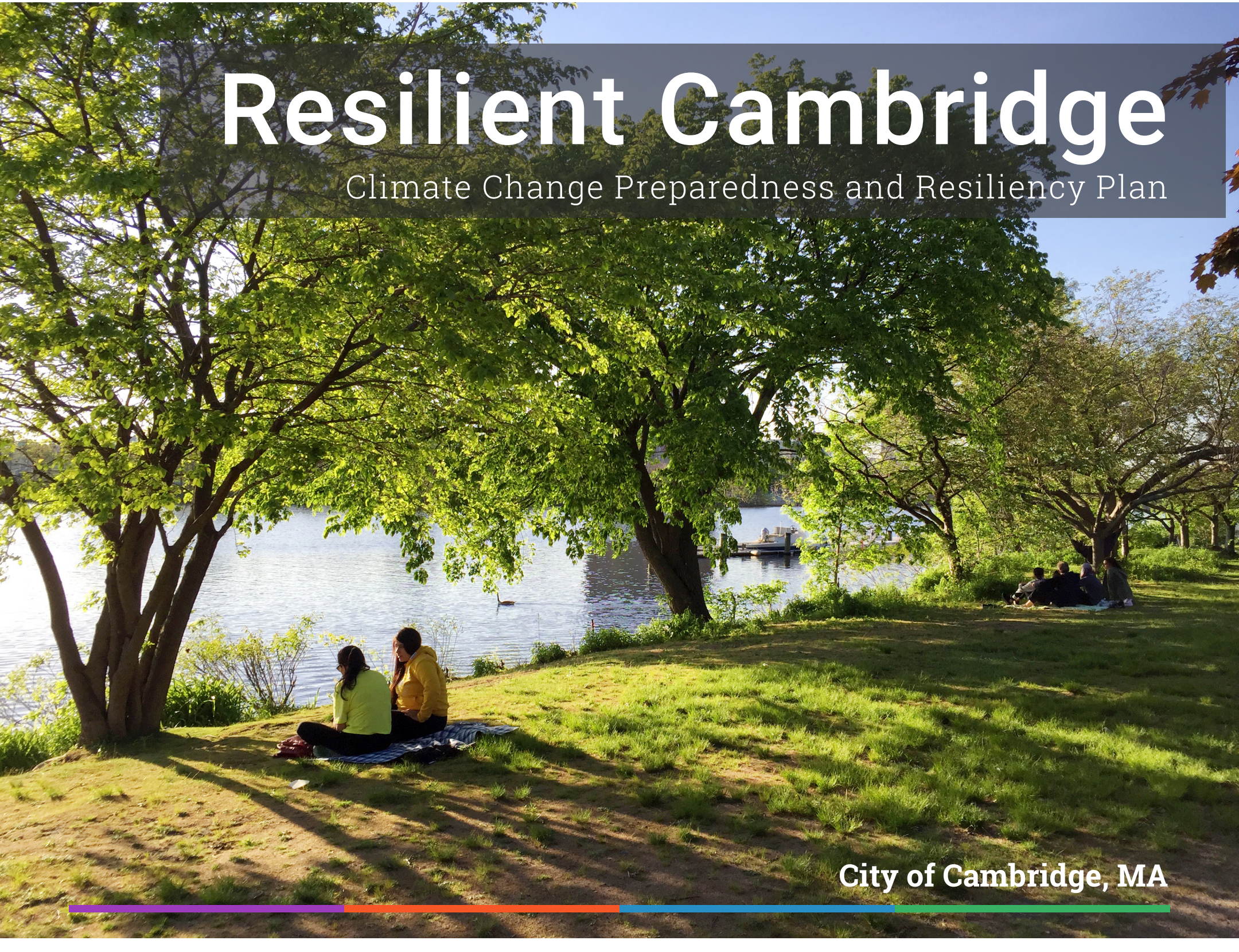

Resilient Cambridge

Climate Change Preparedness and Resiliency Plan

City of Cambridge, MA

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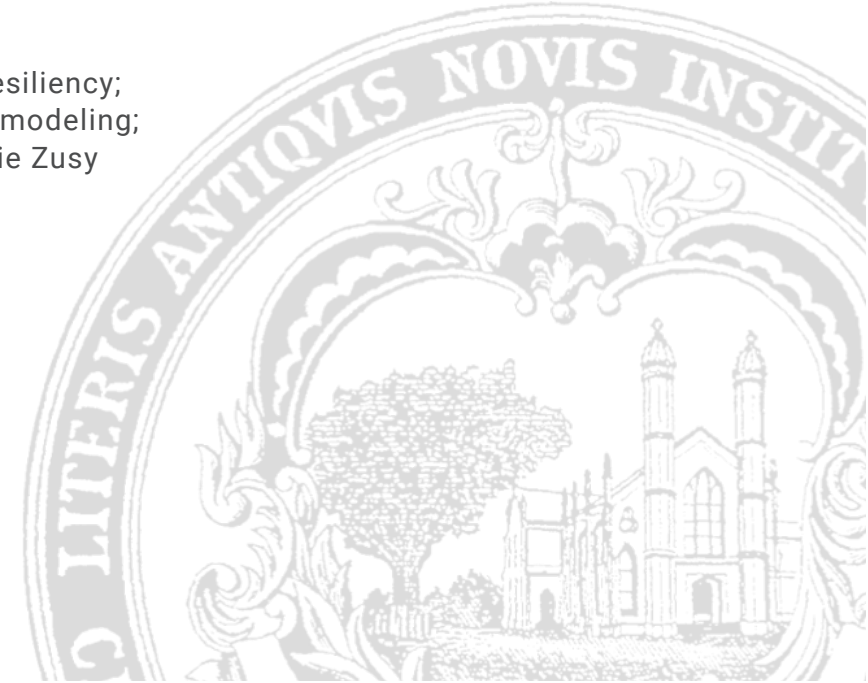


Table of Contents

Glossary of Terms

The terms that are **underlined and bolded** throughout Resilient Cambridge are defined on these two pages.

(RCP 4.5) (RCP 8.5)

These emission scenarios are called “representative concentration pathways,” or RCPs, developed by integrated assessment modelers, climate modelers, terrestrial ecosystem modelers and emission inventory experts for the Intergovernmental Panel on Climate Change (IPCC). RCP 4.5 is described as an intermediate scenario while RCP 8.5 is the worst-case scenario.

10% Annual Storm or 10-Year 24-Hour Precipitation Event

The 10% probability for extreme precipitation over a 24-hour period in any year.

1% Annual Storm or 100-Year 24-Hour Precipitation Event

A 24-hour storm that has a 1% chance of happening in any year.

2070 10% Flood Elevation

The water level elevation based on the projected 10% storm event in 2070, taking into consideration projected changes in extreme precipitation, and sea level rise and storm surge.

2070 1% Flood Elevation

The water level elevation based on the projected 1% storm event in 2070, taking into consideration projected changes in extreme precipitation, and sea level rise and storm surge.

Carbon Neutrality

Refers to achieving net zero carbon dioxide emissions by having or resulting in no net addition of carbon dioxide to the atmosphere.

Cool Roofs

A roof that has been designed to reflect more sunlight and absorb less heat than a standard roof . Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles. For the purpose of this report, it also includes “green roofs” that have a layer of vegetation planted over a waterproofing system installed on top of a flat or slightly sloped roof.

Gray and Green Infrastructure

Gray infrastructure refers to the human-engineered infrastructure for water resources such as pipe upsizing, flow rerouting, and storage tank installation. In the context of this report, green infrastructure is defined as working vegetated landscapes, and other open spaces contributing to the reducing, slowing, and cleaning of stormwater and cooling urban heat island.

Evapotranspiration

The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

Mean Sea Level

The average height of the surface of the sea for all stages of the tide. It is used as a reference for water elevation and also called MSL.

Net Zero Action Plan

The City of Cambridge refers to a building or a community of buildings for which, on an annual basis, all green house gas emissions resulting from building operations are offset by carbon-free energy production.

Passive House Standards

These achieve energy efficiency in a building. Implementation results in ultra-low energy buildings that require little energy for space heating or cooling. Generally, these fall into limiting heating and cooling demand, having an overall low primary energy demand, providing airtightness, and maintaining thermal comfort.

Dear Cambridge Community,

I am very pleased to share with you the Resilient Cambridge Plan, our roadmap to prepare Cambridge for impacts of climate change and make our City resilient. This plan utilizes the best available science to understand what climate change means to Cambridge and how we can effectively reduce our risks and increase community resilience while building a better Cambridge.

This is Cambridge's first climate change resilience plan and puts the City on the cutting edge of cities around the world that are coming to grips with the impacts of climate change. The plan provides a strong foundation for the City government and for all sectors of the community to do the necessary work to create closer neighborhoods, better buildings, stronger infrastructure, and a greener city. The City is engaging with our residents, institutions, businesses, and community organizations to coordinate and collaborate on action. We are also engaging regionally and with the state on actions that need to happen outside our borders to strengthen coastal storm defenses and protect public transit, transportation corridors, and energy and telecommunications systems.

A fundamental premise of this plan is that Cambridge has developed based on the climate of the past. While we have experienced some impacts such as severe street flooding, threats like sea level rise and increasing temperatures present emerging risks that Cambridge has not needed to address. As a result, Cambridge needs to adapt to these ongoing changes.

The plan proposes 34 strategies across four categories that represent a comprehensive and coordinated approach. There are no silver bullets. Through our analysis and planning work, the City has tested the strategies for effectiveness, feasibility, equity, and cost. We can do this.

During the planning process, many actions have been implemented or are in progress. Examples include The Port Infrastructure Project, the Tobin School storage tank, Triangle Park, the Urban Forest Master Plan and its projects, the Climate Change Resilience Zoning Task Force, and many other smaller projects. We are seeing new developments, including our school building projects, designing to 2070 climate standards. And we are working with our neighboring cities and the Commonwealth through three regional climate change collaborations — Metro Mayors Climate Change Preparedness Task Force, Resilient Mystic Collaborative, and the Charles River Climate Compact — to advance regional solutions including a Mystic River storm surge barrier plan.

This plan is about building a stronger, more resilient Cambridge that will see many benefits beyond addressing climate change. This plan is also not a retreat from the important work of reducing greenhouse gas emissions, the primary cause of climate change. Through participation in global efforts to reduce greenhouse gas levels in the atmosphere, we can reduce the amount of climate change to which we have to adapt. While this is the first such plan, this work will be ongoing and will be updated.

I look forward to this important work moving toward a better Cambridge.

Louis A. DePasquale
City Manager

CLIMATE CHANGE AND THE CITY

Weathering a new normal

Climate change action has become one of the most vital conversations of the 21st century. Beginning with the industrial revolution and accelerating since 1950, carbon dioxide and other greenhouse gases have been building up in our planet's atmosphere and are making our climate unstable. We may think of climate as simply being "the weather," but it is the average course or condition of the weather over a period of decades. Climate change is manifested by sea level rise and storm surge, extreme precipitation, and extreme heat. The challenge brought by climate change is that past patterns do not indicate what our future will look like. Conditions can be predicted, but they are not certain. Consequently, our cities have not been built to withstand the different conditions of the future. Climate change is defining a new normal that is already affecting our way of living and how we are inhabiting our cities. Cambridge is designed and built for the climate of the past. We must have a plan that looks forward.

Today, as rising temperatures and extreme weather events around the globe illustrate the need for proactive measures, Cambridge is answering the call to action. The City is tackling climate change with bold new policies, programs, and infrastructure to create a **Closer**, **Better**, **Stronger** and **Greener** Cambridge.

Resilient Cambridge is the culmination of seven years of research and analysis on how we can best prepare for one of the most pressing challenges of our time. It is based on the best available science and acknowledges that there are still many unknowns about climate change. Projections in Resilient Cambridge are based on an ensemble of greenhouse gas emission trajectories, which span from an intermediate scenario (**Representative Concentration Pathway "RCP" 4.5**) to a worst-case scenario (**RCP 8.5**); these scenarios are used by the United Nations intergovernmental body tasked with assessing climate change. The challenge is twofold: we must reduce greenhouse gas emissions to limit the amount of change in the future and adapt to changes already at our doorstep. This is where Resilient Cambridge comes in. While the Cambridge **Net Zero Action Plan** and other initiatives aim to reduce emissions, Resilient Cambridge focuses on adapting to the irreversible impacts of climate change, puts forth strategies for addressing local challenges, and suggests a vision for a vibrant, sustainable City. The reality is stark: globally, we have experienced record-breaking high temperatures for the past seven years (2014-2020), a more than 70% increase in the amount of precipitation in very heavy rainfall events, and Boston Harbor is 1 foot higher than it was 100 years ago .

Hydrology and Flooding History

Climate has already shaped the City. During the Ice Age, glaciers and deposits of volcanic ash, clay, slate, and rock shaped Cambridge and metropolitan Boston. Until about a century ago, Cambridge was directly connected to the Atlantic Ocean by the Charles River, Alewife Brook, and the Mystic River. Cambridge is bounded by two rivers and a tributary, the Charles River to the South, and the Mystic River and Alewife Brook to the Northeast. The Mystic River and Charles River watersheds still define the City's hydrology—the science of water on and below the earth's surface—and determine where water flows.

The City has already been affected by storm surge. The Cambridge Chronicle reported that

on May 10, 1851, extreme storms and high tides submerged areas of Cambridge by as much as 3 feet, with significant damage to the streets and private properties. In November 1871, a nor'easter storm caused tides to overflow into low-lying areas. Surrounding residents were forced to seek refuge in their second stories. Residents were not prepared for this type of coastal flood.

The construction of dams on the Mystic and Charles rivers had a dramatic impact on hydrology and subsequent land development, as the waterways ceased to be tidal. The first Charles River Dam was built in 1910 and the Amelia Earhart Dam on the Mystic River in 1966. In today's urban context, the past hydrology, although often hidden, remains evident in low, flat land along the rivers.

As sea levels rise, the ocean will reclaim the lowlands. The dams were built for storm surge (SS)—but didn't factor in sea level rise (SLR)— and are at risk of being overtopped or bypassed by midcentury (Fig. 1). A dam is bypassed when water goes around one or both sides and is overtopped when water goes over the top of the dam. Areas that were reclaimed from lower ground and wetlands are now most at risk of flooding in the near future. For the past few hundred years, historic events shared through storytelling along with early data collection from experienced events informed Cambridge's building practices. There was no way to predict what could happen in the future. However, if we don't act now, infrastructure, public space, and the built environment are likely to suffer devastating impacts from extreme events in the future.

Extreme precipitation, sea level rise, and storm surge caused by climate change are threatening the City's aging hydrological systems. The recent Massachusetts Coast Flood Risk Model (MC-FRM) for sea level rise and storm surge predicts that the Boston Harbor area, which includes Cambridge, is expected to experience almost 1 foot of sea level rise by 2030 and more than 4 feet of sea level rise by 2070. Based on previous projections published by the City as part of a 2015-17 vulnerability assessment, the Amelia Earhart Dam was at risk of being overtopped by 2045 by the **1% Annual Storm** (Fig. 2)—a storm that has a 1% chance of occurring in any year, also known as a 100-year storm—while the Charles River Dam was at risk by 2055 from a similar **1% Annual Storm**. Today, because of updated SLR and SS projections, the dams will likely be compromised earlier. Alewife, an inland area in western Cambridge, will likely be the first impacted by sea level rise and storm surge due to regional topography and flood pathways.

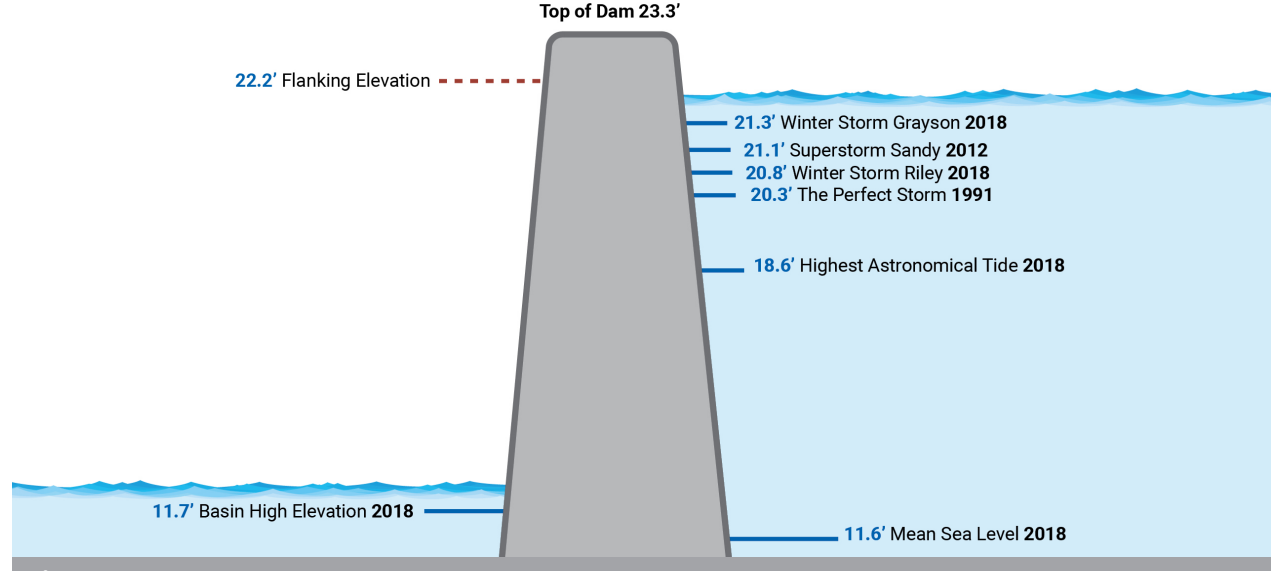


Figure 1. Boston Harbor is 1 foot higher than it was 100 years ago. Pictured are storm surge elevations from recent storms compared to flanking elevation under existing conditions. *Source: Kleinfelder*

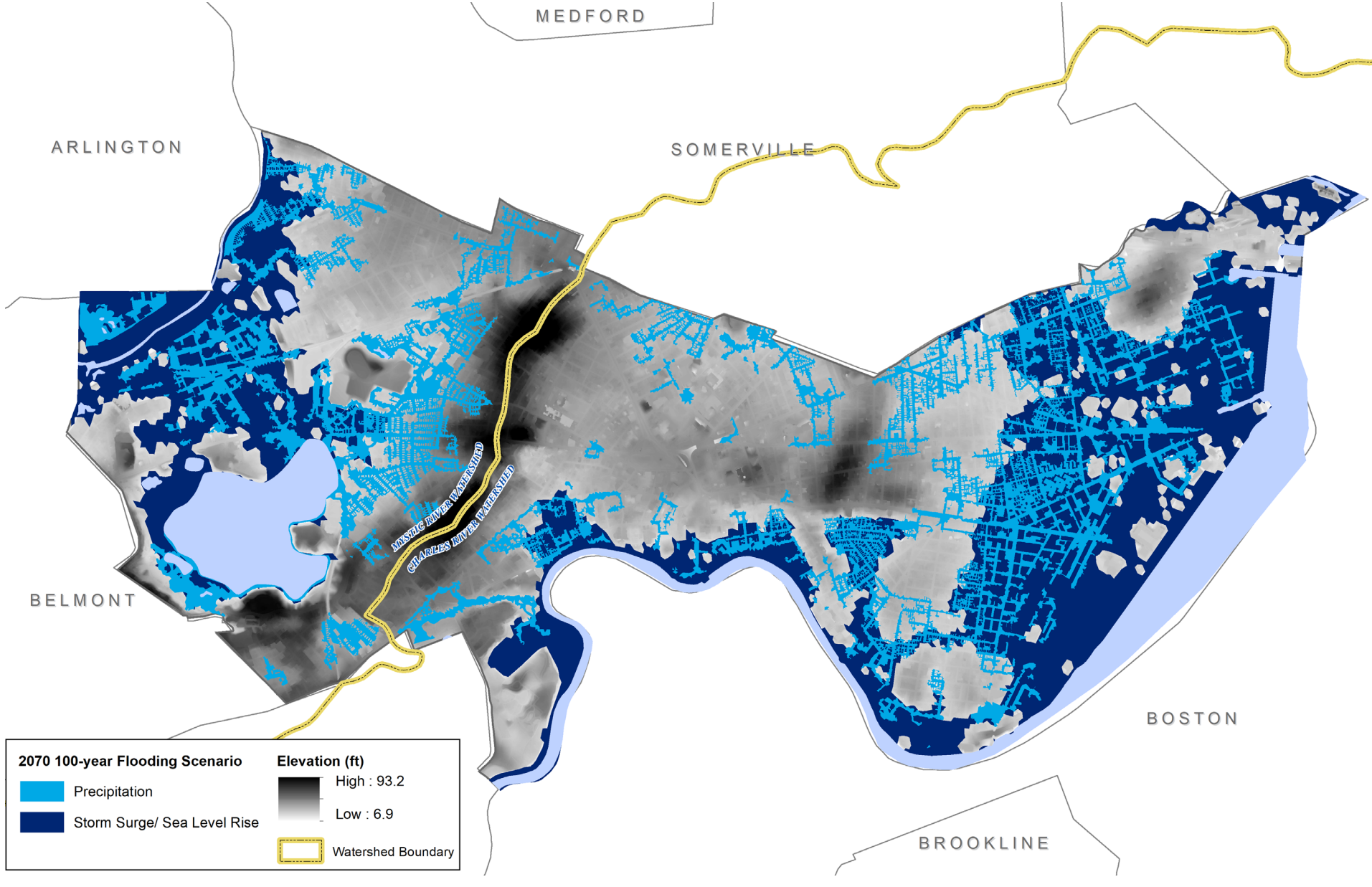


Figure 2. This map illustrates the projected flooding for the 1% Annual Storm in 2070, or the 100-year flood. Source: *City of Cambridge, 2021*

Topography also plays a role in defining stormwater flood pathways. Rainwater flows to either Alewife Brook and the Mystic River or to the Charles River from the City's high points. Flooding can occur rapidly during extreme precipitation, with topography and impervious, or impenetrable, surfaces affecting the City's hydrologic system's stress points, as occurred in July 2010. Frequent and severe flooding is predicted in the future, with the probability of a **10% Annual Storm**—a storm that has a 10% chance of happening in any year, also known as a 10-year storm—with up to an additional 1.5 inches of rain during a 24-hour period from such a storm by 2070.

