CLIMATE CHANGE PREPAREDNESS & RESILIENCE

ALEWIFE PREPAREDNESS PLAN

CITY OF CAMBRIDGE

11.15.2017

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Acknowledgments

CITY OF CAMBRIDGE

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Executive Summary

PURPOSE OF THIS REPORT

The **Climate Change Preparedness and Resilience (CCPR) Plan** is being developed as a practical guide for the City of Cambridge (the City) to implement specific strategies in response to climate change threats (heat, flooding from precipitation, flooding from sea level rise and storm surge). The **Alewife Preparedness Plan (Plan)**, the first neighborhood plan to be developed, will test how the proposed strategies might create a new framework for resiliency in Alewife. It comprises two parts — a Report and a Handbook.

- The Report provides the context, framework, and strategies to create a prepared and resilient Alewife neighborhood.
- The Handbook, a companion document, is a practical compendium of specific preparedness and resiliency strategies and best practices.

WHY ALEWIFE

Alewife was selected for the first neighborhood plan because it is an area within Cambridge that is most exposed to flooding and extreme heat. It is also a hub for the City's infrastructure and ecosystem and a neighborhood of regional importance, connecting Cambridge to the larger Boston metropolitan area. Alewife is critical to the City's economy and houses some of its most vulnerable populations. It is experiencing rapid growth and re-development, which provides opportunities to program early actions and do the "right things."

FRAMEWORK

The preparedness and resiliency strategies developed for Alewife build upon the Cambridge Climate Change Vulnerability Assessment (CCVA) that assessed risks for the City assuming no actions were taken. The Plan recommends strategies for preparedness to projected climate change extreme events and, in the process, to enhance the well-being of the whole community. The "qualities of resiliency" provides for preliminary metrics for evaluation of the strategies and for possible timelines for implementation.

The strategies toward a prepared Alewife have been grouped in four categories:

- **Strategies A: Prepared Community** providing for increased community, social, and economic resilience. Taking into account that extreme heat is a risk likely to occur in the near future and that Alewife is a community with high-risk populations, there is a sense of urgency to implement some of the proposed strategies within the next 10 years. The organizational structure for implementing the Plan already exists since City departments, public health organizations, and community organizations would spearhead this effort.
- **Strategies B: Adapted Buildings** protecting against projected climate change impacts and/or designing for a speedy return to normal operation. By retrofitting existing buildings or providing for re-development to meet enhanced resiliency standards, owners and developers

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can serve as leaders of the proposed strategies. A selected few, such as updating the Massachusetts State Building Code to reflect new flooding requirements and anticipate more frequent extreme heat events, require partnerships with State agencies to change regulations.

- **Strategies C: Resilient Infrastructure** ensuring continued service and/or a swift recovery from climate shocks and stresses. Key proponents for implementation of the proposed strategies are a combination of City departments collaborating with other government agencies at the State and local level, private institutions, and developers. Some key strategies need to be implemented by 2050, since the Amelia Earhart Dam is likely to be bypassed by a 100-year flood by 2045, which would cause significant damage to the functioning of critical infrastructure.

- **Strategies D: Resilient Ecosystems** integrating the built environment with green infrastructure, the urban forest, and natural areas to support an ecosystem resilient to climate impacts. The strategies will reduce the urban heat island (UHI) effect, preserve air quality, improve water quality, and provide additional stormwater storage capacity. For resilient ecosystems, it is the collective implementation of the strategies that are most beneficial and consequently, requires incremental improvements initiated by diverse proponents.

Implementation of the strategies for a prepared and resilient Alewife allows for the transformation of the neighborhood. The proposed strategies will not only protect lives and livelihoods in Cambridge that are at risk from climate change impacts but should also enhance the well-being of the entire community.

