled Ventilation
DFE	Design Flood Elevation
DSS	Distributed Solar Solutions
EDGE	Shelby County Economic Development Growth Engine
EECLP	Energy Efficiency and Conservation Loan Program
EPA	Environmental Protection Agency
ESCO	Energy Services Company
ESPC	Energy Savings Performance Contract
FAR	Floor-Area Ratio
FDIC	Federal Deposit Insurance Corporation
FEMA	Federal Emergency Management Authority
FIRM	Flood Insurance Rate Map
FMA	Flood Mitigation Assistance Program
FMP	Flood Mitigation Plans
FMV	Fair Market Value
FWS	US Fish and Wildlife Services
GSTF	Greatest Savings to the Fund Methodology
HMGP	azard Mitigation Grant Program
HUD	US Department of Housing and Urban Development
HVAC	Heating, Ventilation, and Air-Conditioning
IBC	International Building Code
IECC	International Energy Conservation Code
IHU	Interim Housing Unit
ITC	Investment Tax Credit
LEED	Leadership in Energy and Environmental Design
LID	Low-Impact Design
LIFT	Local Infrastructure Financing Tool
LIHEAP	Low Income Home Energy Assistance Program
LIHTC	Low-Income Housing Tax Credit
LMI	Low or Moderate Income
LWCF	Land and Water Conservation Fund
MDEQ	Mississippi Department of Environmental Quality
MEMA	Mississippi Emergency Management Authority
MISO	Midcontinent Independent System Operator
MLGW	Memphis Light, Gas and Water
MOU	Memorandum of Understanding
MRCAP	Memphis Regional Canopy Action Plan
NABCEP	North American Board of Certified Energy Practitioners
NFIP	National Flood Insurance Program
NFIRA	National Flood Insurance Reform Act
NMTC	New Markets Tax Credit
PACE	Property Assessed Clean Energy Program
PILOT	Payment-In-Lieu-Of-Tax
PTC	Production Tax Credit
PD	Planned Development
PV	Photovoltaic
QEI	Qualified Equity Investment
REC	Renewable Energy Credit
RESP	Rural Energy Savings Program
RFP	Request For Proposals
SEED	STEM, Energy, Economic Development
SFHA	Special Flood Hazard Area
SLAF	State Lands Acquisition Fund
TDEC	Tennessee Department of Environment and Conservation
TELP	Tax-Exempt Lease Purchase
TEMA	Tennessee Emergency Management Authority
TIF	Tax-Increment Financing
TOD	Transit-Oriented Development
TVA	Tennessee Valley Authority
UDC	Unified Development Code
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
UTC	Urban Tree Canopy
WAP	Weatherization Assistance Program
WDB	Workforce Development Board
WEP	Water and Environmental Program