Hydrology in cities connects rivers, ocean, and stormwater infrastructure. Stormwater pipes are designed to channel rainwater to rivers and to the ocean. In the future, the Amelia Earhart Dam and Charles River Dam are likely to be bypassed and overtopped from sea level rise and storm surge, causing higher river water levels. These increased water levels will then flow upstream through existing outfalls and connected pipes in low-lying areas within Cambridge via catch basins and manholes, causing localized flooding even on days with no precipitation. This issue highlights the importance of an integrated approach in addressing flood risk.

Figure 3. A bicyclist rides through flooded streets in July 2010. *Source: City of Cambridge*

Doing nothing, or a no-action scenario, for flooding would disrupt business, mobility, housing, and infrastructure in large swaths of the City. Implementing strategies that are outlined in Resilient Cambridge can mitigate the extreme effects of more frequent rainstorms and minimize the impact of flooding when it occurs.

Warmer planet

The last five years (2015-2020) have been the warmest on record, as reported by the World Meteorological Organization. As summer temperatures in New England get warmer, there will likely be longer and more frequent heat waves. Average summer temperatures in Cambridge, currently around 71 degrees Fahrenheit (ºF), are expected to increase 4 degrees by the 2030s—tripling the number of days each year above 90ºF. By the 2070s, average summer temperature is projected to increase by 6 to 10 degrees, and there could be more than 60 days per year over 90ºF (Fig. 4). Extreme heat affects our health and our ability to function. Heat stress occurs when environmental conditions overwhelm the body's cooling mechanisms, and a healthy body temperature cannot be maintained. A sustained increase of internal temperatures reaching 104ºF can lead to heat stroke and death.

Cities are usually warmer than suburban and rural areas, a phenomenon known as the urban heat island (UHI) effect. The denser and more built-up an area is, the more likely it is that UHI will occur. Roads, parking lots, and dark building surfaces affect urban heat by increasing local temperatures, while parks, green open spaces, the urban forest, and light-colored surfaces mitigate temperatures.

A no-action scenario (Fig. 5) would not only adversely affect temperatures and increase extreme heat during the summer months, it would also lead to a depletion of the urban forest. Implementing strategies recommended in Resilient Cambridge, such as **cool roofs**, maximizing green infrastructure including pervious surfaces, and enhancing the urban forest, can reduce local hot-spot temperatures by 1 to 4 degrees or more. Days that are hotter than the average seasonal temperature in the summer can compromise the body's ability to regulate its temperature and induce heat-related health complications. Consequently, any reduction in temperature can be a significant benefit to people's health. Similarly, even a small reduction in ambient air temperature, or the measured air temperature outside, reduces the load on buildings' air-conditioning systems.

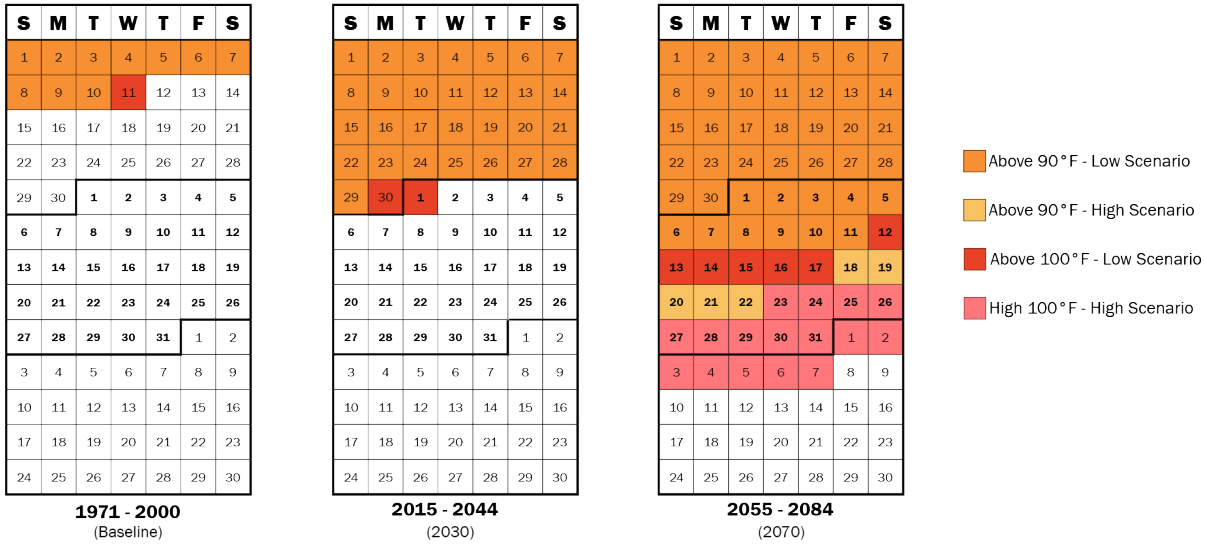


Figure 4. By the 2030s, average summer heat index in the City can be around 95°F, and by the 2070s, average summer heat index can be as high as 110°F. *Source: CCVA Part 1. City of Cambridge.*

Ever-changing City

A hub for innovation and research, Cambridge is constantly evolving. The City's technology market continues to thrive, increasing its population and invigorating its economy. With a growing immigrant population, the Cambridge community is more vibrant and diverse than ever. At the same time, the City is grappling with economic disparities and a shortage of affordable housing. The changing climate unfolding against a backdrop of stresses on aging infrastructure and natural systems adds a layer of complexity. Rising to these challenges requires a holistic approach that will redefine Cambridge as a livable, sustainable place for everyone.

Planning for this new normal requires imaginative, responsive change. Resilient Cambridge is substantive and optimistic and provides a comprehensive set of actions and strategies. Their implementation will require the collaboration and dedication of our government, businesses, institutions, and residents. Tackling climate change can feel daunting, but there is so much that can be done at the scale of the City to ensure a safer, more equitable future for us all. **Resilient Cambridge is a call to action. Our goal is to empower citizens to take action to tackle climate change by defining a shared mission. Together, we can adapt and shape a transformed City.**

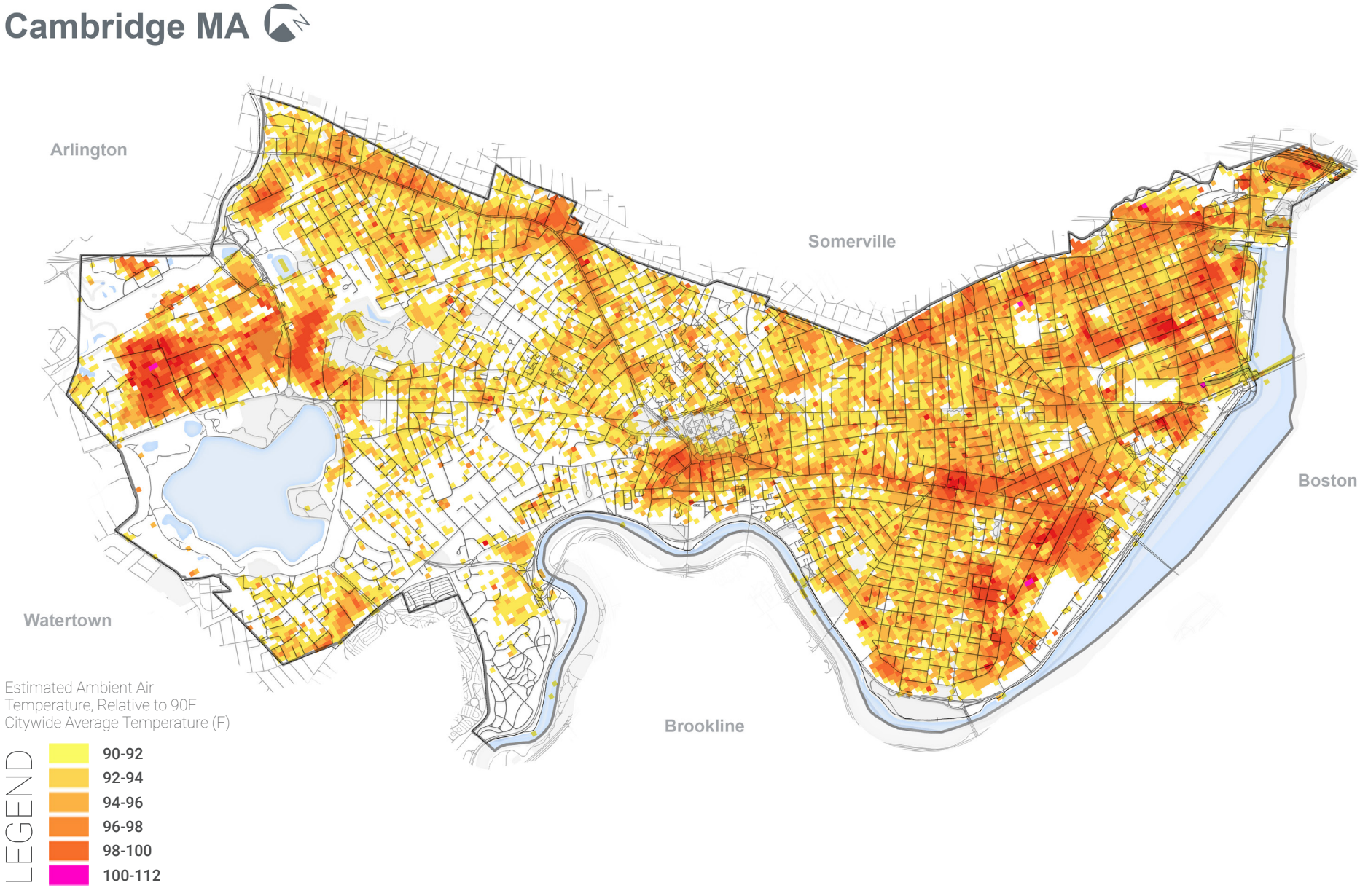


Figure 5. The map shows the modeled ambient air temperature for existing conditions in 2018 relative to a 90°F citywide average temperature.
Source: Urban Heat Island Technical Memorandum, Kleinfelder for the City of Cambridge, 2020

Pandemic, Racial Justice, and Resiliency

The 2020 coronavirus pandemic has radically changed our lives. COVID-19 has highlighted many vulnerabilities in our built environment, infrastructure, and social and economic systems—particularly the disproportionate impact it has had on people of color and lower-income residents. At the same time, the resiliency mechanisms that the pandemic has triggered overlap with strategies developed in Resilient Cambridge to support communities during climate-related events. We have come to rely on our parks and open spaces as places to see one another while remaining socially distant. Safe and stable housing is even more crucial as we stay home and quarantine. Interruptions in business and school operations are challenging our economy, social fabric, and well-being. COVID-19 has urgently underscored the need for access to affordable and secure housing, resilient healthcare, reliable communication systems, stable food sources, community mutual aid, and essential workers willing to serve our most at-risk residents. We are confronting extreme circumstances as transportation, schools, workplaces, and cultural institutions are shut down. These scenarios could occur during, or as a result of, extreme weather events. The flexibility, innovation, and collaboration shown during this crisis are the same characteristics that we will need to face climate change.

Resilient Cambridge is also being written during a powerful and crucial moment in history. The death of George Floyd in May 2020 further galvanized the Black Lives Matter movement, which calls for justice, equal rights, and the protection of Black lives in the face of systemic and structural racism. In response, the City of Cambridge declared racism a public health emergency in June 2020.

Community is what makes Cambridge a special place. It is important that climate resiliency works for all Cambridge residents, not just those who can readily afford to adapt to climate change, and that any improvements avoid unintended consequences, such as gentrification and displacement. **Resilient Cambridge intends to elevate the voices of those who are often marginalized and prioritize strategies that empower and protect residents who are at risk.**

TRANSFORMATIVE STRATEGIES

The City of Cambridge, an urban ecosystem comprising diverse and complex parts, functions best when these parts all work together. This ecosystem consists of people (society), buildings and infrastructure (the built environment), and vegetation and the urban forest (natural systems). Each component is being tested by shifting climate conditions. Resilient Cambridge analyzes each of these parts and reimagines how they can work together to create greater community resilience and to prepare the Cambridge community for the stresses of climate change. The components addressed in this Plan are **Closer Neighborhoods**, **Better Buildings**, **Stronger Infrastructure,** and a **Greener City**.

The City is committed to designing for climate change according to the best available science, integrating the latest data and best practices into its planning, guidelines, policies, and actions.

Key considerations:

- Climate science is evolving, and Resilient Cambridge is based on a snapshot at the time of writing.
- Designs and standards can be modified as new information becomes available.
- A process will be formed to regularly revisit the science and update Resilient Cambridge as needed.
- Hard-to-reach communities must be included to ensure fair representation.
- A scientific advisory panel should be established to review updated projections the State and City use.
- Although climate projections change, there is a lot we already know, and the City is ready to use the information to start taking actions, protecting residents, and creating a vibrant, adaptive, and equitable Cambridge.

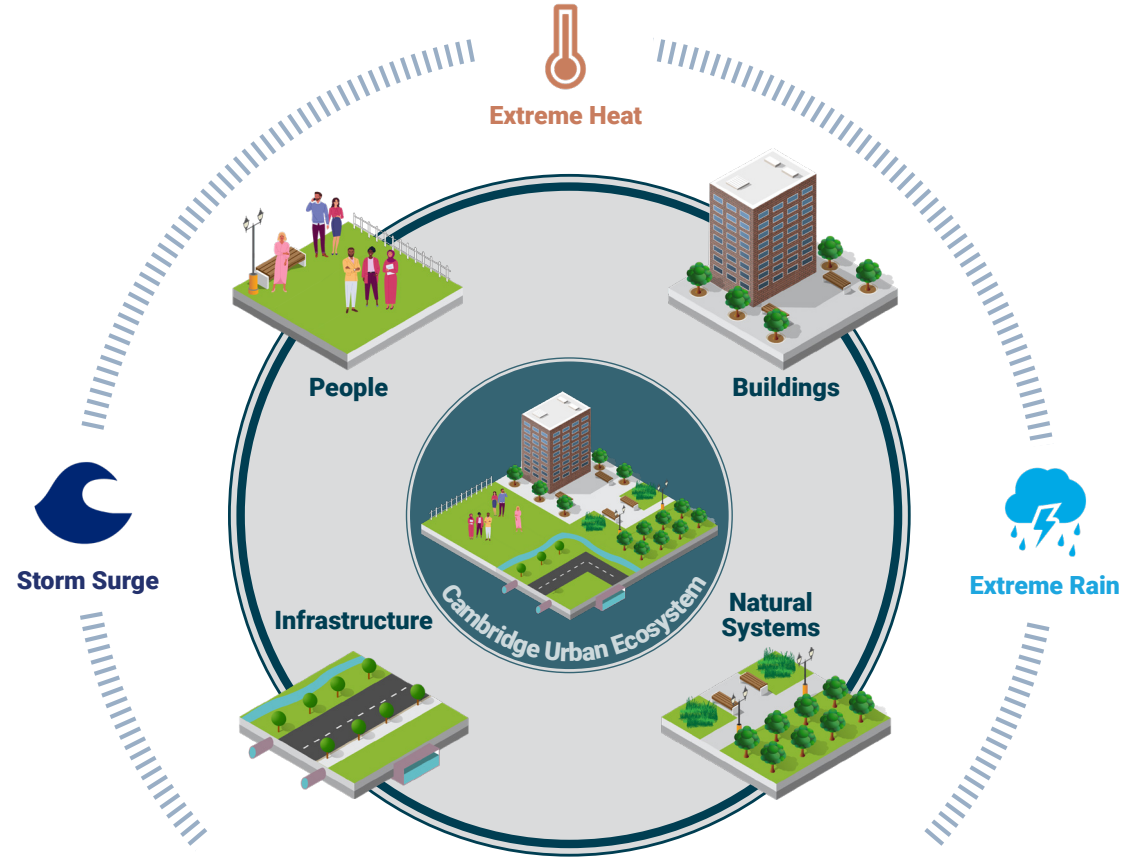
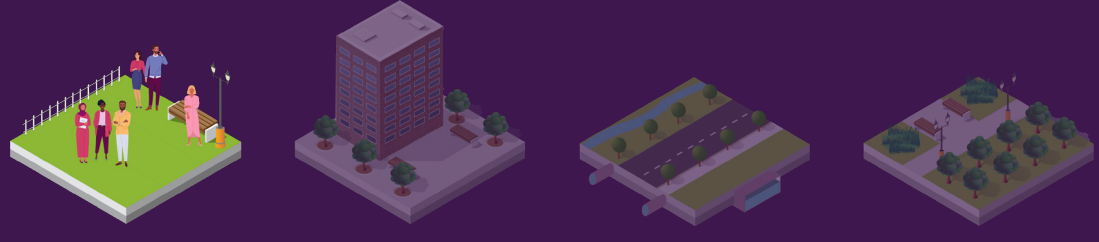


Figure 6. The City is made of ecosystems that together shape its character. These ecosystems are made of natural systems, infrastructure, buildings, and the people of Cambridge. Climate change is adding new stresses on these ecosystems and testing the resiliency of the City.



Resilient means our communities will feel more connected and supported

Closer Neighborhoods

A

Closer Neighborhoods

Strong community networks—neighbors, family, and local organizations that we can rely upon in times of need—are an important aspect of a resilient community. They connect us to critical services during a crisis; provide housing, food assistance, transportation, loans, medical assistance, mental health services, critical communication, and internet access; and help navigate bureaucratic recovery processes. These strong social bonds help our communities forge a resilient network to meet the challenges of uncertain circumstances.

Historical, social, economic, political, planning, and development trends influence the urban ecosystem. Not all residents have equal opportunities to experience and access the benefits of the urban ecosystem. In terms of climate change, this translates to some residents facing greater exposure to climate hazards because of where they live or because they have fewer economic resources. Resilient Cambridge's Closer Neighborhoods focuses on how to equitably work toward climate preparedness by connecting residents to resiliency resources. By understanding the characteristics of each neighborhood and what supports these communities, Resilient Cambridge recommends ways to build stronger social networks for all Cambridge residents (Fig. 7).

A key goal for Closer Neighborhoods is that all residents will be able to adapt to climate change, remain safe in the face of increasing hazards, and that the City will remain vibrant and livable. Some areas of Cambridge are more at risk of flooding or experience more severe heat stress during heat waves. Community resources can provide places of refuge, help in preparing for climate events, and recovery support. When responding to climate change, the needs of residents vary based on their social, economic, and physical characteristics. The Closer Neighborhoods strategies aim to help reduce systemic and structural barriers to providing access to resources and increasing self-resilience during extreme weather events.

The mechanisms needed to build Closer Neighborhoods are based on the observed fact that strong networks help residents prepare and recover faster and better. Personal relationships provide emotional, material, practical, financial, and professional support by:

- Creating bonds based on common identity and shared culture or ethnicity.
- Building bridges that stretch beyond shared identity to distant friends, colleagues, and associates.
- Establishing links to people, groups, or institutions including workplaces, community resources, or government services that can provide support in times of crisis.