Existing Alewife

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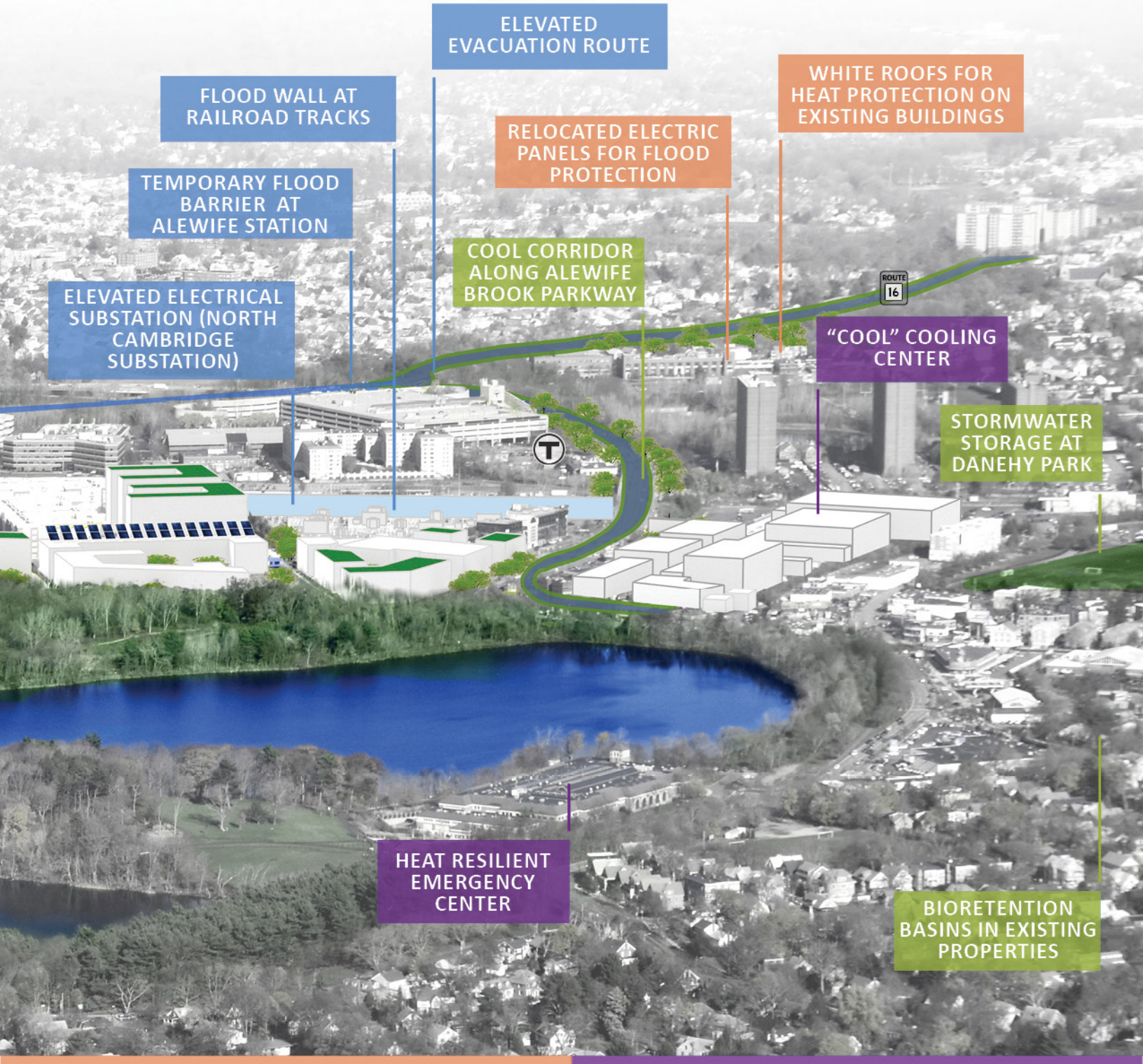
CONCLUSIONS AND RECOMMENDATIONS

The implementation of the Plan will provide for a transformed Alewife resilient to heat and flooding from precipitation and sea level rise (SLR) and storm surge (SS). In areas of projected growth and re-development—for example, "the Quadrangle"—the integration of resiliency strategies into the planning and design of new buildings and infrastructure presents unique opportunities for a transformed urban neighborhood. A transformed Alewife will not only benefit Cambridge but will increase regional resiliency because the Alewife area serves as a regional hub for several key infrastructure systems (energy, transportation, drinking water, ecosystems) and includes elements of the natural environment, such as the Alewife Brook and Alewife Brook Reservation.

NEXT STEPS

As was the case in the development of the Climate Change Vulnerability Assessment, it is recognized that the resiliency strategies herein are based on climate change scenarios developed for Cambridge that are drawn from the best available science but involve ranges of uncertainty. These strategies will need to be revisited frequently to ensure community preparedness plans continue to reflect updated projections specific to local climate change.

Moving forward, the next steps will also be to provide for the quantification of cost and economic opportunities, and will proceed with a robust stakeholder engagement process. The strategies developed for Alewife will be reviewed for applicability in other neighborhoods and will also inform the citywide plan.



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Introduction

PURPOSE OF THIS REPORT

The **Climate Change Preparedness and Resilience (CCPR) Plan** is a practical guide for the City of Cambridge (the City) to implement specific strategies in response to climate change threats (heat, flooding from precipitation, flooding from sea-level rise and storm surge). The City begins the process with neighborhood-level plans for areas identified as high risk; these will be gathered into a comprehensive citywide CCPR Plan that will also address regional issues.