Appendix: Case Study List

Appendix: List of Map Data Sources

Dataset Name	Original Source	Year	Edits	Comments
Airports	Esri	2007	Projected, Clip	
AquiferRechargeAreas	CAESAR	2016	Projected, Clip	
Bridges	National Bridge Inventory: https://www.fhwa.dot.gov/bridge/nbi/ascii2017.cfm	2017	Converted DMS to DD, imported to GIS, projected, clipped, and merged	Field descriptions available in metadata folder
BuildingFootprints	Shelby and DeSoto Counties	2012/2013	Projected and merged	Shelby is from 2012 and DeSoto is from 2013. No data available for Marshall or Fayette.
CensusBlockGroups	US Census: 2010 Decennial Census and American Communities Survey--see metadata	Varies	Table selection, field calculations, joins, clip, merge	Sources and field descriptions available in metadata folder
CityBoundaries	Census	2017	Projected, Clipped, and Merged	From Census Tiger files
CommunityCenters	Office of Sustainability	Unknown	Projected	
ConservationPriorityAreas	Wolf River Conservancy; author: Ryan Hall	2018	Projected and clipped	Separate metadata document is included
ContaminatedSites	Sent by MPO; originally from EPA	2014	Projected	
CountyBoundaries_US	https://catalog.data.gov/dataset/	2016	Projected, Clip	
CrowdsourcedFloodAreas	Online flood mapper created by Sasaki	2018	Exported	
DEM25FT	USGS	2015	Merged	Digital elevation model
EarthquakeVulnerability	Central United States Earthquake Consortium	2008	Merged, projected, clipped, and added description field	
EcologicalPriorityAreasCorridors	https://geoportal.memphis.edu/layers/geonode%3Aecological_connecting_framework	2017	Projected	
ElectricityServiceAreas_DeSoto	DeSoto County	Unknown	Projected	
ElevationContourLines	MPO	Unknown	Projected	
EPAFacilitiesOfInterest	https://www.epa.gov/enviro/geospatial-data-download-service	2018	Selected and Clipped	Used the "FACILITY_INTERESTS" layer as an aggregate of the sub-categories
ExtentRectangleRegional	Sasaki	2017	Created	
FEMAFloodZones	FEMA	2017	Projected, Clipped, and Merged	
FireStations_DeSoto	DeSoto County	Unknown	Projected	
Flood2011ExtentDepthShelby	Shelby County Map Package	2012	None	Only includes Shelby County
Flood2011InsuranceClaimsDeSoto	DeSoto County	Unknown	Projected	
Flood2014FlashFloodAreas_DeSoto	DeSoto County	Unknown	Projected	
Flood2014StructureDamage_DeSoto	DeSoto County	Unknown	Projected	
FloodAreasCityOfBartlett	City of Bartlett	2018	Added description field and merged	3 types of points: general flooding from 2010, residential flooding from 2014, and commercial flooding from 2014
FloodLocationsComposite	Multiple: indicated in the table of attributes	Varies	Created using multiple inputs. In some cases, flood areas were digitized from descriptions	
Floodplain100YR	FEMA	2017	Selection from FEMAFloodZones	A and AE zones

Appendix: List of Map Data Sources (continued)

Dataset Name	Original Source	Year	Edits	Comments
Floodplain500YR	FEMA	2017	Selection from FEMAFloodZones	A, AE, and X zones marked as having a .02% chance of annual flood
FloodProtectionStructures	Sent by MPO; originally from FEMA	Unknown	None	
GasDistricts_Hernando	DeSoto County	Unknown	Projected	
GrantProjectBoundariesApproximate	Regional: actual boundary; South Cypress: traced detailed boundary; Others: traced rough zoomed out image	2017	Digitized manually	Meant to show approximate project boundaries for the 4 federal NDRC grant projects
HighSchoolCatchments	County provided two files, one for Memphis and one for Shelby County suburbs	2018	Merged, clipped, and standardized field names	
HospitalsDeSoto	DeSoto County	Unknown	Projected	
ImpairedWaterways	TDEC and MDEQ	2018	Projected, Clipped, and selected imparied segements	EPA 303d streams for TN and MS
LandCover	NLCD	2011	Projected	
LargeScaleWaterDetentionSitesProposed	Sasaki	2019	Custom created	Proposed large scale water detention sites. See Recommendation 2.1.
Libraries	Office of Sustainability	Unknown	None	
LULC_USGS	USGS	1986	Projected, Clip	Land use / land cover
MPO Boundary	MPO	2013	None	
Parcels_DeSoto	DeSoto County	Unknown	Projected	
Parcels_Shelby	Shelby County FTP	2016	Projected	
Parks_Shelby	Shelby County FTP	2008	Projected	
ParksAndProtectedOpenSpace	Merge of Parks_Shelby, ParksState_TN, PublicLand, and Parks from Greenprint	Varies	Merge	
ParksState_TN	http://tn-tnmap.opendata.arcgis.com/datasets	2017	Projected, Clip	
ParksAsFloodMitigation	Selection from ParksAndProtectedOpenSpace	Varies	Selection	
PoliceStations_DeSoto	DeSoto County	Unknown	Projected	
Ports	MPO	2008	None	
PowerPlants	TVA documentation	2017	Digitized	See Recommendation 2.4 for criteria for selection
PublicLand	Shelby County Map Package	Unknown	None	
PublicTransit	Office of Sustainability	2015	Projected	
ResilienceZones	Sasaki	2019	Merged multiple analysis layers	See Recommendation 4.1 for methodology and zone descriptions
RiversAndCreeks	Shelby County Map Package	Unknown	Clip	
RoadsAll	MPO	Unknown	Clip and added future 269 and 69 segments from MPO	
RoadsInterstates	RoadsPrimaryAndSecondary	Unknown	Selected interstates and exported	
RoadsPrimaryAndSecondary	PriSecRoads from TN, AR, and MS. Downloaded original files from https://catalog.data.gov/dataset/	2013	Projected, Clip, and Merge	