Some residents of our communities are more at risk. Having different cognitive abilities, levels of education and English proficiency may affect how a person processes and understands information. Having different physical abilities may affect a person's mobility, making critical movement or emergency evacuation during a disaster difficult without assistance. Young children rely on caregivers for protection and older adults might experience dangerous heat stress due to underlying health conditions.

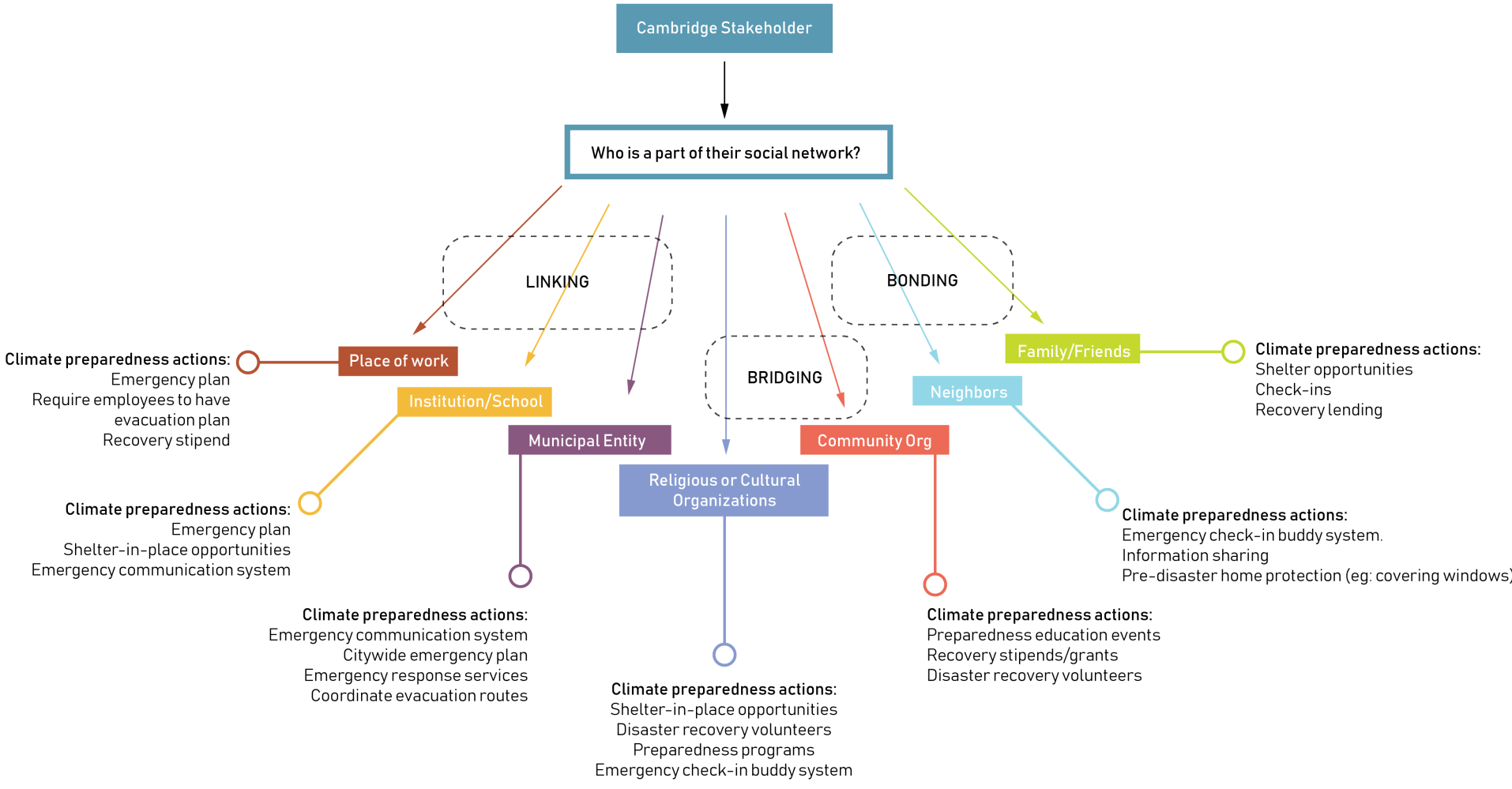


Figure 7. This image illustrates the connection of people to other people, places and resources: "Linking," "Bridging," and "Bonding." *Source: Kleinfelder, 2020*

Individuals who live alone may experience social isolation without the benefit of a family member or housemate checking on them or collaborating on decision making. Resources designed with these residents in mind could ensure their resiliency and limit their hardships.

Housing security affects the success of a resilient community. Renters often have limited physical control over their units and cannot adapt their homes to climate impacts. They may also be at risk of displacement after a storm event if their unit is damaged or they cannot pay the property owner because of financial hardship. Individuals experiencing homelessness are already affected by extreme temperatures and precipitation events. Residents who live below the poverty line may be unable to afford preparedness measures and may need to rely on support from community groups, or government-issued monetary relief to recover.

A key indicator of a prepared, connected community is the density and diversity of community resources available for building networks and providing critical support in times of crisis. Resources include:

- Affordable housing: public housing facilities, housing authorities and assistance, affordable housing developments and developers
- Public facilities: City Hall, public library, critical assets, and community-resource facilities
- Food supplies: food pantries and assistance, farmers markets, bodegas, grocery stores
- Public health facilities: clinics (including walk-ins), pharmacies, hospitals, urgent care centers, senior service centers
- Community-based organizations (CBOs): non-profits, community centers and development corporations, job training centers, art centers
- Educational facilities: preschools, elementary schools, high schools, colleges, universities, adult learning centers, tutoring centers, childcare centers
- Places of faith: churches, mosques, synagogues

Community resources provide opportunities for residents to bond with one another, which serve as cornerstones of resiliency. Research shows that individuals are more likely to engage with a community group if they are within walking distance and 31.4% of city households do not own a vehicle. Therefore, living close to one of these resources may enhance the strength of a social network.

A lack of density of community resources can also be a risk factor (Fig. 8). Volunteers and providers benefit from physical proximity to the communities they serve. The Wellington-Harrington and Strawberry Hill neighborhoods have the highest percentages of populations at risk and lack a robust network to serve these residents since many of the City's CBOs are concentrated near Harvard and Central squares. The City could partner with this network to extend services citywide, with the first goal of developing an inventory of services and skills so crucial providers can be efficiently mobilized to help residents in need. The Port, East Cambridge, North Cambridge, and Riverside also have high percentages of populations at risk, but they are better served than other neighborhoods in terms of the total number of community resources and diversity of resources within each neighborhood.

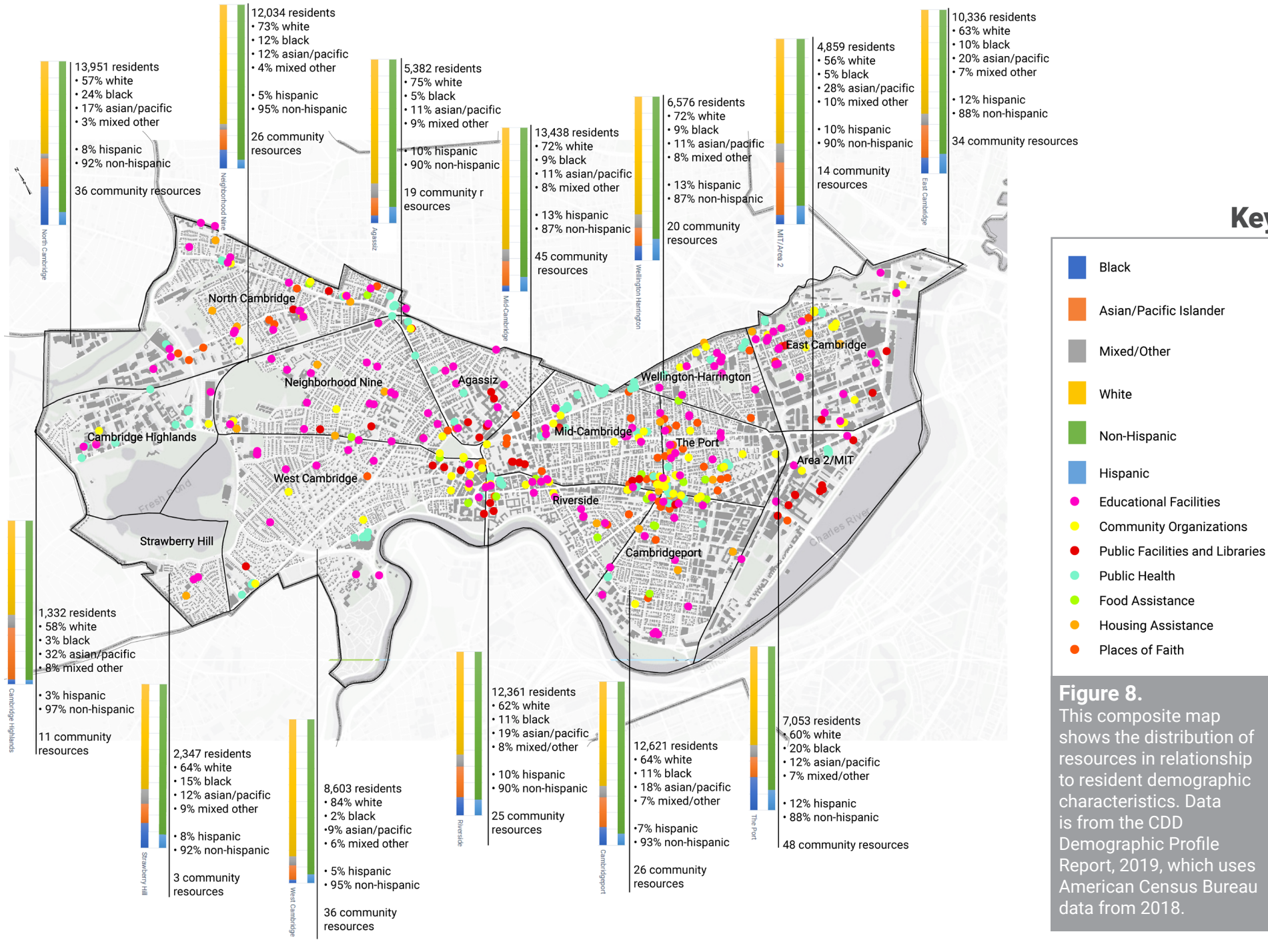


Figure 8.
This composite map shows the distribution of resources in relationship to resident demographic characteristics. Data is from the CDD Demographic Profile Report, 2019, which uses American Census Bureau data from 2018.

Recommended early actions

Cambridge already has a rich network of community-based organizations (CBOs), an asset we should build upon to successfully take on the strategies for Closer Neighborhoods. CBOs provide useful services to and opportunities for all demographic groups, but it is hard to know which residents regularly engage with these types of organizations. The first course of action can be to develop an inventory and a "hierarchy of services and skills" so that these crucial providers can be efficiently summoned to help residents at risk. The City could survey all organizations in the inventory to better understand their current capacity to serve residents. An online Community Resilience Network with an integrated referral service could be developed, building on the City's existing networks.

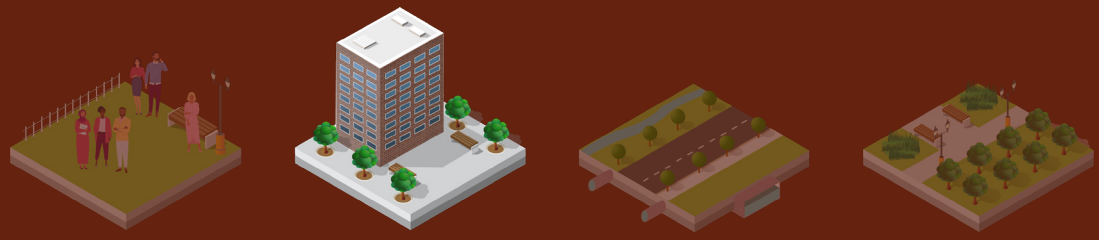
The City should work with its healthcare providers, first responders, and volunteer groups to develop a pre-disaster training program for these "front-line workers." Disaster and climate-related events present many unpredictable circumstances for which preparation is difficult. When an event occurs, "front-line" workers, those who provide essential services, and volunteers are called upon to provide for communities in exceptional ways.

The physical facilities that house these resources must be adapted for climate change to remain operational in times of crisis. This is a crucial step in ensuring service continuity and the resilience of residents. Community resources at risk should consider adopting recommendations for preparedness to extreme events, such as upgrading buildings to be prepared for flooding, raising utilities, and adding shading devices to buildings to protect from extreme heat.

During the 2020 coronavirus pandemic, CBOs and faith-based institutions have played a vital role in collecting and distributing resources to those most vulnerable. These same community resources would lead resiliency and volunteer efforts. The City could work with them to develop remote-function contingency plans to guarantee service continuity and help volunteers train for emergency scenarios.

Figure 9. Strong community networks are an important aspect of a resilient community. *Source: Kleinfelder*

Figure 10. Community resources, like the Margaret Fuller Neighborhood House, are a cornerstone of resiliency. *Source: Margaret Fuller Neighborhood House*



Resilient means our neighborhoods, homes, and buildings can withstand extreme weather

Better Buildings

Better Buildings

Cambridge has a diverse mix of housing types, historic buildings, small businesses, modern laboratories, and offices, as well as academic, cultural, and government institutions. The architecture of these buildings influences how we go about our day-to-day activities, how we interact with one another, and our ability to safely withstand the effects of climate change. An essential component of the urban ecosystem, buildings not only provide us with shelter and places for work and socializing, but also affect climate and the environment. Resilient building design can reduce urban heat, protect against flooding, reduce energy usage, and contribute to better stormwater management. Resilient Cambridge's Better Buildings strategies identify ways that Cambridge residents, property owners, and developers can adapt their buildings to our changing climate.

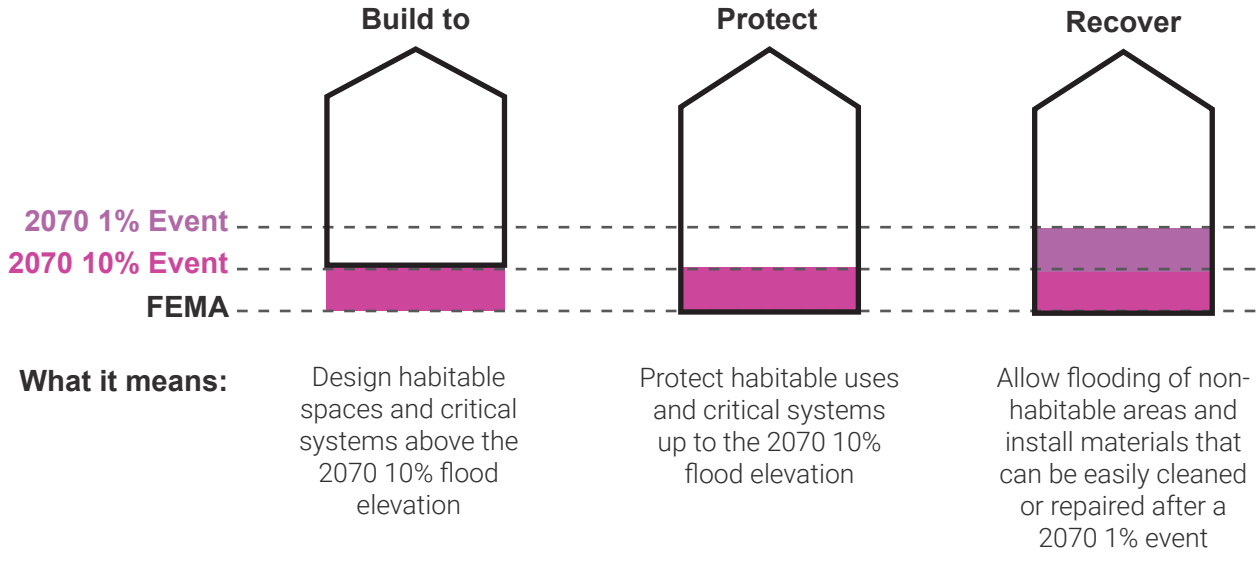


Figure 11. This figure defines the Build to/Protect to the 2070 10% Flood Elevation and Recover From the 2070 1% Flood Elevation. *Source: Better Buildings Technical Memorandum, Kleinfelder*

The City is an early adopter of sustainable building standards and has taken actions to mitigate the causes and impact of climate change. In 2013, the "Getting to Net Zero" Task Force put Cambridge on a trajectory toward achieving **carbon neutrality** by 2050, with a focus on reducing greenhouse gas emissions from building operations. However, acknowledging that climate change is already having an impact on the City, Cambridge is working with owners and developers to adopt new standards and practices that will make existing buildings resilient and new construction adaptable (Fig. 11). Resilient Cambridge's goal is to improve the resiliency of the citywide building portfolio.

The City is prioritizing flood mitigation infrastructure and supporting measures that property owners can take now to protect their buildings and improve resiliency. At the same time, the City is advocating for resiliency enhancements to regional infrastructure like the Amelia Earhart and Charles River dams and participating in watershed-scale green infrastructure studies. These measures would reduce flooding caused by precipitation, sea level rise and storm surge.

There are many ways buildings can be altered or designed to address climate hazards, and fully protecting a building requires a holistic approach to mitigate the risks of flooding and extreme heat. Measures such as insulation, dry floodproofing, wet floodproofing, energy resilience, passive and active ventilation, and cooling can help minimize operational disruptions and reduce physical damage to property. Better Buildings provides recommendations for policies, projects, and programs that guide the design of new buildings to address future climate conditions and to facilitate retrofitting existing buildings.

Flooding in the City is expected to increase and could result in damage to property and loss of life. The target is for all new buildings in Cambridge to be built to sustain functionality and protect to the **2070 10% Flood Elevation**—the water level elevation based on the projected **10% Annual Storm** event in 2070—from precipitation or sea level rise/storm surge, whichever is higher, and to recover from the **2070 1% Flood Elevation**—the water level elevation based on the projected **1% Annual Storm** event in 2070—from precipitation or sea level rise/storm surge, whichever is higher. The year 2070 is used as a target for building resilience based on the assumption that a building existing today would be replaced or significantly renovated in the next 50 years. Building permits for substantial renovations, such as exceeding 50 percent of the building, would also trigger similar requirements to assure that existing buildings are improved to sustain greater flooding risk.

About 6% of the buildings in Cambridge are at risk of flooding during a **10% Annual Storm** by 2070, and 6% of buildings are at risk of flooding from a 10% storm surge/sea level rise event by 2070 (Fig. 12). Less than 300 (< 2%) of the buildings in Cambridge are currently in the FEMA 1% Special Flood Hazard Area. Being proactive now will allow for new construction and major renovations to incorporate resiliency recommendations in a timely, cost-efficient manner.