The **Alewife Preparedness Plan** is the first neighborhood plan to be developed. It will test how proposed strategies might create a new model of living in Alewife. These strategies will be reviewed for applicability in other neighborhoods and will inform the citywide plan.

The Alewife Preparedness Plan comprises two parts—a Report and a Handbook.

- The Report provides the context, framework, and strategies to create a prepared and resilient Alewife neighborhood.
- The Handbook, a companion document, is a practical compendium of specific preparedness and resiliency strategies and best practices.

Appendices of technical analyses and research supporting key strategies presented in the Report and the Handbook are included herein.

WHAT IS "PREPAREDNESS AND RESILIENCE?"

The City of Cambridge was settled in the 1630s in its pre-urban condition and has been under continuous development and re-development. The 1777 map of Cambridge (Figure1) shows Alewife in its historic context, where a significant portion of the land was a saltwater marsh. Climatic conditions have changed considerably over time, and the patterns of temperature, precipitation, and sea level that were used to design buildings and infrastructure, locate critical facilities, and preserve open spaces are shifting to new ones that will affect the built environment, ecosystems, and residents. The blue shaded area in Figure 1 illustrates the projected extent of flooding from sea level rise/storm surge (SLR/SS) by 2070. Without preparation and adaptation, climate change poses significant threats to the future of Cambridge's economy, quality of life, public health, and safety.

Climate change preparedness is a state of readiness or adequate preparation for anticipated impacts such as extreme or repeated flooding and higher temperatures. For the City of Cambridge, these have been assessed according to two time horizons: 2030 and 2070. Resilience is the City's ability to recover from the impacts of climate change, with recovery often measured in time and cost. It follows that resilience and preparedness will increase if risk-reduction strategies are implemented.

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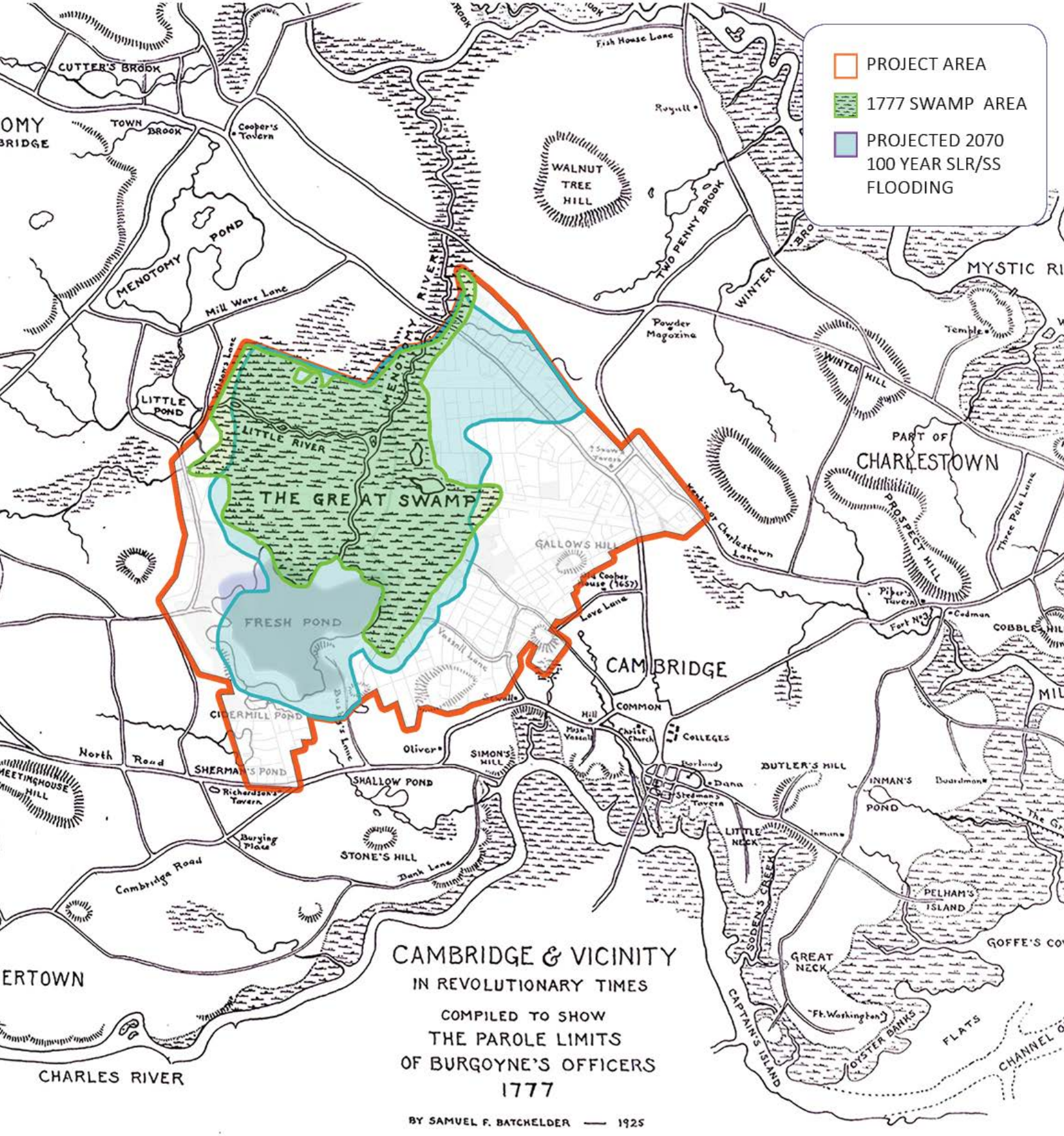