Appendix: List of Map Data Sources (continued)

Dataset Name	Original Source	Year	Edits	Comments
RoadsROWOutlines	Shelby County	Unknown		
SewerServiceAreas_DeSoto	DeSoto County	Unknown	Projected	
Soils	NRCS SSURGO	2018	Projected, merged, clipped, and fields appended	
SolidWasteFacilities_Shelby	Jared via email	2017	None	
StateBoundaries	https://www.census.gov/geo/maps-data/data/cbf/cbf_state.html	2016	Projected, Clip	
StormwaterInfrastructure	Memphis City Engineering Office by way of Lissa from RSA	2018	None	
StreamRestorationCorridorsProposed	Sasaki	2019	Custom created	Stream corridors recommended for high-priority restoration. See recommendation 1.1
TAZs	MPO	2018	None	
TrailsExisting	Shelby County and ArcGIS Online	2013	Projected and merged	
TrailsProposedGreenprint	Shelby County	2017	None	
TrailsProposedOther	Shelby County	2017	None	
UnfundedPhase2Projects	County documents on website	2017	Digitized and projected	
UnmetNeedProperties	Shelby County	2017	Projected	Properties with unmet need from 2011 flood
Water	NHD. Combined individual waterarea and waterbody polygons	2017	Merge	Need to revisit for accuracy
WaterDotsGreenDensity	Crowdsourced at RRMP Workshop 1	2018	Density analysis of original points	Green = positive relationship with water
WaterDotsRedDensity	Crowdsourced at RRMP Workshop 1	2018	Density analysis of original points	Red = negative relationship with water
WaterDotsWorkshop1	Crowdsourced at RRMP Workshop 1	2018		Green = positive relationship with water / Red = negative relationship with water
WaterServiceAreas_DeSoto	DeSoto County	Unknown	Projected	
Watersheds	CAESAR	2017	Projected and selected features intersecting project boundary	
Zoning_DeSoto	DeSoto County	Unknown	Projected	

Appendix: Jurisdiction Interviews

During the course of the Regional Resilience Master Plan, the Shelby County Office of Resilience interviewed several of the communities within the region to understand their resilience-related challenges, current initiatives, recent accomplishments, future wish-list, and primary partners. This section documents those interviews.

DeSoto County, MS

Flooding is the primary resilience concern in DeSoto County, which is driven largely by runoff and upstream development. Straight line wind and storm damage are lesser concerns, thanks largely to the efforts of Roads & Bridges. Current resilience initiatives include a new ordinance restricting development in the floodplain and implementing a 2' freeboard requirement. DeSoto County's resilience wish list includes additional water detention, increasing developer accountability for drainage and runoff, dredging Arkabutla Lake, unclogging stream tributaries, cleaning up Horn Lake Creek, mitigating flooding and runoff from Camp Creek Canal, a countywide hydrology study, limiting open ditch detention for houses in the floodplain, reducing flooding along Fog Road by elevating it 4 – 5', additional sewage treatment capacity, and flood mitigation of HWY 51 from Goodman to the area west of the highway . The expansion of the interstate will spur new development and may create new floodplain issues in the southeast portion of the County. DeSoto County's primary resilience partners include MDEQ, the USACE, the regional drainage districts, NRCS, and FEMA.