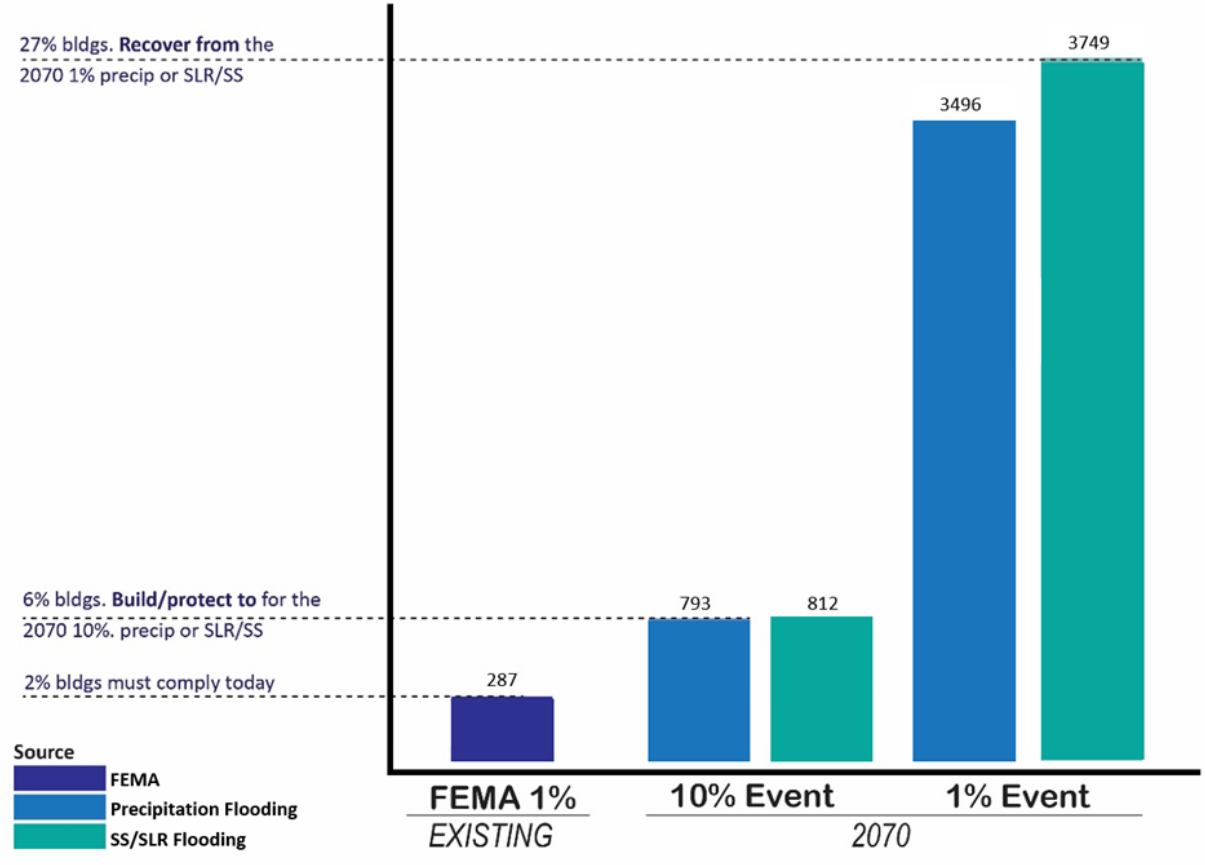


Figure 12. This chart identifies the number of buildings at risk of flooding in Cambridge. *Source: Woods Hole Group*

Several neighborhoods are more susceptible to flooding. The neighborhoods most impacted by the 2070 **10% Annual Storm** are located within the Wellington-Harrington, Cambridgeport, and The Port neighborhoods. Neighborhoods most impacted by 2070 10% storm surge/sea level rise flooding are North Cambridge, East Cambridge, and Cambridge Highlands.

Most of the actual buildings at risk of flooding in Cambridge are residential buildings, yet the most square footage at risk of flooding are in research and development (R&D), large commercial, and institutional buildings. Partnering with developers and institutions to implement resiliency measures will therefore have significant benefits in flood mitigation.

The City recognizes that critical facilities—fire stations, hospitals, utility services—need to withstand exceptional conditions during crises to maintain continuity. There are 35 critical facilities in Cambridge, of which 17 are at risk of flooding, and the recommendation is that they are protected up to the 2070 **1% Annual Storm**.

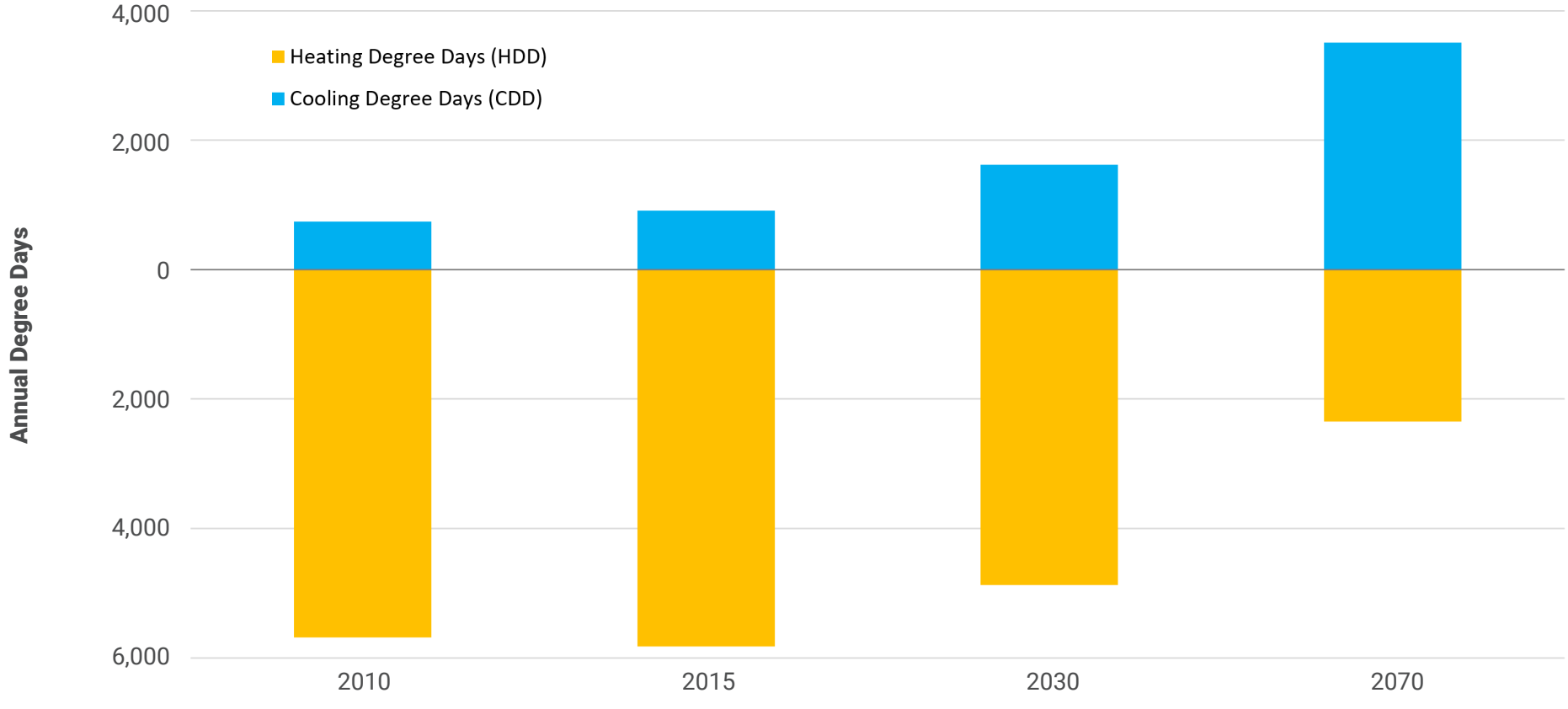


Figure 13. This chart shows the historic and projected annual heating and cooling degree days. By 2070, there will be more cooling degree days than heating.
Source: Adapted by Buro Happold from Petri, Y. and Caldeira, K. Impacts of global warming on residential heating and cooling degree-days in the United States, 2015.

Historic buildings also require special considerations due to their architectural and functional characteristics. Thirty-three buildings designated on the National Register of Historic Places are at risk of precipitation or coastal flooding. Most of the historic buildings in Cambridge are wood-framed structures, which are at risk of infestation, mold, humidity, and water damage. Working with the Cambridge Historical Commission, the City could assess which structures are most in danger and perform full risk and vulnerability assessments.

Mitigating heat and maintaining livable indoor temperatures are important to ensuring the health and well-being of Cambridge residents. Energy shortages might be more frequent as our infrastructure is stressed during heat waves, tropical storms, and hurricanes. To ensure human comfort and healthy air quality, new construction and major retrofits must adopt practices appropriate to our warming climate, which will create resilient buildings that can withstand extreme heat and higher humidity.

Although many residents in Cambridge tolerate summer heat with limited air conditioning (AC), rising temperatures to extreme heat will increase the need for cooling systems (Fig. 13). Compared to present-day building cooling loads, by 2030, cooling loads could double, and by 2070, cooling loads could be twice that of heating loads. It will be essential to utilize passive cooling strategies and site strategies that contribute to indoor comfort, as well as provide shade to the public realm.

Although the State requires landlords to maintain a livable temperature between 68ºF and 78ºF between mid-September and mid-June (the heating season), there is no similar requirement for cooling.

As part of the urban ecosystem, buildings can contribute to UHI reduction with lighter, reflective façades and **cool roofs**. Building roofs make up a significant amount of the land surface area in Cambridge, therefore improvement of those spaces to reduce UHI could have significant impacts on how the City feels.

Implementing Better Buildings strategies also means our neighborhoods, homes, and buildings can help reduce energy demand and greenhouse gas emissions. If each property adopts these strategies, the result would be a resilient citywide building portfolio, supporting the City in achieving carbon neutrality by 2050.

To effectively implement resiliency strategies, the following should be accounted for:

- Structure:
  - » Flooding causes pressure that can affect physical structures; the higher the depth of water, the greater the impact. Risks should be assessed based on the projected depth of flooding.
- Utilities:
  - » Location of utilities can play a vital role in the vulnerability of a building. Most critical heating, cooling, and electrical equipment is in the basement and must be replaced/relocated if exposed to flooding.
  - » Buildings that have mixed-mode ventilation systems, which include passive cooling, air source heat pumps, and ceiling fans, allow for redundancy of cooling methods and minimize energy consumption.
- Basement conditions:
  - » To prevent flooding in finished basements, openings in the building envelope can be enclosed or waterproofed. Windows at grade, exterior doors, exhaust, and utility penetrations must be assessed for their risk of flooding.
- Building envelope and openings:
  - » Impervious surfaces and materials that can withstand prolonged contact

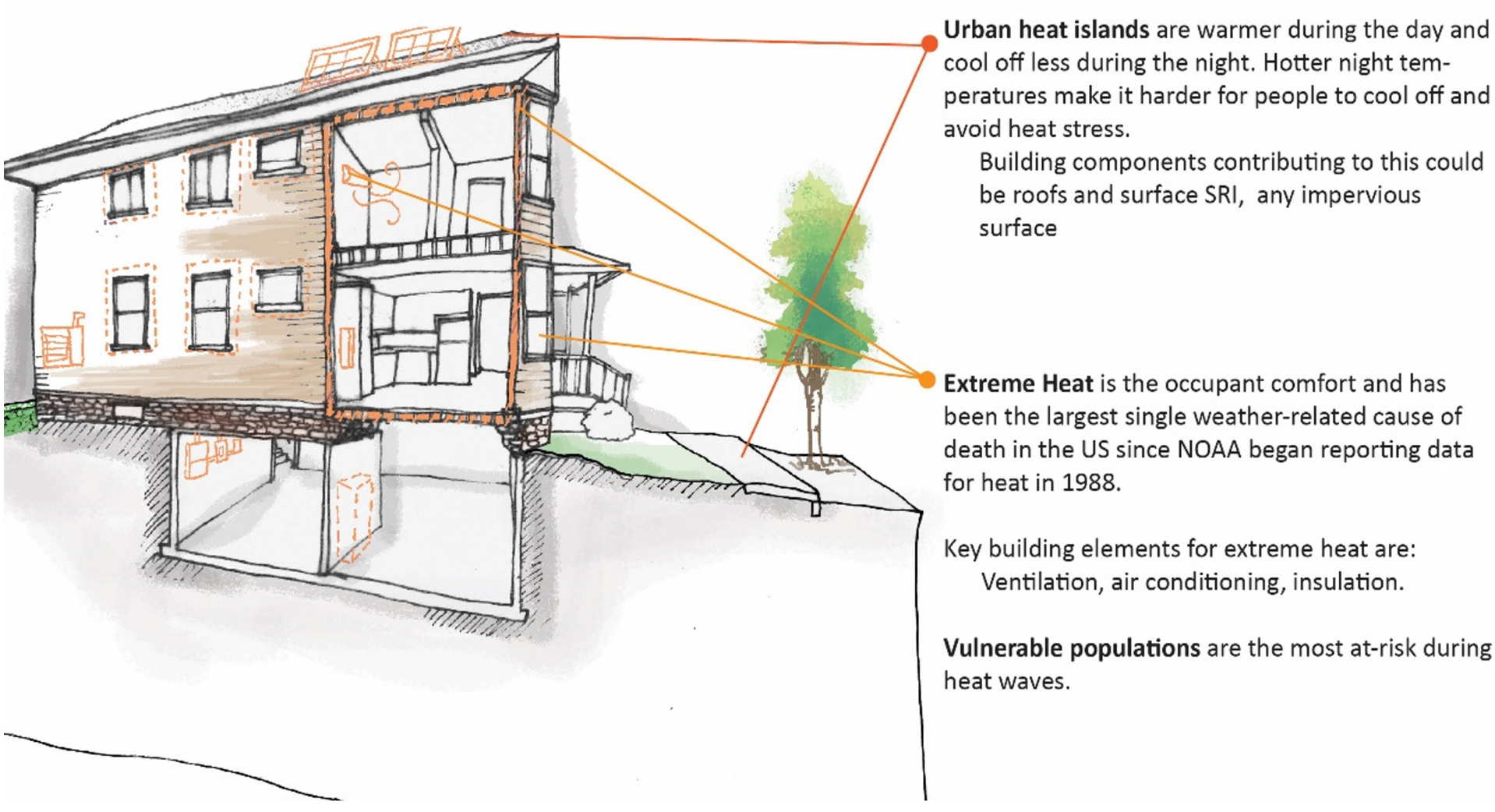


Figure 14. This diagram offers heat resiliency strategies for renters. *Source: City of Cambridge MVP Tool Kit, 2019*

with flooding, can survive repeated wetting and drying, and be cleaned to remove pollutants are important when designing for flooding. Concrete or masonry cladding stops water from penetrating the envelope, while wood-stud construction with a shingle cladding system allows water to enter through exterior walls.

» As Cambridge moves from a climate requiring more days of cooling than heating, existing conditions where vapor barriers are on the interior side of the wall will allow condensation to form. Creating a tight building envelope provides the most resilience during an extreme heat event by maintaining indoor comfort for longer when mechanical cooling and heating are not available.

» Windows allow passive cooling and more control of temperature during shoulder season weather. Glass is a good conductor of heat, specifically from direct light, often allowing too much heat to come into buildings, thereby heating up the interior. Window shades, shade structures, solar films, and triple-glazed windows can divert and minimize direct sunlight from heating up an interior space.

• Roof:

» Roof-scape green infrastructure can

	Strategy	Residential			Commercial and Research & Development	
		1-3 Unit Res.	4-25 Unit Res.	26+ Unit Res.	Small Com.	R&D/Large Com.
Flooding	Dry floodproofing	$ - $$	$$ - $$$	$$ - $$$	$$ - $$$	$$ - $$$
	Elevation of critical systems	$$$ - $$$$	$$$ - $$$$	$$$ - $$$$	$$$ - $$$$	$$$ - $$$$
	Elevation of structure	$$$ - $$$$	N/A	N/A	N/A	N/A
	Green infrastructure	$$	$$	$$	$$	$$
	Impervious surface replacement	$	$$	$$	$$	$$$
	Secure critical systems/infrastructure	$$ - $$$	$$$	$$$	$$$	$$$
	Water alarms	$	$	$	$	$
	Wet floodproofing	$$	$$	$$	$$	$$ - $$$
Heat	Cool Roofs	$ - $$	$$ - $$$	$$ - $$$	$$ - $$$	$$ - $$$
	Energy storage	$$	$$$ - $$$$	$$$ - $$$$	$$$ - $$$$	$$$ - $$$$
	Green roofs	$$ - $$$	$$$ - $$$$	$$$ - $$$$	$$$ - $$$$	$$$$
	Operable windows/shading structures	$$	$$	$$	$$$	$$$

Table 1. This table explains the relative cost of implementing resiliency strategies for residential and commercial buildings. *Source: Cadmus for the Better Buildings Technical Report by Kleinfelder, 2020.*

improve stormwater quality and blue roofs can detain water during peak rain events.

» White roofs or **cool roofs** reduce the building's contribution to UHI and can reduce energy load on the building by decreasing air-conditioning needs. Green roofs can reduce UHI and reduce heat loads on buildings due to their insulative properties; vegetation is a terrible conductor of heat.

One of the main challenges in ensuring that all Cambridge buildings are adapted for climate change is residents' ability to implement resiliency measures. Barriers may include Cambridge's high percentage of renters, building constraints that make implementation difficult, lack of adaptation knowledge, and insufficient funds.

Figure 15. Better Buildings strategies will help foster resilient neighborhoods protected from climate change. *Kleinfelder photo*

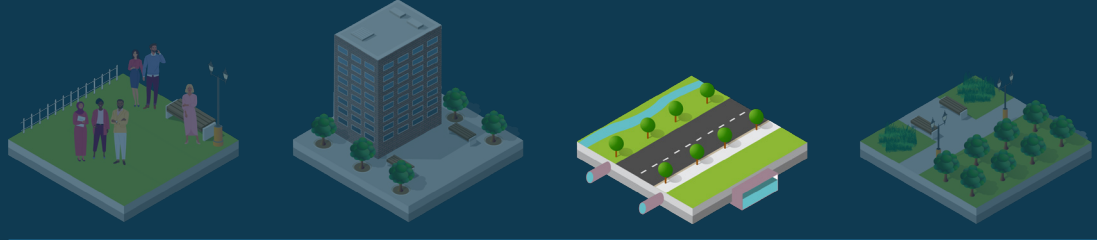
Recommended early actions

The Better Buildings strategies will help develop resilient neighborhoods that are protected from climate change impacts and designed for a rapid return to normal. To speed up the rate at which buildings are designed or retrofitted for future climate conditions, policies, projects, and programs will need to be developed to improve the resiliency of the buildings in Cambridge. The City will also continue advocating for resiliency strategies that are most effective at the regional scale.

The City could formalize recommended strategies by adopting regulations that support adaptation and resiliency to flooding and heat through zoning for new and retrofit buildings. New buildings are an opportunity for inherent resiliency features to be incorporated into these structures. To become a more resilient City, it will be critical to update existing buildings to be more resilient. The City could determine triggers for how retrofitted buildings could be required to meet standards for resiliency to flooding and extreme heat. By 2050, it is expected that most buildings will undergo a renovation of 50% or greater, which would be a good time to include adaptation and mitigation strategies. Analysis will be needed to understand the trade-offs between cost-benefit estimates for retrofits and the potential impacts of new policies and regulations on equity, housing affordability, and gentrification. Another policy could be requiring notification at a point of sale or in a rental agreement of risks from climate change impacts if the property has not been retrofitted for resiliency.

The City might consider developing a program to support small and medium residential and small commercial properties implement strategies for increasing the resiliency of their assets. Such a program could provide resources, technical information, or financial assistance. The City could work with institutions and large commercial/R&D property managers individually or as a group, using existing platforms such as the Cambridge Compact to share resources and expertise on the best approaches for resiliency.

Figure 16. Finch Cambridge, a housing project in the Alewife Quadrangle area, demonstrates resiliency best practices and can withstand extreme heat, power outages, and flood impacts. *Photo credit: Gregg Shupe*



Resilient means our City will be safer, cleaner, more flexible, and more enjoyable

Stronger Infrastructure

C

Stronger Infrastructure

The overall functionality of a city is necessarily tied to its infrastructure, much of which is out of public view or simply goes unnoticed until it ceases to function. In our daily life, we count on infrastructure to be efficient, affordable, and reliable. Our jobs, homes, and services depend on energy, water, transportation networks, and telecommunication to be functioning 24/7, most of which are parts of larger regional systems. Cambridge is a dense, urban city whose energy, communication, transportation, and water system infrastructure is complex and robust. Without functioning infrastructure, cities cease to function as designed, and populations become both physically and virtually stranded. Hurricanes Sandy and Katrina showed how fundamental and far-reaching that dependency can be. Residents were left without basic services for weeks, forcing individuals into temporary shelters, a disruption that further highlights existing inequities.

New design standards must incorporate future climate projections, and new projects must adopt progressive standards to alleviate the need to rebuild in the near future. The goal is for daily life to remain uninterrupted during climate-related events.

Most of the City's infrastructure was not built considering future climate change. The systems and services need to be enhanced to adapt to a new normal and larger and more frequent flooding caused by extreme precipitation, sea level rise, and storm surge.

Additionally, extreme heat will challenge progress toward Net Zero greenhouse gas emissions due to increased energy demand. Transportation and communication networks need to be modified and upgraded, which will require partnerships with State agencies and service providers. These new demands provide an opportunity to reimagine the system. The mechanisms to achieve

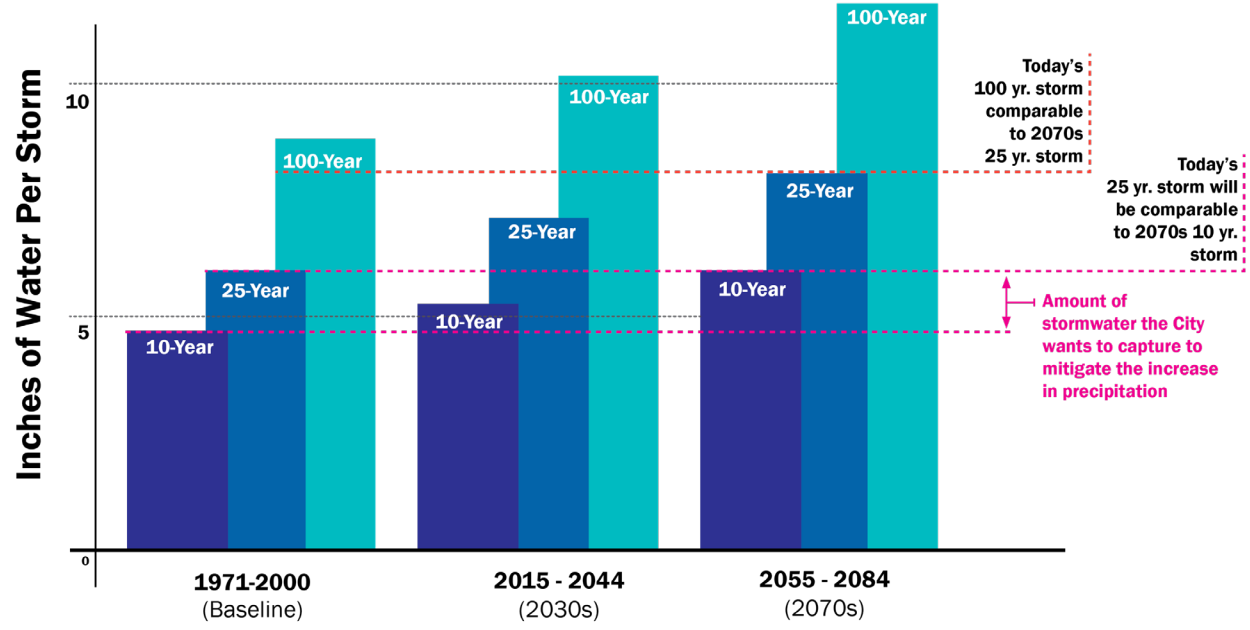


Figure 17. This chart shows precipitation projections. *Source: Kleinfelder based on ATMOS projections November 2015*

Stronger Infrastructure require an integrated approach that prioritizes the benefits of improved water quality, UHI mitigation, carbon storage, and air quality benefits. Investing in new infrastructure and retrofitting existing infrastructure to new climate conditions will pave the way toward resilience. The Stronger Infrastructure strategies include targets for mitigating flooding, adapting energy and telecommunication infrastructure facilities and systems, supporting resilient mobility, and protecting the drinking water supply.

The City is committed to improving stormwater infrastructure improvements with a goal of managing flooding from a **10% Annual Storm** by 2070 so it is no worse than a **10% Annual Storm** of today. This commitment will require upgrading the City's infrastructure accordingly to capture a significant volume of water accumulated during intense rain events and reduce runoff. In addition, it is recommended that these critical facilities be built or retrofitted using the resiliency recommendations for the **1% Annual Storm** in 2070, sea level rise/ storm surge, or precipitation event, whichever is higher.

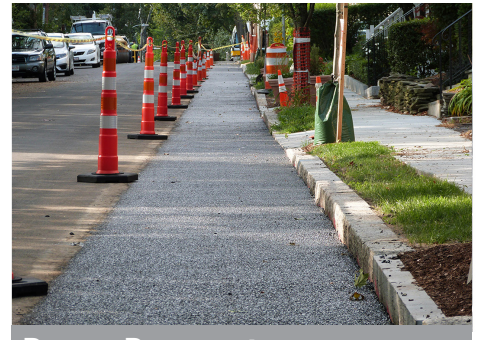
The City's analysis of its stormwater infrastructure applied a novel approach to assess flood impacts by evaluating both localized flooding within a small drainage area, as well as cumulative flooding at a larger scale within neighborhoods. This approach allows identifying effective combinations of **Gray and Green Infrastructure** strategies that can mitigate flooding impacts in each neighborhood.

The Fresh Pond Reservoir, our drinking water supply, needs to be protected because overland flooding can affect water quality and increased temperatures can lead to algal growth. The Walter J. Sullivan Water Purification Facility is one of 16 critical facilities identified in Better Buildings that should be protected from the **1% Annual Storm** in 2070 to ensure continuity of services.

Integrating **Gray and Green Infrastructure** could significantly reduce stormwater flooding in certain areas. The flood mitigation benefits of distributed green infrastructure have greater potential in drainage areas located upstream (higher elevation areas within Alewife or Neighborhood Nine). In these and other areas, the City is already considering co-benefits when planning and designing solutions to mitigate precipitation-based flooding, such as water-quality improvements, UHI mitigation, air quality benefits, greenhouse gas mitigation, and ecosystem and habitat improvement. A key finding for The Port neighborhood is that a

Green Roof

Rain Garden



Porous Pavement

Leaching Catch Basin

combination of **Green and Gray Infrastructure** strategies can effectively mitigate flooding from a high-intensity, short-duration storm (cloud burst, thunderstorm, or flash flood). These events are hyperlocal, meaning their impacts vary across Cambridge. The analysis is informed by the identification of the main causes of flooding, which vary by neighborhood and include piped infrastructure capacity and conditions, restrictions on catch basin openings, imperviousness and drainage system connectivity, topography, soil and groundwater conditions, and land use.

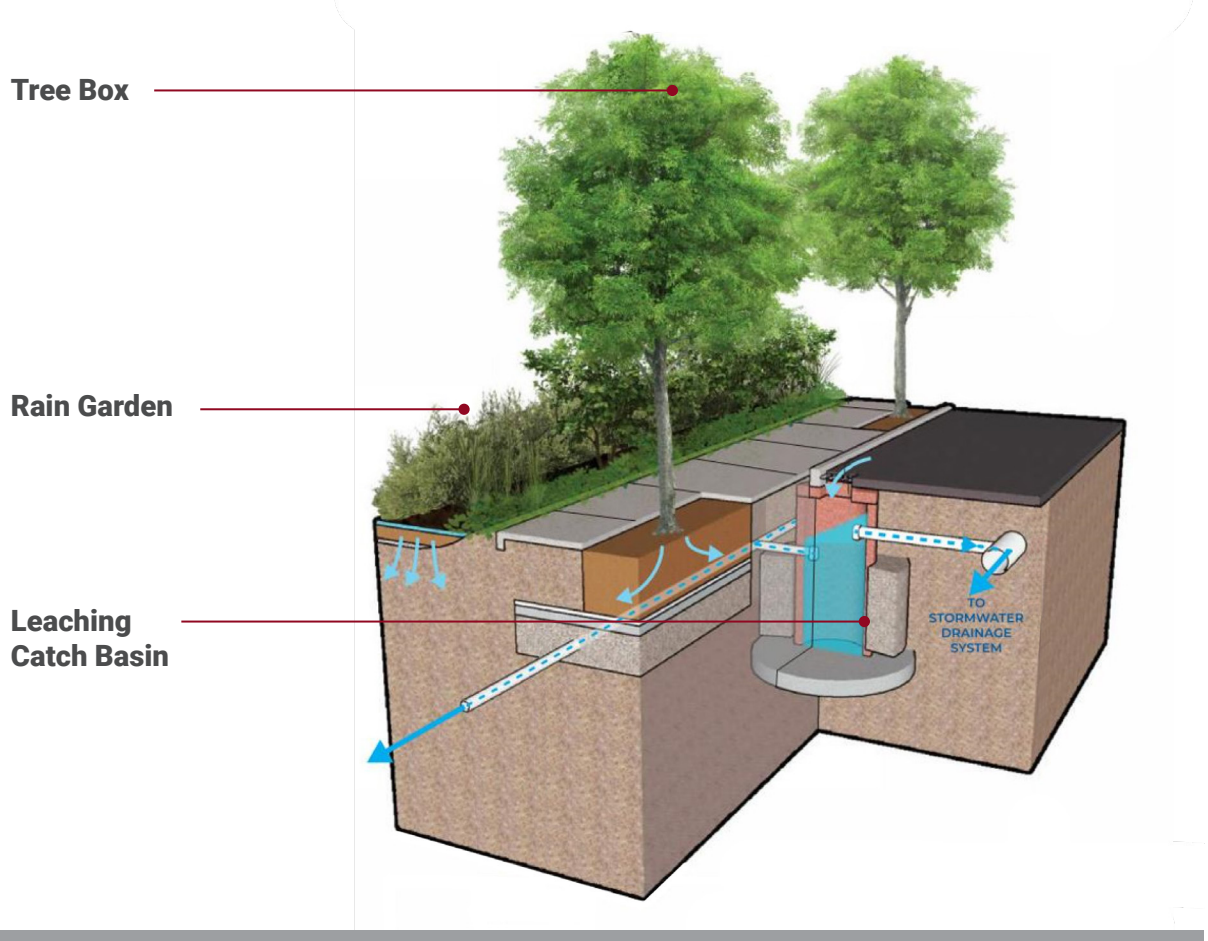


Figure 18. This diagram is a conceptual approach for connecting tree box filters and leaching catch basins. *Source: Kleinfelder, 2019*

Implementing "complete streets" design on main mobility corridors is an ideal opportunity for increasing green space, tree planting, and infrastructure strategies to mitigate UHI impacts and flooding (Fig. 19). Complete streets design also promotes reconfigured roadways that contribute to pedestrian and cyclist comfort.

Buildings and vegetated areas along main transportation corridors can provide shade and cooling to the public realm and contribute to a resilient mobility network for pedestrians, bicyclists, and public transportation users (Fig. 21). Increasing the reliability, comfort, and safety of these modes of transportation will also help minimize reliance on personal vehicles and reduce emissions.

Sustainable energy strategies will enhance resilience because they are designed to provide autonomy during extreme events while also reducing ongoing greenhouse gas emissions. Microgrids and community energy systems were studied as viable options for The Port and could work for other neighborhoods. Microgrids are groups of interconnected loads (buildings or other energy consumers) and distributed energy resources (on-site solar panels with batteries or natural gas generators) that can be controlled as a single entity,

continuing to deliver power during outages. Because microgrids require new construction, generation sources, and approvals processes, they are often costly to implement. A short-term solution may be community energy systems—groups of energy resources that are managed virtually. These can serve as the first step toward a traditional microgrid implementation and provide more time for financing and regulatory challenges to be resolved.

Telecommunication is increasingly essential as we rely more on the internet for work and for communicating. Equal and equitable access to reliable telecommunication infrastructure is critical not only for the continuity of operations for all sectors of the economy, but critical also for the resilience of communities when they are preparing for and recovering from a climate-related event. Telecommunication providers must build or upgrade their facilities to the City's Better Buildings recommendations to ensure service continuity during and after climate-related events. There are also promising solutions for more resilient networks that should be explored by providers in collaboration with the City.

Figure 19. This image is a "complete street," including flood and heat resiliency strategies.

Recommended early actions

The City is considering the following recommendations to address stormwater flooding and reduce urban heat:

- Integrate findings from the citywide analysis about where green/gray infrastructure strategies can be implemented into the design of priority projects (sewer and drain infrastructure plans, sidewalk and street reconstruction plans, sewer overflow management plans, open space plan).
- Consider the potential flood mitigation benefit, water quality improvements and UHI mitigation of individual projects as part of ongoing capital improvement planning.
- Integrate green and gray infrastructure recommendations into the identification, planning, and design of future projects.
- Retrofit catch basins within the highest green infrastructure opportunity areas and replace these with leaching catch basins, where existing soil conditions support the feasibility of such installations.
- Consider a requirement for new rooftops to maximize implementing green/blue roofs or a combination with other energy strategies like the New York City law that requires green roofs or solar panels on all new construction or on buildings undertaking major roof renovations.
- Develop citywide guidance materials for owners interested in implementing green/gray infrastructure in dense urban settings.
- Revisit stormwater policies for private development and major retrofits.
- Map out soil conditions, ground water, and soil contamination conditions to help identify locations where infiltration systems are suitable.
- Budget for the regular operation and maintenance of any green or gray infrastructure installation.
- Undertake a feasibility study to implement microgrids in Cambridge.

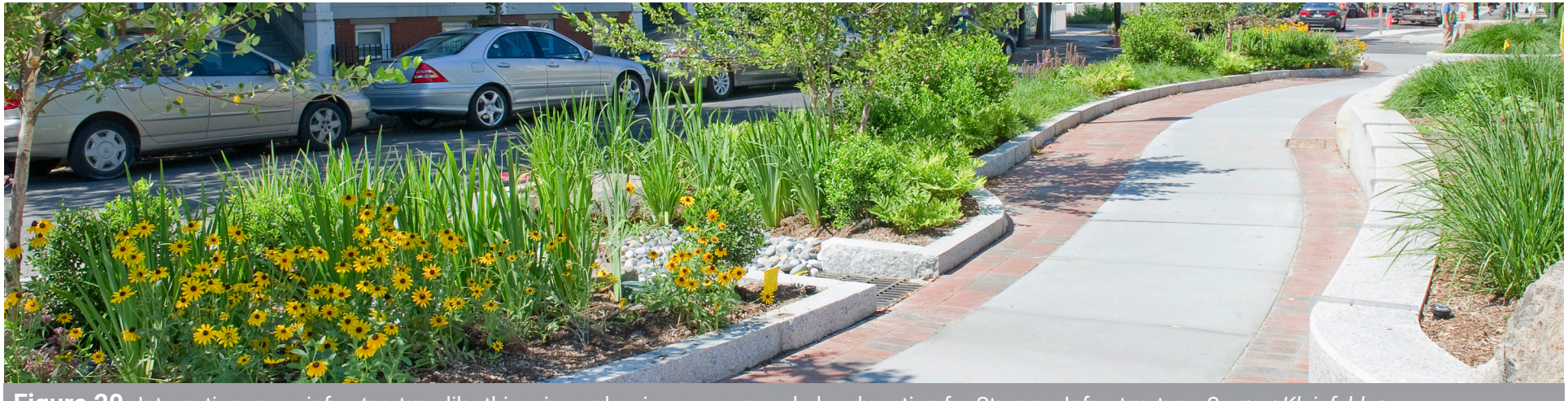


Figure 20. Integrating green infrastructure, like this rain garden, is a recommended early action for Stronger Infrastructure. *Source: Kleinfelder*

Figure 21. Vegetated areas along transportation corridors provide shade and cooling and contribute to a resilient mobility network. *Kleinfelder photo*

Resilient means more trees and plants on our roofs, streets, and buildings

Greener City

D

Greener City

The Charles River and Alewife Brook shape the City's eastern, southern, and western borders. Each is lined with green networks—large parks and institutional campuses—that provide spaces for residents to gather, while pocket parks provide neighborhoods with places to relax and meet, and tree-lined streets allow shady routes to traverse the City (Fig. 22). The dense urban environment in Cambridge complicates the implementation of new planting, and large areas of impervious surfaces exacerbate UHI impacts and flooding. Congested uses of the public right of way and development contributes to tree canopy loss and an increasing amount of impervious area. The challenge for Cambridge will be to balance its gray hardscape environment with its green planted environment, the latter of which is experiencing stress as climate change affects natural germination cycles and growing conditions.

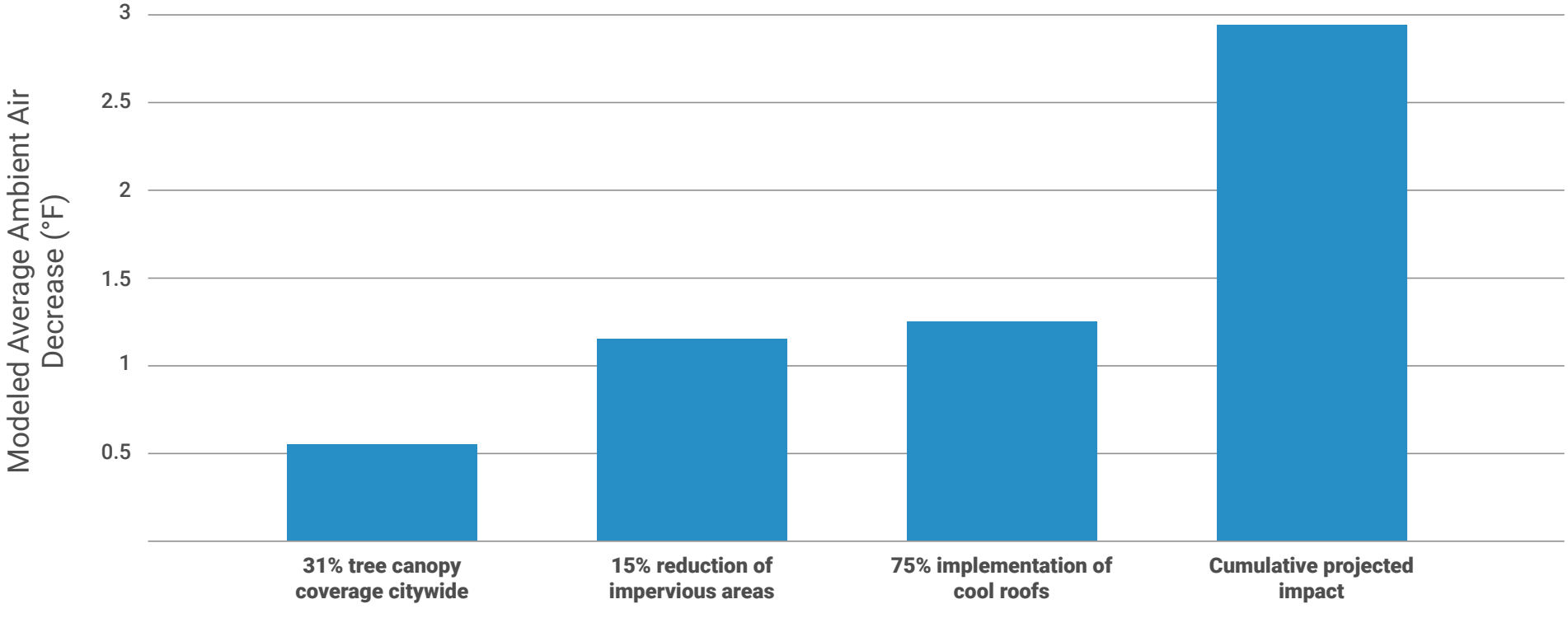


Figure 22. This chart shows the cooling potential for the proposed strategies. *Source: Urban Heat Island Technical Report, Kleinfelder for the City of Cambridge 2020*

The goals of Greener City cover four categories: increase vegetated areas (including roofs), expand the urban tree canopy and increase shade, enhance access to open space and healthy air quality, and promote the health and protection of waterways. Together, they add up to a more equitable living-systems network that all Cambridge residents can enjoy.

To achieve an equitable distribution and access to a Greener City, specific targets have been set for all neighborhoods: 40% of the City will have vegetated cover or be pervious; neighborhoods will see 25% minimum tree canopy coverage, with 30% coverage citywide; and neighborhoods will have access to open spaces that allow people to meet and play. The quality of vegetated areas is also an indicator for healthy planting that is being monitored by the City. Options for incentivizing healthy planting are being considered in proposed resilient zoning changes including the introduction of a "Cool Factor".

To better understand Cambridge's green spaces, an existing conditions baseline analysis determined higher priority neighborhoods with respect to indicators— such as tree canopy, pervious area, quality of vegetation—and found that neighborhoods east of Harvard Square have a low vegetation index and lack the amount of pervious surfaces and tree canopy found elsewhere in the City (Table 2). Yet these neighborhoods score high on proximity and accessibility to an open space network, providing some relief to people but with room for improvement. Strategies for a Greener City are prioritized to address inequities between urban neighborhoods.

Neighborhood	Pervious Area	Tree Canopy Cover	Vegetated Area (NDVI)	Access to Open Space
East Cambridge	High	High	High	Medium
Area 2/MIT	Medium	High	High	Low
Wellington-Harrington	High	High	High	Medium
The Port	High	High	High	Medium
Cambridgeport	High	High	Medium	Medium
Mid-Cambridge	High	High	Medium	Medium
Riverside	High	High	Medium	Medium
Agassiz	Medium	Medium	Low	Medium
Neighborhood Nine	Low	Low	Low	Medium
West Cambridge	Low	Low	Low	Medium
North Cambridge	Medium	Medium	Medium	Medium
Cambridge Highlands	Low	Medium	Medium	Low
Strawberry Hill	Low	Low	Low	Low

Key
- High Priority
- Medium Priority
- Low Priority

Table 2. This table illustrates the priority levels for the implementation of planting strategies by neighborhood. *Source: Greener City Technical Report*

In dense residential East Cambridge, The Port, Wellington-Harrington, Cambridgeport, Riverside, and Mid-Cambridge, there are fewer vegetated and pervious areas and tree canopy cover. Strategies in these areas should be targeted at the scale of the urban and public realm, including public right-of-way improvements, park retrofits, and land-use changes to facilitate the creation of publicly accessible open space. Strategies targeted at private parcels should acknowledge space limitations and consider building-scale strategies, such as green roofs, vegetated façades, and improvements to small lawn areas through ground and shrub planting.