Highest Impact Recommendations

1.1 1.2 2.1 2.2 2.3 2.4 3.1 3.2 3.3 3.5 4.1 4.3 5.1 5.2 5.3 5.4 5.5 6.1 6.2 7.1 7.2 7.3 7.4 7.5

Bartlett, TN

Flooding and straight line winds are the two biggest climate and weather-related challenges facing Bartlett. Pipes are only sized for the 10 – 25 year storm and flash flooding is a common issue. Aging bridges is another challenge facing the City. Current resilience initiatives include FEMA hazard mitigation planning, increasing stream channel setbacks, elevated freeboard requirements, an enhanced dispatch center with backup, and the purchase of repetitive loss properties. Bartlett's resilience wish list includes more details in response plans for train derailment and hazard mitigation, minimizing development in the floodplain (and promoting this as a best practice across the region), additional green space, a greenway trail along Fletcher Creek, improved building codes and development policy, mitigation banks with land to the north, bridge repair, improvements in water and sewer lines in the older parts of town, and repaving. Lack of funding and frequent turnover in government leadership were identified as two key barriers to achieving resilience objectives. Bartlett's primary resilience partners include TDEC, the Shelby County Office of Preparedness, the USACE, and the local water and sewer utilities.

Highest Impact Recommendations

1.1 1.2 2.1 2.2 2.3 2.4 3.1 3.3 3.4 3.5 4.1 4.3 5.1 5.2 5.3 5.4 5.5

Collierville, TN

Collierville's main resilience challenges include flooding—especially in older subdivisions—and damaging wind. The primary concern with damaging wind is property damage, although power outages are also a concern in certain areas. A key driver of flooding is the erosion of the banks of the Wolf River and Nonconnah Creek, where many of the laterals are head cut. Another challenge is older, undersized storm infrastructure. New infrastructure is being built to accommodate gradually more severe storms, progressing from designing to 10-year events to currently designing to 25-year events. New subdivisions are designed to 10-year storm requirements. Collierville's most current Building Codes are in line with best practices elsewhere in the US. Another local resilience initiative is to expand detention and stream buffers: currently a minimum of 30' is required from the top of the side bank, and for larger projects the buffer is 60'. Wolf River restoration is at the top of Collierville's resilience wish list.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 2.4 3.1 4.1 4.3 5.2 5.7

Appendix: Jurisdiction Interviews (continued)

Southaven, MS

Flooding, straight line winds, and post-storm debris clean-up are Southaven's primary resilience challenges. Areas of particular concern for flooding include Sweeney Road and some of the older parts of town to the west. Southaven is implementing several resilience initiatives including allocating $500K per year for drainage maintenance and improvements, a major H&H drainage basin study, pursuing changes to on-site detention requirements, expanding tree canopy coverage, increasing open space and pervious paving requirements for new development, 10 – 20' stream buffers for new construction, stream channel improvements, raising funds for watershed protection, completing a $20M restoration along John's Creek, increasing attention on post-storm debris clean-up, the creation of a flooding hotspot map, a new web based storm and road closure alert system, and an updated local emergency response plan. Southaven's resilience wish list includes passing an ordinance for undergrounding power lines, replacing the culvert or bridge on Stateline Road, securing federal support for additional stream restoration, enhancements to the local ditch network, additional emergency response vehicles, and updating aging utility infrastructure. Funding and time are the biggest barriers to implementation. Southaven's primary resilience partners include MDOT, the MPO and CoG, the USACE, NRCS, the Federal Highway Administration, the Red Cross, Entergy, Atmos, Southaven sewer and water, and the Nesbit Water Association. The City has mutual aid agreements with several nearby jurisdictions.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 3.1 3.2 3.3 4.1 4.3 5.1 5.2 5.3 5.4 5.5 6.2

Germantown, TN

Germantown's primary resilience challenges include drainage issues on the north end of town, storm debris cleanup, and utility service disruptions from falling trees. Several resilience initiatives are underway, including a grant to support long-range planning, updated emergency response plans, bank stabilization and drainage improvements supported through block grant funding, a comprehensive Drainage Master Plan that has $150K allocated to it per year, and a new backup emergency operations center and dispatch. One example of local success is mitigating flooding at Mimosa Gardens. Germantown's resilience wish list includes additional storm debris cleanup planning, continuity plans for train derailment, additional Wolf River drainage and stabilization improvements, and sewer crossings to protect underground power lines. Germantown's primary resilience partners include nearby jurisdictions, FEMA, the USACE, TVA, the 911 Board, the Council of Faith, local ham radio clubs, and MLGW. Germantown has mutual aid agreements in place with several of the surrounding local jurisdictions.