West Cambridge, North Cambridge, Neighborhood Nine, Cambridge Highlands, and Strawberry Hill have a less dense urban fabric and more open, private parcel areas that can be improved through planting.

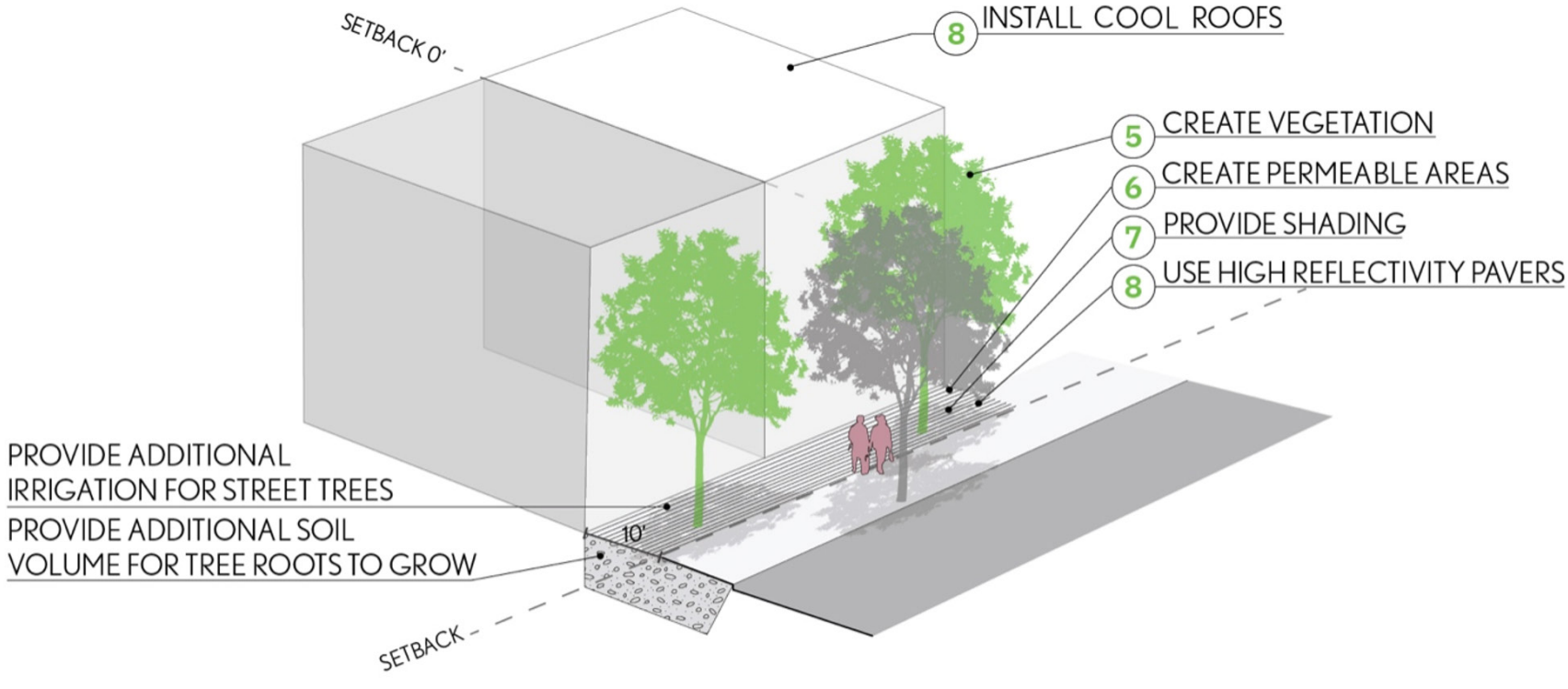


Figure 23. Illustration of proposed public realm enhancement by implementing a "Cool Factor." *Source: Kleinfelder, Reed Hildebrand and Weston & Sampson, 2020*

Strategies here might focus more on policies and programs for private property owners and developers to increase the quality and density of their vegetation.

Concurrently, the City is working with a Climate Resilience Zoning Task Force to foster best practices for new development and major renovations. The task force is developing a Cool Factor score proposed to be included in zoning guidelines (Fig. 23). Informed by Greener City analyses, the draft recommendations for the Cool Factor provide incentives for more trees and pervious surfaces adjacent to the public right-of-way, as well as suggested improvements to reduce extreme heat in private properties. While the focus is to implement "green" or planting strategies for enhanced thermal comfort, it is assumed that in certain locations, planting options may be limited. Consequently, hardscape alternatives are also encouraged to reduce UHI and reduce outdoor temperature to benefit both people and ecosystems.

Nature, like people, benefits when it is part of a network or system. Resilient Cambridge aims to look at the landscape as an integrated system with recommendations that foster a Greener City holistically.

Recommended early actions:

- Complete the development of the performance-based heat resilience standard discussed by the Climate Resilience Zoning Task Force and amend the Cambridge Zoning Ordinance accordingly.
- Complete a financial feasibility study of a small grant or subsidy program for property owners in East Cambridge, The Port, Wellington-Harrington, Cambridgeport, Riverside, and Mid-Cambridge neighborhoods to make vegetative improvements to their properties based on the menu of options provided in the Cool Factor.
- Implement recommendations of the Urban Forest Master Plan to improve tree canopy in the public right-of-way, including allocating more space within the street for tree plantings. Integrate Greener City resiliency strategies and considerations into the City of Cambridge Open Space Plan update .

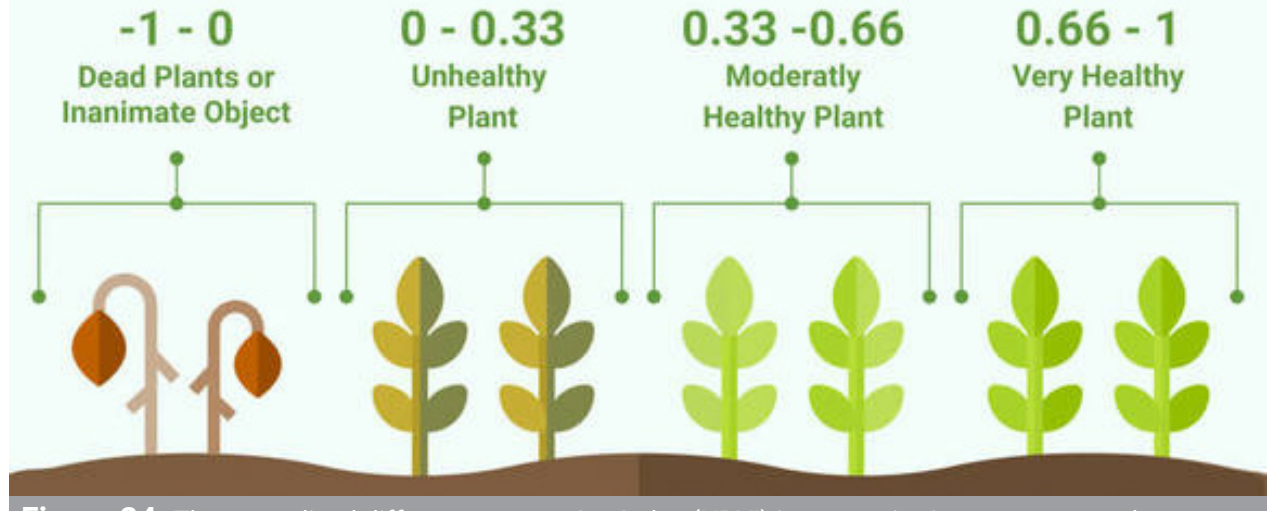
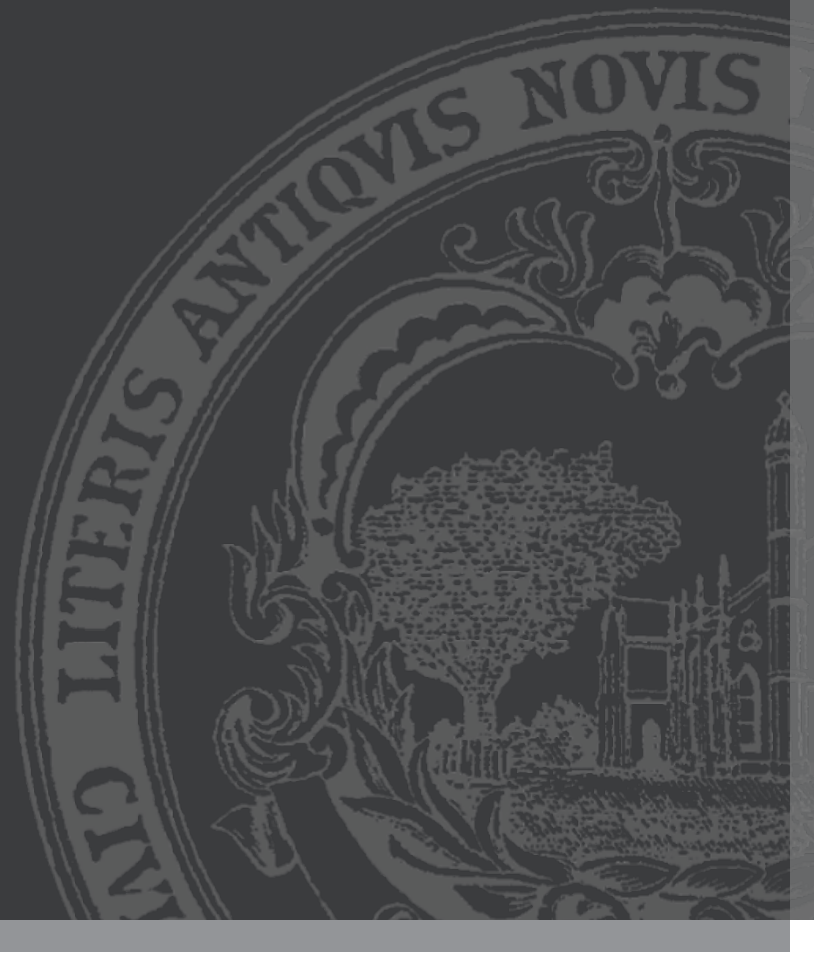


Figure 24. The normalized difference vegetation index (NDVI) is a quantitative measure used to indicate the presence and quality or density of vegetation. NDVI values range from +1.0 to -1.0. Areas of barren rock or sand show very low NDVI values (for example, 0.1 or less). Sparse vegetation such as shrubs and grasslands or aging crops may result in moderate NDVI values (approximately 0.2 to 0.5). *Source: USGS*

The City's water bodies and wetlands are significant components of the urban landscape, with Fresh Pond Reservoir having the added importance of serving as the City's primary drinking water supply. Improvements to the City's green, vegetated spaces will help improve water quality in downstream water bodies in addition to other benefits. The 3.4-acre Alewife Stormwater Wetland (Fig. 25) was created to receive and treat stormwater before slowly discharging it into the Little River. The wetland is an example of a successfully implemented project in the City that highlights the interaction of native vegetation with water to provide flood mitigation, enhanced water quality and wildlife habitat, and public access to a green space.

Figure 25. The Alewife stormwater wetland also serves as open space for residents to enjoy. *Source: Stantec*

A RESILIENT FUTURE



A Resilient Future

The City of Cambridge is tackling climate change with bold new policies, programs, and infrastructure. These actions are preparing our City for immediate changes while helping limit the impact of climate on our neighborhoods and communities, thereby contributing to healthier lives and a resilient economy.

Cambridge is already responding

In the last few years, the City has led a comprehensive and integrated planning effort to address both climate mitigation and adaptation. Initiatives include:

- The Envision Cambridge citywide plan, which highlights resiliency actions related to climate and the environment
- The Climate Change Vulnerability Assessment
- Preparedness and resiliency plans for Alewife and The Port
- An updated Climate Action Plan aligned with the **Net Zero Action Plan**
- A comprehensive Urban Forest Master Plan to evaluate, maintain, and expand the urban forest canopy
- An Open Space Plan to enhance and strategize planning of open spaces
- A Climate Resilience Zoning Task Force to build on climate planning efforts, with a focus on amending development standards.

The City has also built projects to enhance resiliency, such as:

- The Alewife Stormwater Wetland, a significant enhancement of vegetation and hydrologic ecosystems and a noteworthy collaboration between the City's Department of Public Works and the State's Department of Conservation and Recreation
- A 400,000-gallon tank in The Port to reduce flooding from stormwater during precipitation events (Fig. 26)
- Continued sewer separation to prevent combined sewer overflows from the Huron/Concord neighborhood to Alewife Brook, Mystic River, and Boston

The City is building for change. Government action is not enough. Cambridge needs the buy-in and actions of its citizens to ensure our neighborhoods and futures are stronger, safer, and healthier. In the last few years, many public and private developments have incorporated resiliency and sustainability elements by designing with progressive design flood elevations or meeting the Net Zero goal for achieving carbon neutrality by 2050. In the last 10 years, there has been a 20% increase in **cool roofs**, or green roofs, which help reduce the effects of UHI. Finch Cambridge, a housing project in the Alewife Quadrangle area, demonstrates resiliency best practices by meeting **Passive House Standards** to achieve energy efficiency in buildings—and can withstand extreme heat, power outages, and flood impacts. Residential units are located above the projected flood elevation from the **1% Annual Storm** in 2070, while the ground level includes essential services that can easily rebound from flooding. There is a community room located on the upper level, above the flood elevation, that can function as an emergency shelter-in-place location.

The City is communicating change, making information available and accessible to all. An online tool called the FloodViewer provides design flood elevations for every Cambridge parcel within the projected flood areas, so

developers and owners have clear information on their flooding risk under present conditions and in the future. The City plans to keep updating the FloodViewer to provide residents with the best available data on climate change projections and future flood risks.

The City is engaged for change. Since 2012, residents, businesses, and institutions have participated in discussions about climate change's impact on Cambridge. Neighborhood plans in Alewife (2017) and The Port (2019) were shaped by the voices of the community and provide a vision for resilient neighborhoods. Resilient Cambridge provides a suite of strategies and an implementation roadmap for near-term actions that are shaped by the community's needs. Stakeholder engagement has been diverse. One example is a 2018 collaboration between the Public Health Department and teenagers in the Mayor's Summer Arts Program. Along with a companion workshop guide, a video featuring interviews with residents on climate change issues in The Port is available for community organizations to further encourage residents to protect themselves and their neighbors. The City

Figure 26. The construction of the PL6 tank in the Port is part of a comprehensive plan to capture excessive stormwater in the neighborhood during extreme weather events. *Source: City of Cambridge, June 2020.*

Remembrance of Climate Futures

"Remembrance of Climate Futures" by Thomas Starr is a series of site-specific installations that address the urgent civic issue of climate change by contrasting the distance between its global scale and the local effects on people's lives and their communities.

Using VR to Learn About Our Climate

Virtual reality technology (VR) helps imagine a climate changed future at a specific location. With VR, one can view flooding scenarios in The Port neighborhood caused by extreme precipitations in 2070. The VR experience also illustrates resilient strategies that could be implemented in that specific location. *(Developed by Kleinfelder for Resilient Cambridge)*

developed a set of four toolkits for preparing for extreme heat and flooding that were funded by the state's Municipal Vulnerability Preparedness grant program (MVP). These toolkits address the unique resiliency needs of renters, homeowners, small businesses, and large organizations.

Art, too, has the capacity to help residents imagine what the future may look like—one with no action taken and one with positive changes implemented. It can be a useful tool for understanding the possible transformations brought by climate change and generating discussion about what is at stake. In May 2019, local artists presented their interpretations of the current state of climate change in the exhibit "Untold Possibilities at the Last Minute" at the Cambridge City Hall Annex. The exhibition and opening provided a forum to express fears and hopes about a City changed by climate. Inspired by the discussion, the Jose Mateo Dance Company created Dance for the World, which aims to empower participants to collaborate in the well-being of their community.

Regional considerations

An urban ecosystem will fare better if it acknowledges the strength of working together with surrounding communities and operates with that collaborative spirit. Regional efforts can take many forms. The City of Cambridge has been a leader in initiating regional discussions about resiliency, particularly since many of these discussions lie outside the jurisdiction of single communities. The City is working with key stakeholders and partners, including the Department of Conservation and Recreation, State agencies such as the Massachusetts Emergency Management Agency and the Executive Office of Energy and Environmental Affairs, the Mystic River Watershed Association, Resilient Mystic Collaborative (RMC), the Charles River Watershed Association, and the Metro Mayors Climate Preparedness Task Force.

In 2019, to better understand regional UHI impacts, Boston's Museum of Science and local citizen scientists working with City planners collected data to map out ambient air temperature variabilities in Boston, Cambridge, and Brookline at different times during typical summer days. The project, supported by a National Oceanic and Atmospheric Administration grant, entailed teams that drove together during hour-long mapping periods. The 3D-printed car-mount and heat-sensing equipment allowed them to attach a sensor device to the car and record the temperature and location data of surrounding areas. The City of Cambridge is now collaborating with the Metropolitan Area Planning Council on a regional heat analysis and implementation plan funded by the State MVP program. This "Wicked Hot Mystic" project will develop a regional map of day- and night-time "real feel" ground-level heat and humidity, allowing municipalities to prioritize investments into the hottest UHIs and measure the cost effectiveness of various interventions.

As part of the RMC's Upper Mystic Stormwater Working Group, Cambridge received a State MVP grant in 2019 to refine the watershed-wide flood model and identify opportunities for stormwater flood mitigation on a regional scale. "Shovel ready" pilot projects using green infrastructure to reduce stormwater flooding and increase water quality were identified by ranking the 425 open space parcels of 3 acres or more across the Upper Mystic River Watershed. A second MVP grant was awarded to support advancing the design of three constructed wetlands to provide both local and regional flood-reduction benefits. The intent of these projects is to contribute toward developing a regional stormwater management plan at the watershed scale. The projects revealed that it is unlikely there are sufficient resources to create enough wetlands to fully manage stormwater flooding and further underscores the need for regional cooperation.

In 2020, MassDOT updated the Boston Harbor Flood Risk Model with the Massachusetts Coast Flood Risk Model (MC-FRM), which uses the latest sea level rise projections that the State has adopted as part of the integrated 2018 State Hazard Mitigation and Climate Adaptation Plan. According to this updated model, the average sea level, or **Mean Sea Level**, in the Boston Harbor is expected to be 1.2 feet by 2030, 2.4 feet by 2050, 4.2 feet by 2070 and 7.6 feet by 2100 under a "high" scenario. The City is committed to using the model's best available data to inform future flood risk from sea level rise and storm surge, as well as in developing adaptation strategies to mitigate these risks within Cambridge and in the region.

The flanking and overtopping of the Amelia Earhart Dam and the Charles River Dam have regional consequences and are significant concerns for many communities in the Mystic River watershed and the Charles River watershed, including Cambridge. By 2050, both dams are at risk of being bypassed or overtopped. A suite of strategic site interventions at and around these dams can increase their flood resiliency, as well as protect towns and cities in these watersheds (Fig. 27). The analyses performed by the City found that over 7,550 acres of land area could be protected by these interventions. Across the 15 municipalities that are shown to benefit from these interventions, this protection extends to over 11,750 individual properties and would protect over $58 billion of real estate value within the Mystic River and Charles River watersheds (over $25 billion of which is in Cambridge). It is estimated that the 10 SLR/SS interventions collectively protect more than 108,000 people across the municipalities, including many socially vulnerable populations, proportionally (i.e., minority, low-income, elderly, English isolation, and those without vehicle access).

The City's analysis found that without these interventions, flooding from a 1% coastal SLR/SS event in 2070 would significantly impact key commercial hub areas, as well as key institutional and knowledge economies, research and development engines, and core biotech, life sciences, finance hubs. Impacts would also be significant to low-lying regional energy and utility infrastructure; at least 10 MBTA rail stations; key local/state roadways; significant historic/cultural assets and drivers of regional tourism and recreational activity; and the regional produce food distribution center. The City is collaborating with the State and other entities on evaluating intervention options, such as berms or flood barriers at strategic sites, to increase flood resiliency in the Mystic and Charles River watersheds.

The City will continue working with regional infrastructure owners, such as the Massachusetts Bay transportation Authority (MBTA), the Massachusetts Water Resources Authority (MWRA), Eversource, and telecommunication providers for increasing the resilience of their infrastructure. For example, the MBTA is conducting a climate change vulnerability assessment for the Red Line and the City has been coordinating with MBTA to share data as needed.