Highest Impact Recommendations

1.1 1.2 2.1 2.2 2.3 2.4 3.1 3.3 3.4 3.5 4.1 4.3 5.1 5.2 5.3 5.4 5.5

Olive Branch, MS

The primary resilience challenge for Olive Branch is straight line winds. Some flooding mitigation is needed along Camp Creek and Lick Creek, but flooding is less of a concern for the City overall. Current resilience initiatives include changes in development ordinances, USACE-assisted creek stabilization, and negotiations to purchase the airport. Olive Branch's resilience wish list includes sewer expansion, an update to the comprehensive plan, updated zoning code, expanded public works fleet maintenance, engineering inspectors, and public works facility expansion. Olive Branch's primary resilience partners include MDOT, North MS Power, and local gas, water, and sewer utilities. The City also has mutual aid agreements with several nearby jurisdictions.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 2.4 3.1 3.3 4.1 4.3 5.1 5.2 5.3 5.4 5.5 5.7

Horn Lake, MS

Flooding is the primary resilience challenge facing Horn Lake. Areas of particular concern include the intersection of HWY 302 and I-55, Shadow Oaks, Adams Circle, Bullfrog Corner, and Jackson Cove. Current resilience initiatives include a public outreach video communicating flood risks, adding new ordinances to improve floodplain management, collaboration with other nearby jurisdiction (such as Southaven), Horn Lake Creek bank improvements, and a stormwater mitigation project with the USACE now in Phase II. Horn Lake's resilience wish list includes additional restoration of Horn Lake Creek locally and in TN, riprap and bank stabilization maintenance for Alphead Creek, and funding to produce topo data for Horn Lake Creek. A stormwater fee has been considered but is not currently in effect. Horn Lake's primary resilience partners are DeSoto County, the USACE, the Mississippi Soil and Water Conservation Commission, NRCS, Entergy, and Atmos Energy.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 2.4 3.1 3.2 3.3 4.1 4.3 5.1 5.2 5.3 5.4 5.5

Appendix: Jurisdiction Interviews (continued)

Hernando, MS

Flash flooding and damage to electrical lines from thunderstorms are the two primary climate and weather-related challenges facing Hernando. Flash flooding hotspots include under the railroad bridge, along HWY 51, and on W Oak Grove Road. Other challenges include the lift station at Montclaire not functioning properly and flooding in Notting Hill due to its overlap with the floodplain. FEMA's upcoming round of flood map revisions will change the status of Notting Hill subdivision. The Monclaire lift station is being upgraded to address flaws in the prior design and is in Phase III of work. Hernando's resilience wish list includes a Drainage Master Plan and Capital Improvement Plan. There is also a demand for greater open space and the desire for funding to support berms, trails, and/or leveling at Renaissance Park. Hernando's primary resilience partners include the USACE, the NRCS, Urban Forestry, the DeSoto County EMA, Wagner, and Civil Link.

Highest Impact Recommendations

1.1 1.2 2.1 2.2 2.3 2.4 3.1 3.3 3.4 3.5 4.1 4.3 5.1 5.2 5.3 5.4 5.5 5.7

Lakeland, TN

Flooding is the top climate and weather-related challenge for Lakeland, while damaging wind is also a concern but of a lesser magnitude. The area north of the Loosahatchee flood regularly and tops its banks at least 3 times per year. Other flooding hotspots include New Brunswick Road and Steward Road. Lakeland's current resilience initiatives include a flood mitigation grant to construct a holding pond north of HWY 385, dam breach contingency plans, a public acquisition of the fire department that will eliminate the fire fee, several major road renovations, buyouts of flood prone residences, undergrounding of utility lines in newer subdivisions, and a new sewer interceptor along Clear Creek. Lakeland's current resilience wish list includes improved growth management strategies, enhanced local disaster response planning, a park that can provide some flood mitigation function north of the Loosahatchee, and better flood control for parks and trails. Lakeland's primary resilience partners include the USACE, the West TN River Basin Authority, the HOA around the Lake, and MLGW.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 2.4 3.1 3.3 4.1 4.2 4.3 5.1 5.2 5.3 5.4 5.5 5.7