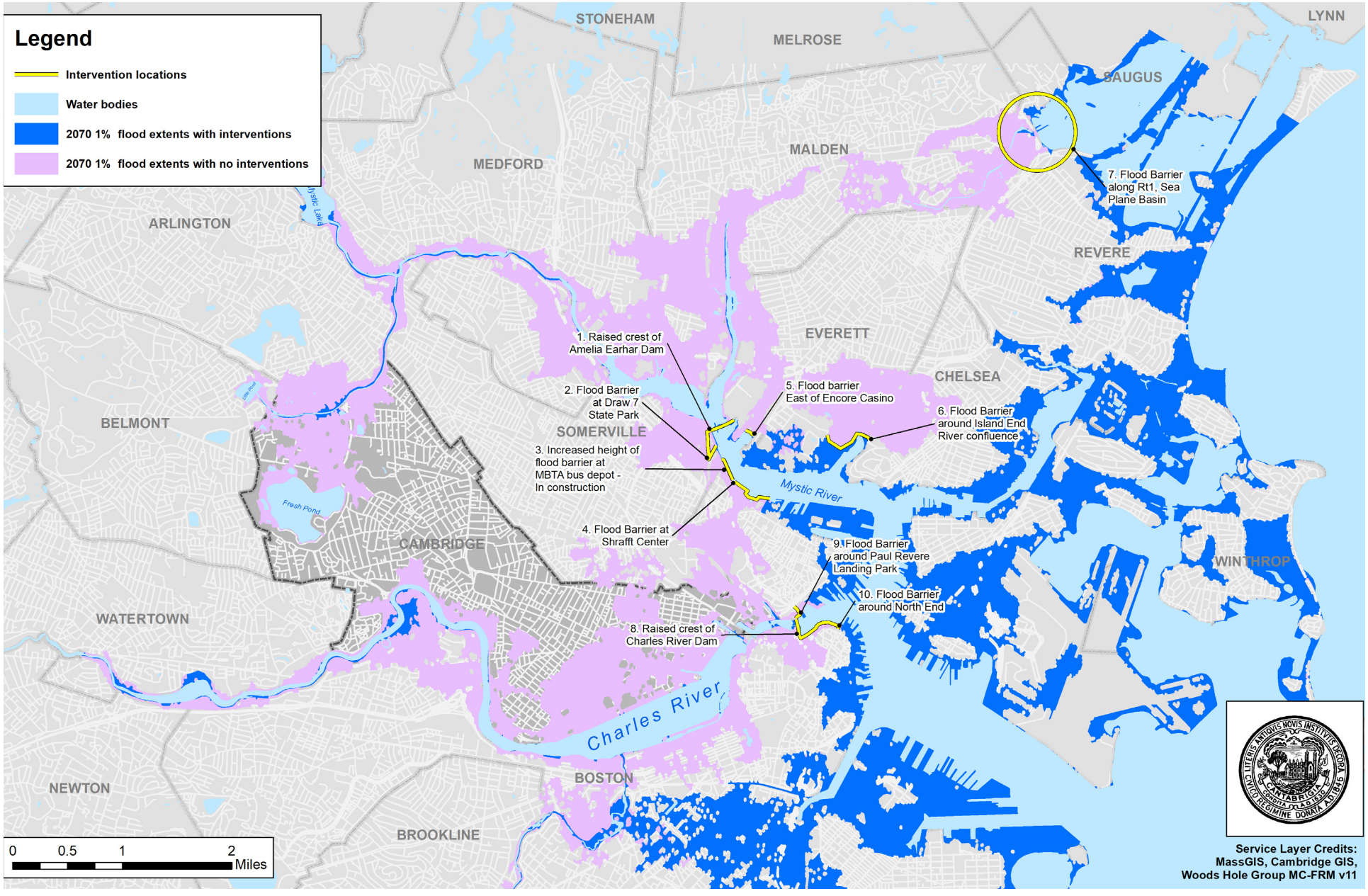


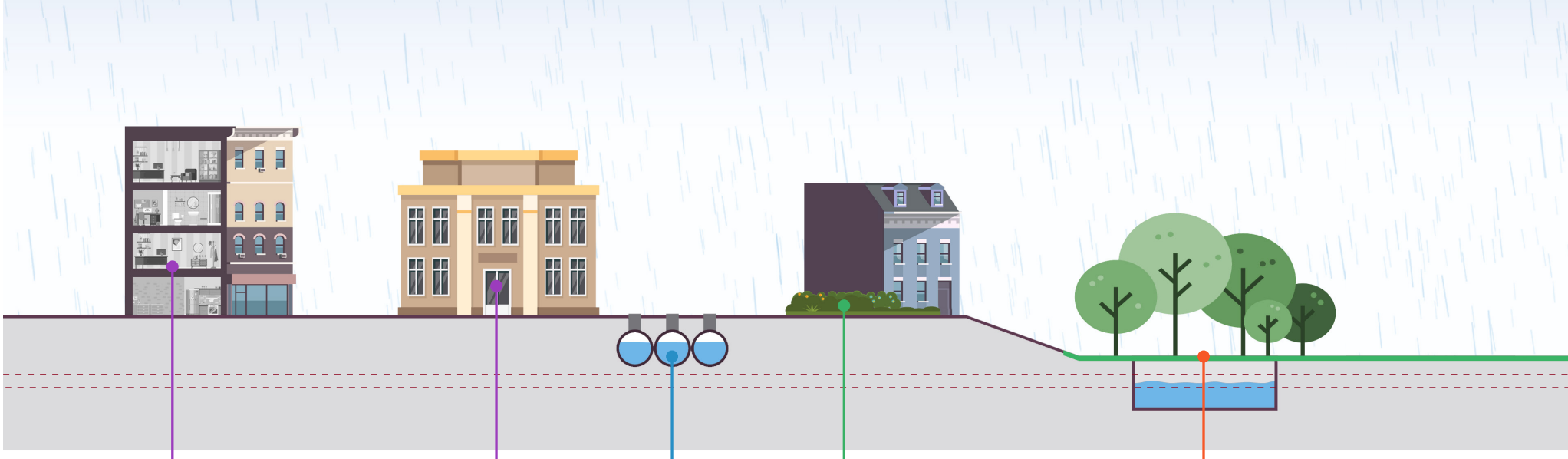
Figure 27. This map illustrates where flooding will occur. Cambridge proposed interventions at the Amelia Earhart Dam and the Charles River Dam to protect upstream municipalities from sea level rise and storm surge. *Source: Woods Hole Group*

Visions for a Transformed City

The City of Cambridge is preparing for the effects of climate change. We are ready for the positive changes that we will experience in our City and lives when we take action. The following pages illustrate what the City will look like in the resilient future. Together, cool streets, flood-resilient neighborhoods, and climate-prepared communities will help build a stronger, healthier, and more connected City.

It starts with cool streets that provide safe, flexible urban spaces. They are built with light-color materials and include green infrastructure and trees for an enhanced urban forest. These strategies could reduce the temperature in localized hot spots by 1-3°F, contributing toward a heat-resilient urban ecosystem.

The flood-resistant neighborhoods follow, protecting our buildings, infrastructure, and communities so we are better prepared to mitigate flood risks and enhance the quality of our natural environment. Buildings, or their key utilities, are elevated above projected



Help business associations prepare a disaster preparedness plan **(A)**

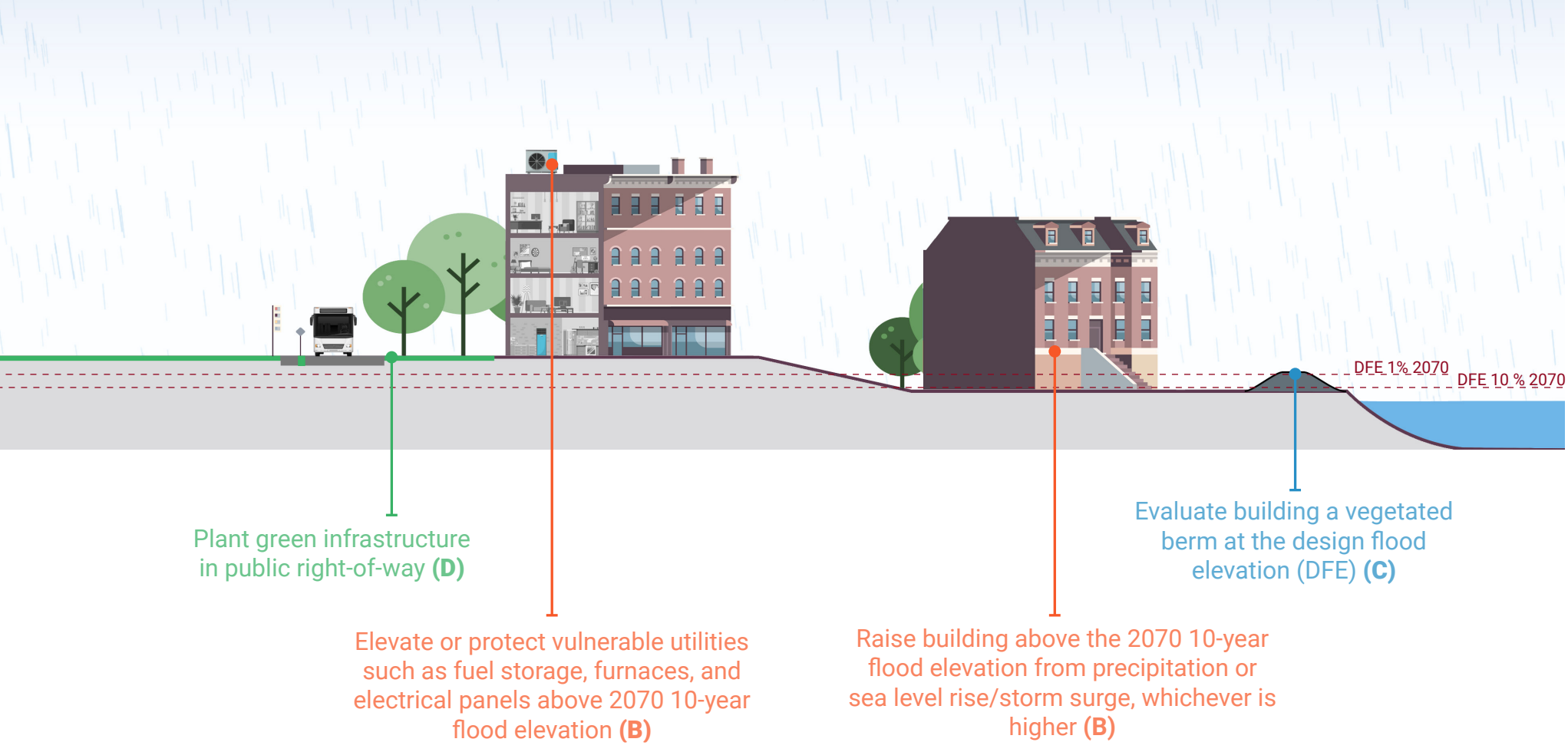
Establish support hubs **(A)**

Maximize Inflow & Infiltration **(C)**

Implement rain gardens on properties to retain water on a parcel **(D)**

Implement on-site store/ retain/delay strategies for stormwater (B)

flood elevation, and gray and green infrastructure are maximized to capture, slow, and clean stormwater flow. Implementing these strategies could mean the more frequent and intense 10% Annual Storm of 2070 is no worse than the 10% storm of today.



Finally, we achieve a Resilient Cambridge comprising a climate-prepared community with neighbors who connect, live in better buildings, benefit from stronger infrastructure, and enjoy a Greener City .

Before

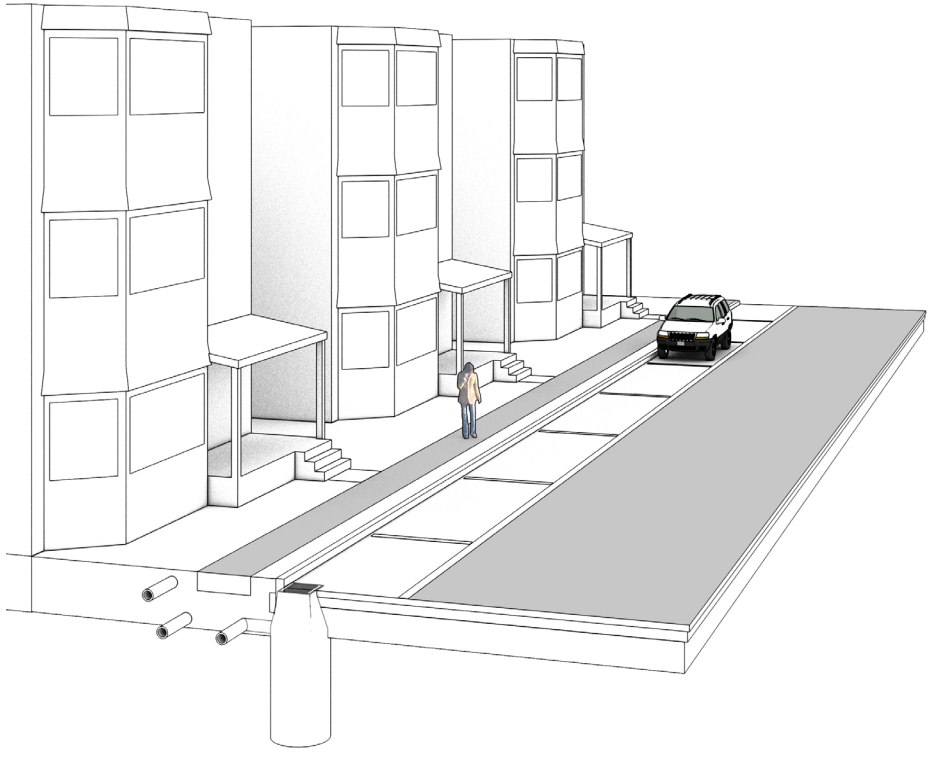
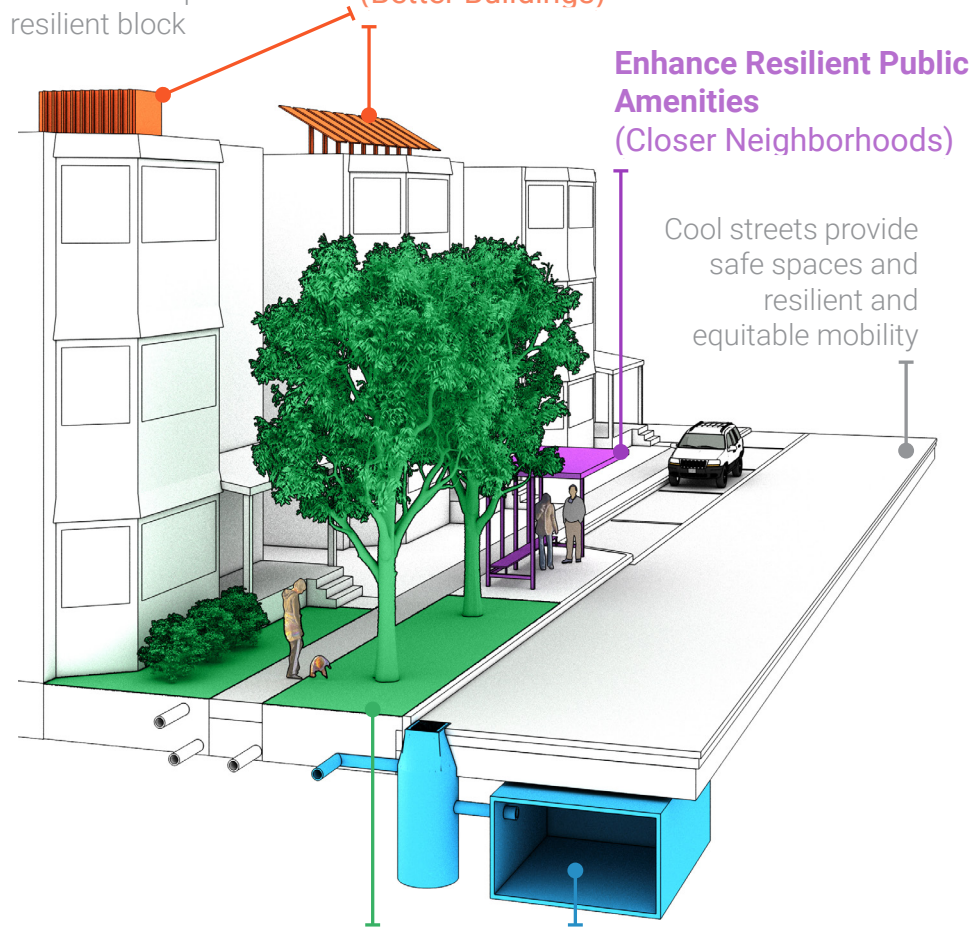