Arlington, TN

Flooding is the primary resilience challenge in Arlington. The "500-year storm" is happening more frequently now, including during the 2016 storms that dropped 5" of rain in 45 minutes. Flooding is common along Airline Road, Hayes Road, Forrest Street, Douglass Street, and HWY 70. The Town also experienced an MLGW plant explosion in 2016, and it took 6 months to return to normal operations. Current resilience initiatives include building to the 25-year storm instead of the 10-year storm, adding 3 new regional water retention basins, maintaining a designated staff person responsible for flood management, charging a stormwater fee to fund watershed management, restricting development in the floodplain, requiring 1.5' above BFE, a new weather siren at city hall, proactive emergency training programs, a feasibility study for a second fire station, a TDOT grant to improve frequently flooded rights-of-way, and working with TDOT to upsize culverts on HWY 70. Some of the concrete ditches on private property are prone to clogging, and the Town is working to acquire them to be public easements. The lack of funding and insufficient staff time are the two biggest barriers to implementing new resilience initiatives. Arlington's primary resilience partners include TN state government and representatives, Shelby County, TDOT, and the development community.

Highest Impact Recommendations

1.1 1.2 2.1 2.2 2.3 2.4 3.1 3.2 3.3 4.1 4.3 5.1 5.2 5.3 5.4 5.5 5.7

Holly Springs, MS

Some areas of Holly Springs experience flooding, but they are mostly in agricultural areas, although roads are often washed out during heavy spring rains. Tornadoes, though not frequent, have hit the town in recent years causing significant damage and loss of life. Current resilience initiatives include restricting new development in the floodplain, going beyond the 1" runoff requirement for new subdivisions, the completion of a USACE streambank stabilization project, a 50% green space requirement for new developments, the construction of roadways built to handle heavy trucking use, and the push for updated IT systems and data collection protocols. Undergrounding more power lines is a major goal for the community. Holly Springs' primary resilience partners include the Industrial Development Authority, Holly Springs Electric, North Central Power, Lafayette Power (Oxford), NE Power, Union Power, and the Chickasaw Trails Industrial Park.

Highest Impact Recommendations

1.1 1.2 2.1 2.2 2.3 2.4 3.1 3.2 3.3 4.1 4.3 5.1 5.2 5.3 5.4 5.5 7.1 7.4

Appendix: Jurisdiction Interviews (continued)

Oakland, TN

Severe flooding is a frequent issue in Oakland. To assist with mitigation and disaster preparedness, the Town secured a FEMA grant in 2012 and is updating its emergency response plans. Additional flood mitigation will be provided by USACE improvements along Cypress Creek. Oakland's resilience wish list includes additional tornado shelters and medical/emergency vehicles. Funding and staff are two critical barriers to pursuing new resilience initiatives. The Town enjoys a mutually beneficial relationship with a strong network of surrounding municipalities. Their primary resilience partners are the Fayette County EMA, the Red Cross, and the Chickasaw Electric Co-op.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 3.1 3.3 4.1 4.3 5.1 5.2 5.3 5.4 5.5

Walls, MS

Flash flooding, heat, and drought are the primary resilience challenges facing Walls. Downed power lines are not as much of an issue, although damaging winds recently took down 10 power lines near Horn Lake High School. Current resilience initiatives include the procurement of a generator at City Hall and plans for the Fire Department to provide storm shelter. The main resilience partners for Walls includes county government, the sheriff's department, and MEMA.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 2.4 3.1 3.2 3.3 3.4 3.5 4.1 4.3 5.1 5.2 5.3 5.4 5.7

Gallaway, TN

Flooding and managing drainage are the key resilience issue facing Gallaway, particularly in the southern areas of town and within the A and E floodplain zones. One of the culverts under the rail alignment is too small and must be manually cleaned after heavy rain events. Current resilience initiatives include the restriction of new buildings in the floodway, keeping storm drains clear (especially near the rail line), and a new interchange on I-40 that will mitigate some localized flooding issues. Gallaway's resilience wish list include raising the sewage lagoons south of town, a new park with a lake near the banks of the Loosahatchie with flood resistant design, a track hoe to more effectively clear out bridges and drains, and septic systems for new subdivisions with a recirculating sand-system. Funding limitations and staff size are the two biggest barriers to implementation. Gallaway's primary resilience partners are the Fayette County EMA, the local gas company, Southwest electric, TexGas, Medigen, the railroad, Advanced Metal Fabricators, and the local limestone cutters. The town has mutual aid agreements with several nearby jurisdictions and has a close working relationship with Arlington.

Highest Impact Recommendations

1.1 1.2 2.1 2.2 2.3 2.4 3.1 3.2 3.3 4.1 4.3 5.1 5.2 5.3 5.4 5.5

Rossville, TN

Flooding is a significant issue that shuts down businesses and roads, particularly at the water plant and along HWY 194 north of town through downtown. The problem is severe enough that it hinders downtown development. HWY 194 is getting repaved soon, which will improve drainage and decrease flooding. Current resilience initiatives include downtown sidewalk repairs led by TDOT. Updating the water plan is a key resilience need. Rossville's primary resilience partners are its surrounding municipalities, the Fayette County EMA, the Red Cross, the Chickasaw Electric Co-op, and the TVA. There is opportunity for strengthening the collaborating between Fayette and Shelby County.

Highest Impact Recommendations

1.1 1.2 2.2 2.3 3.1 4.1 4.3 5.1 5.2 5.3 5.4 5.5

Appendix: Hydraulic Model Overview

Purpose and Background

The evaluation of the unmet recovery needs from the April 2011 storm indicated that several of the activities proposed to be included in the Greenprint for Resilience project lacked the needed scientific data be included. The activities in the upper portion of the watershed provided some local relief, but due to the lack of engineering data, it was impossible to determine the increased resilience to the downstream vulnerable communities. The approach to the project included the goal to provide the tool to obtain that data.

One of first steps in the regional planning effort was the development of a HEC-RAS model of the Loosahatchie, Wolf, and Nonconnah drainage basins, including their major tributaries extending in adjoining counties and states (Tipton County, TN, Fayette County, TN, DeSoto County, MS). This model has the capability to provide information on the effect a wetland or retainage basin upstream would have on the potential flooding in the lower portions of the drainage basin. This model can be invaluable in leveraging the development of future green space and wetlands with the long term effect of reducing flooding in the areas with the most vulnerable populations. The data from this model also has the ability to predict the cost of future flood events, including the influence of a changing climate. By incorporating prediction of rainfall in a given area, the HEC-RAS model can be used as a tool to provide a map of the potential areas which are most subject to flooding prior to storm events.

The model consists of two major databases. The first is the hydrological model which established the water quantity based on each specific rain event that was modeled. This data also included the water flow from the tributaries into the river channel. The second database is the hydraulic model (HEC-RAS model) which utilizes the water flow established by the hydrology model to delineate the areas that are inundated by the stormwater. This model is the base model that can be used to gauge the effect of future projects or rain events.

One method that can be used to determine the effect of a project or series of projects is to first adjust the flow from one of the tributaries to reflect the reduction in stormwater flow of the project at a specific rain event (100 year, 500 Year, etc.). This data is used to modify (tweak) the hydrological model which is utilized by the HEC-RAS program to model the hydraulics of the reduced flow to determine if the areas indicated to be inundated by the base model has reduced.

The models are housed at the Surface Water institute at Christian Brothers University and available for use by the engineering community.