Illustration not to scale

After

Strategies combine to create a super resilient block



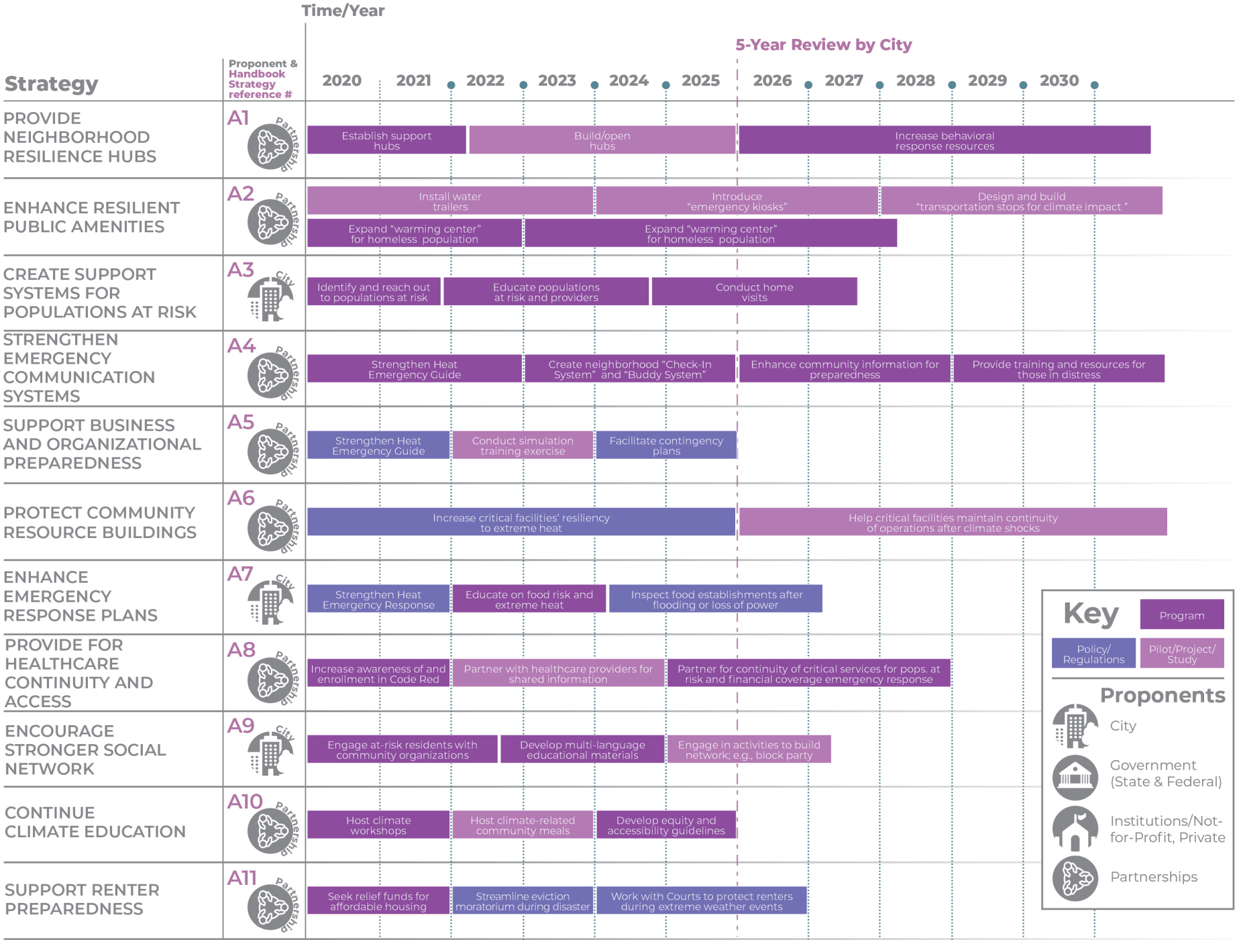
THE WAY FORWARD

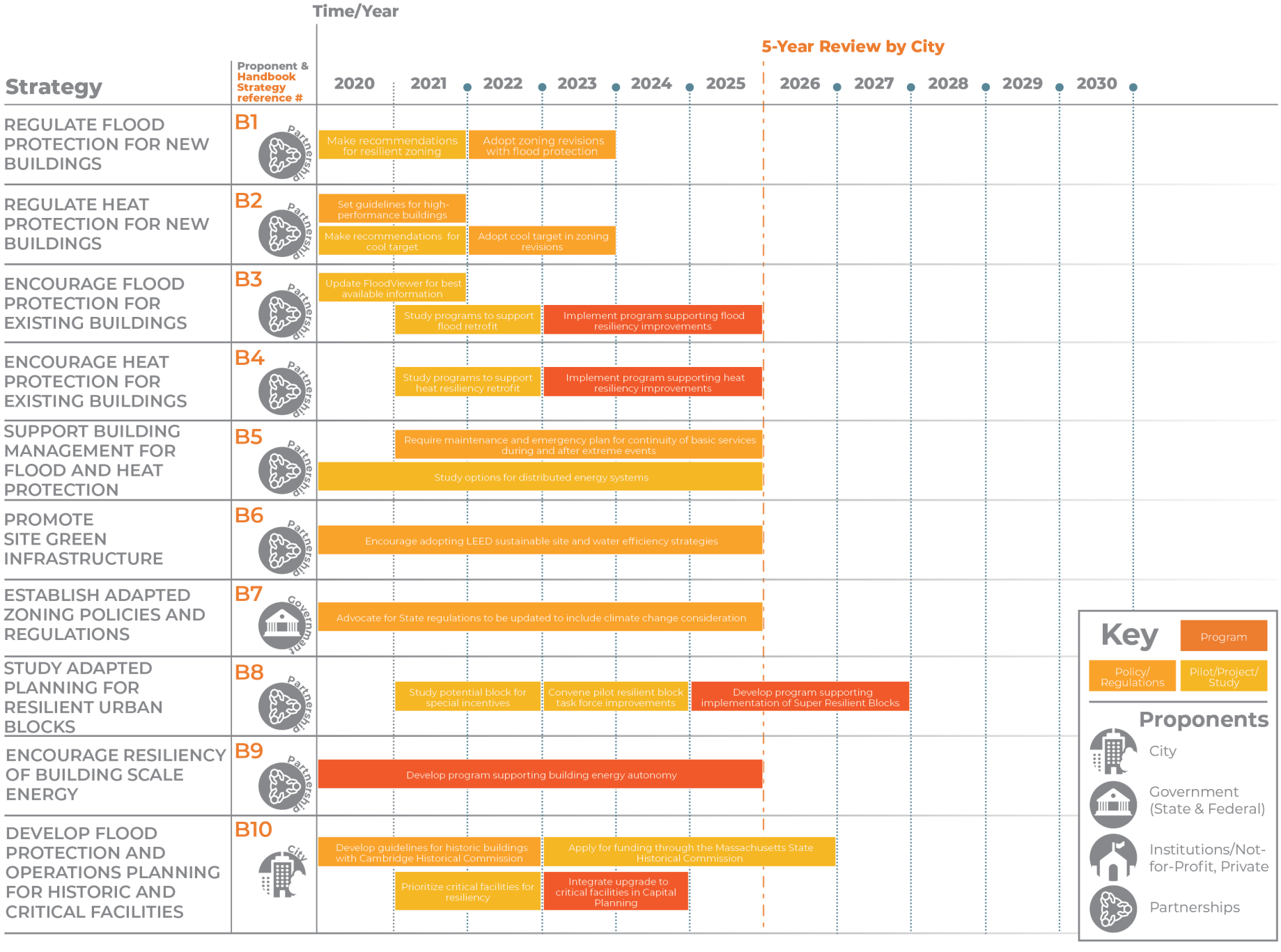
The Way Forward

Addressing climate change requires that we be proactive. Climate change is not distant or intangible; it is already affecting our environment, our approach to business, and our lives. Strategies in Resilient Cambridge have been developed to demonstrate the variety of ways we can act now to provide for a better and safer future.

Resilient Cambridge lays out a roadmap based on four groups of strategies to create a Cambridge that is more prepared and resilient for a changing climate. The effort will be continuous. Recommendations are made for specific actions to be taken over the next 10 years. Updates to Resilient Cambridge will be made periodically to build on this work and to adjust to new information, technology, and opportunities.

Figure 28. Resilient Cambridge will enable us to continue celebrating Cambridge. *Source: Cambridge Arts*


Time/Year
5-Year Review by City
Strategy
Proponent & Handbook Strategy reference #
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
PROVIDE NEIGHBORHOOD RESILIENCE HUBS
A1
Partnership
Establish support hubs
Build/open hubs
Increase behavioral response resources
ENHANCE RESILIENT PUBLIC AMENITIES
A2
Partnership
Install water trailers
Introduce "emergency kiosks"
Design and build "transportation stops for climate impact "
Expand "warming center" for homeless population
Expand "warming center" for homeless population
CREATE SUPPORT SYSTEMS FOR POPULATIONS AT RISK
A3
City
Identify and reach out to populations at risk
Educate populations at risk and providers
Conduct home visits
STRENGTHEN EMERGENCY COMMUNICATION SYSTEMS
A4
Partnership
Strengthen Heat Emergency Guide
Create neighborhood "Check-In System" and "Buddy System"
Enhance community information for preparedness
Provide training and resources for those in distress
SUPPORT BUSINESS AND ORGANIZATIONAL PREPAREDNESS
A5
Partnership
Strengthen Heat Emergency Guide
Conduct simulation training exercise
Facilitate contingency plans
PROTECT COMMUNITY RESOURCE BUILDINGS
A6
Partnership
Increase critical facilities' resiliency to extreme heat
Help critical facilities maintain continuity of operations after climate shocks
ENHANCE EMERGENCY RESPONSE PLANS
A7
City
Strengthen Heat Emergency Response
Educate on food risk and extreme heat
Inspect food establishments after flooding or loss of power
PROVIDE FOR HEALTHCARE CONTINUITY AND ACCESS
A8
Partnership
Increase awareness of and enrollment in Code Red
Partner with healthcare providers for shared information
Partner for continuity of critical services for pops. at risk and financial coverage emergency response
ENCOURAGE STRONGER SOCIAL NETWORK
A9
City
Engage at-risk residents with community organizations
Develop multi-language educational materials
Engage in activities to build network; e.g., block party
CONTINUE CLIMATE EDUCATION
A10
Partnership
Host climate workshops
Host climate-related community meals
Develop equity and accessibility guidelines
SUPPORT RENTER PREPAREDNESS
A11
Partnership
Seek relief funds for affordable housing
Streamline eviction moratorium during disaster
Work with Courts to protect renters during extreme weather events
Key
Program
Policy/ Regulations
Pilot/Project/ Study
Proponents
City
Government (State & Federal)
Institutions/Not-for-Profit, Private
Partnerships


Time/Year
5-Year Review by City
Strategy
Proponent & Handbook Strategy reference #
2020
2021
2022
2023
2024
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2026
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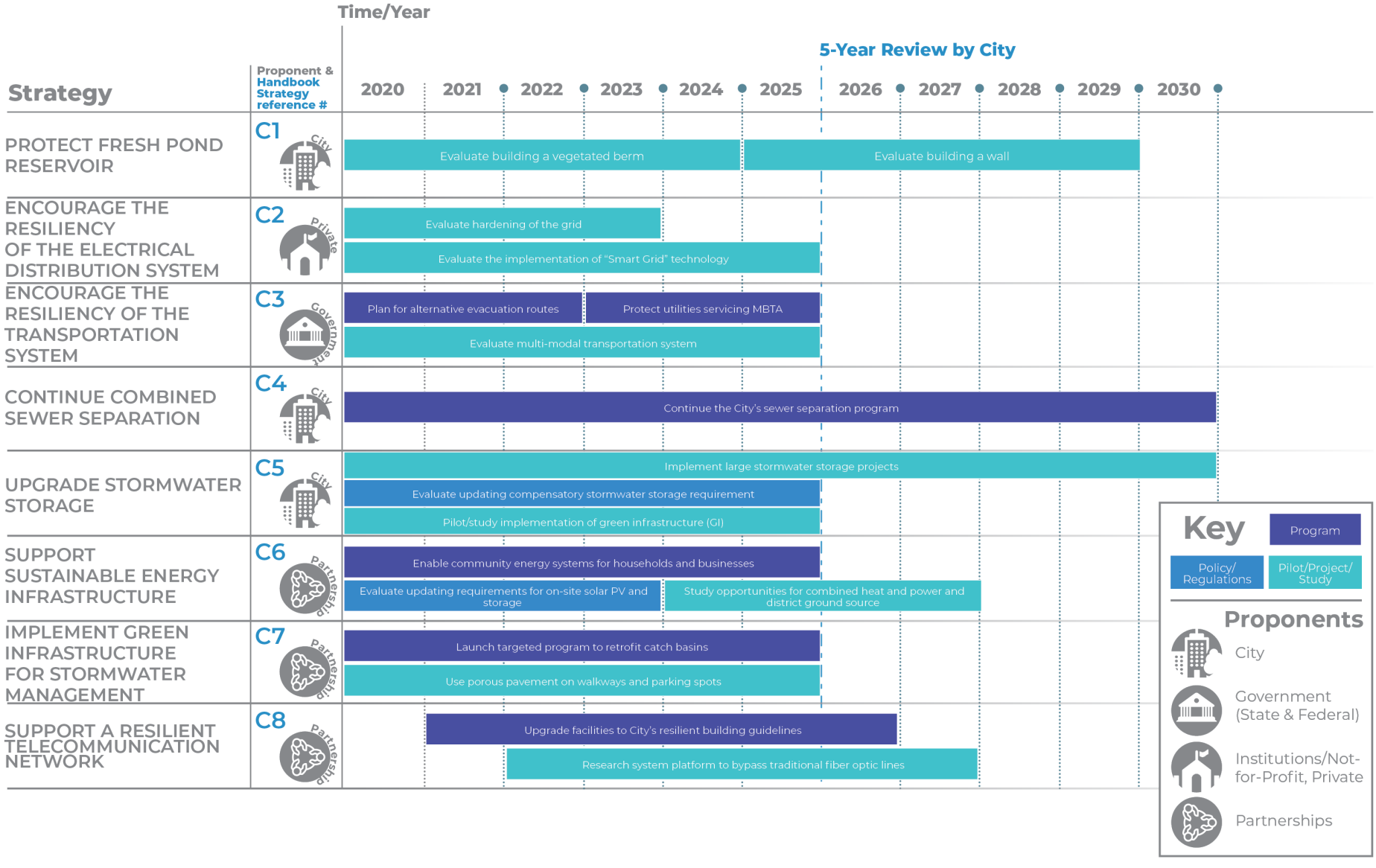
2028
2029
2030
REGULATE FLOOD PROTECTION FOR NEW BUILDINGS
B1
Partnership
Make recommendations for resilient zoning
Adopt zoning revisions with flood protection
REGULATE HEAT PROTECTION FOR NEW BUILDINGS
B2
Partnership
Set guidelines for high-performance buildings
Make recommendations for cool target
Adopt cool target in zoning revisions
ENCOURAGE FLOOD PROTECTION FOR EXISTING BUILDINGS
B3
Partnership
Update FloodViewer for best available information
Study programs to support flood retrofit
Implement program supporting flood resiliency improvements
ENCOURAGE HEAT PROTECTION FOR EXISTING BUILDINGS
B4
Partnership
Study programs to support heat resiliency retrofit
Implement program supporting heat resiliency improvements
SUPPORT BUILDING MANAGEMENT FOR FLOOD AND HEAT PROTECTION
B5
Partnership
Require maintenance and emergency plan for continuity of basic services during and after extreme events
Study options for distributed energy systems
PROMOTE SITE GREEN INFRASTRUCTURE
B6
Partnership
Encourage adopting LEED sustainable site and water efficiency strategies
ESTABLISH ADAPTED ZONING POLICIES AND REGULATIONS
B7
Government
Advocate for State regulations to be updated to include climate change consideration
STUDY ADAPTED PLANNING FOR RESILIENT URBAN BLOCKS
B8
Partnership
Study potential block for special incentives
Convene pilot resilient block task force improvements
Develop program supporting implementation of Super Resilient Blocks
ENCOURAGE RESILIENCY OF BUILDING SCALE ENERGY
B9
Partnership
Develop program supporting building energy autonomy
DEVELOP FLOOD PROTECTION AND OPERATIONS PLANNING FOR HISTORIC AND CRITICAL FACILITIES
B10
City
Develop guidelines for historic buildings with Cambridge Historical Commission
Apply for funding through the Massachusetts State Historical Commission
Prioritize critical facilities for resiliency
Integrate upgrade to critical facilities in Capital Planning
Key
Program
Policy/ Regulations
Pilot/Project/ Study
Proponents
City
Government (State & Federal)
Institutions/Not-for-Profit, Private
Partnerships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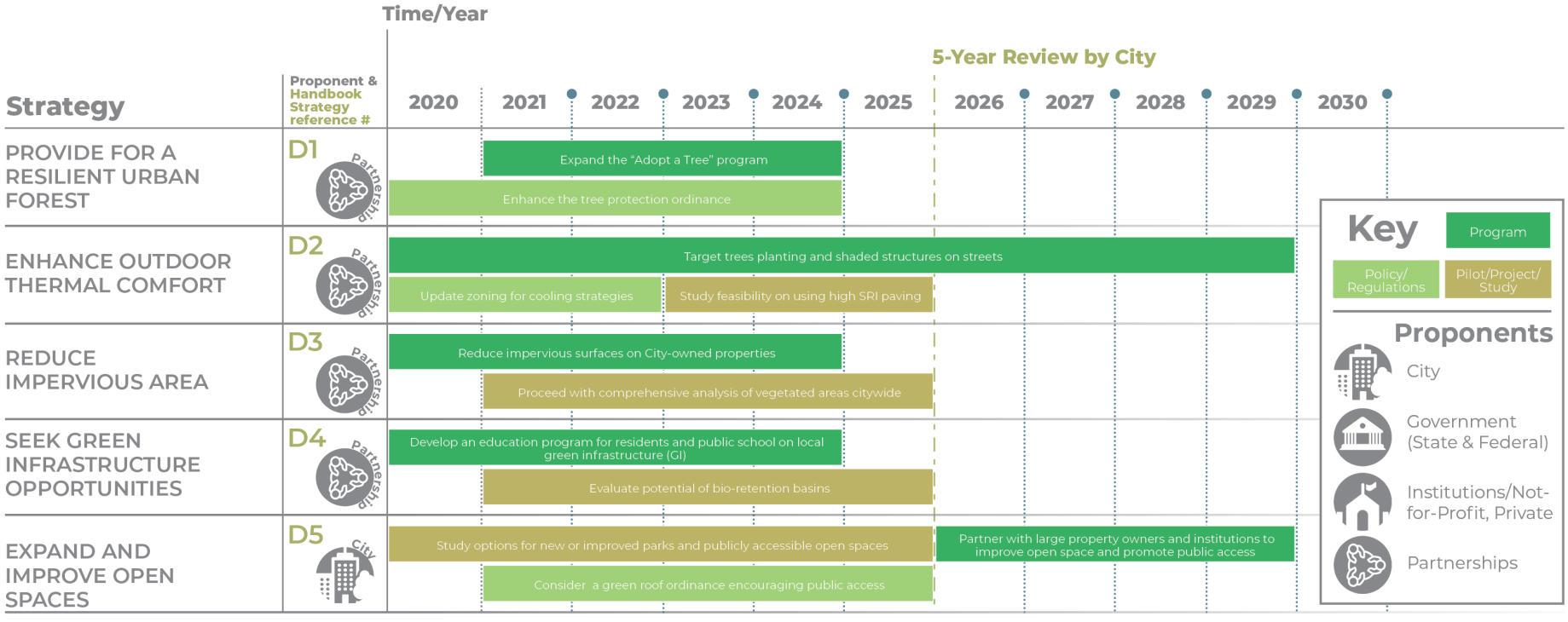
2030
PROTECT FRESH POND RESERVOIR
C1
City
Evaluate building a vegetated berm
Evaluate building a wall
ENCOURAGE THE RESILIENCY OF THE ELECTRICAL DISTRIBUTION SYSTEM
C2
Private
Evaluate hardening of the grid
Evaluate the implementation of "Smart Grid" technology
ENCOURAGE THE RESILIENCY OF THE TRANSPORTATION SYSTEM
C3
Government
Plan for alternative evacuation routes
Protect utilities servicing MBTA
Evaluate multi-modal transportation system
CONTINUE COMBINED SEWER SEPARATION
C4
City
Continue the City's sewer separation program
UPGRADE STORMWATER STORAGE
C5
City
Implement large stormwater storage projects
Evaluate updating compensatory stormwater storage requirement
Pilot/study implementation of green infrastructure (GI)
SUPPORT SUSTAINABLE ENERGY INFRASTRUCTURE
C6
Partnership
Enable community energy systems for households and businesses
Evaluate updating requirements for on-site solar PV and storage
Study opportunities for combined heat and power and district ground source
IMPLEMENT GREEN INFRASTRUCTURE FOR STORMWATER MANAGEMENT
C7
Partnership
Launch targeted program to retrofit catch basins
Use porous pavement on walkways and parking spots
SUPPORT A RESILIENT TELECOMMUNICATION NETWORK
C8
Partnership
Upgrade facilities to City's resilient building guidelines
Research system platform to bypass traditional fiber optic lines
Key
Program
Policy/ Regulations
Pilot/Project/ Study
Proponents
City
Government (State & Federal)
Institutions/Not-for-Profit, Private
Partnerships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2021
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2028
2029
2030
PROVIDE FOR A RESILIENT URBAN FOREST
D1
Partnership
Expand the "Adopt a Tree" program
Enhance the tree protection ordinance
ENHANCE OUTDOOR THERMAL COMFORT
D2
Partnership
Target trees planting and shaded structures on streets
Update zoning for cooling strategies
Study feasibility on using high SRI paving
REDUCE IMPERVIOUS AREA
D3
Partnership
Reduce impervious surfaces on City-owned properties
Proceed with comprehensive analysis of vegetated areas citywide
SEEK GREEN INFRASTRUCTURE OPPORTUNITIES
D4
Partnership
Develop an education program for residents and public school on local green infrastructure (GI)
Evaluate potential of bio-retention basins
EXPAND AND IMPROVE OPEN SPACES
D5
City
Study options for new or improved parks and publicly accessible open spaces
Partner with large property owners and institutions to improve open space and promote public access
Consider a green roof ordinance encouraging public access
Key
Program
Policy/ Regulations
Pilot/Project/ Study
Proponents
City
Government (State & Federal)
Institutions/Not-for-Profit, Private
Partnerships

Our Commitment

After seven years of research, the task at hand was to present a viable roadmap for a vibrant future, and we believe that Resilient Cambridge does exactly that.

For each suggested strategy, there is a key proponent identified as spearheading that implementation—it could be the City, other government agencies at the state or federal levels, private owners, institutions, nonprofit organizations, or some form of partnership.

The goal is to empower our citizens to take the action needed to tackle climate change by defining a shared mission that can rouse, rally, and ultimately safeguard the people of Cambridge.

Additional Resources

Resilient Cambridge is based on the following documents.
To view the technical reports, visit www.cambridgema.gov/ResilientCambridge. Appendices are available upon request.

Closer Neighborhoods [A] Technical Report

- Appendix A1_Cambridge Community Resource Database
- Appendix A2_Impacted Resources
- Appendix A3_Vector Borne Disease Risk in Climate Change
- Appendix A4_Public Health Planning Workshop
- Appendix A5_COVID-19 Emergency Response Observations

Better Buildings [B] Technical Report

- Appendix B1_Cost Estimate for Building Resiliency
- Appendix B2_Methodology for Using Assessor Data

Stronger Infrastructure [C] Technical Report

Appendix C1_The Port Short Duration Storms

Greener City [D] Technical Report

Urban Heat Island [UHI] Technical Report

Appendix UHI1_Summary of UHI Analysis

Sea Level Rise/Storm Surge Flooding Regional Analysis [RA] Technical Report

Appendix RA1_Upper Mystic Regional MVP Case Study
Appendix RA2_Cambridge DPW Letter to Massachusetts DCR
Appendix RA3_Regional SLR-SS - Real Estate Analysis Supporting Data
Appendix RA4_Regional SLR-SS - Population Analysis Supporting Data
Appendix RA5_Regional SLR-SS Mapbook 1 - Real Estate Analysis (per municipality, by Land Use
Appendix RA6_Regional SLR-SS Mapbook 2 - Real Estate Analysis (per municipality, by Ownership
Appendix RA7_Regional SLR-SS Mapbook 3 - Population Analysis (per municipality)

Resilient Cambridge

City of Cambridge, MA