Figure 1. The Alewife project area and projected flooding in the historical context of The Great Swamp (1777) [Source: Samuel F. Batchelder Publisher]

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WHY ALEWIFE?

Alewife was selected for the first neighborhood plan for the following reasons:

1. Highly flood-prone
2. Significant exposure to heat
3. Transportation hub connecting Cambridge to the Boston metropolitan area
4. Vital ecosystem connections
5. Rapid growth and development
6. Critical to the City's economy
7. Houses some of Cambridge's most vulnerable populations

Figure 2. 1905 tidal marshland photo between Fitchburg Railroad and Concord Avenue, looking east [Source: Cambridge Historical Society]

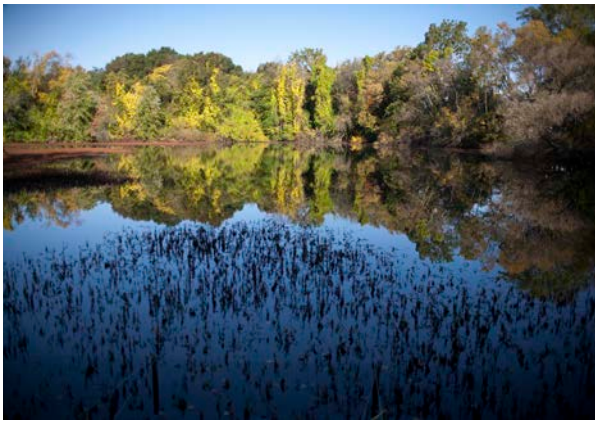

Figure 3. Fresh Pond Reservoir [Source: City of Cambridge]

Highly flood-prone: Much of Alewife was a tidal marshland, as shown in the 1905 picture in Figure 2. Alewife already experiences flooding from precipitation that is likely to get worse as extreme storm events increase in frequency and intensity. It is also likely to be the first Cambridge neighborhood to experience SLR/SS flooding as early as 2045. Sea level rise and storm surge flooding may involve salt water, which—if it reaches Fresh Pond—could contaminate the City's drinking water supply, shown in Figure 3. Storm surge flooding will pose risks to populations, buildings, and infrastructure. By 2070, storm surge modeling predicts that large swaths of the Alewife-Fresh Pond area could be subject to flooding contaminated with salt water once every five years.

Significant exposure to heat: Alewife is one of the areas most exposed to the urban heat island effect due to its impervious character and lack of vegetation. The areas at greatest risk for human health impacts from heat in 2030 and 2070 correlate to areas that lack tree canopy coverage. The most prominent of these zones include the Quadrangle area, the Fresh Pond Mall area, and Alewife Center. Figure 4 shows projected ambient temperature variability by 2030 on a day when average "feels-like" temperature is 96 degrees Fahrenheit with a relative humidity of 50-55 percent[1].

1) For more information refer to Appendix B: Green Infrastructure Analysis and Urban Heat Modeling

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Transportation hub connecting Cambridge to the Boston metropolitan area: Alewife's key infrastructure assets are of local and regional importance, such as the Massachusetts Bay Transportation Authority (MBTA) Red Line station and railway tracks, electrical substations, telecommunication facilities, and major state roadways (Alewife Brook Parkway and access to Route 2). All these transportation assets are at risk. Failure of major infrastructure will adversely affect abutting populations and businesses, public safety, and the economy.

Important ecosystem connections: Alewife includes a rich open-space system of local and regional importance that is at risk of flooding: Fresh Pond Reservation—the City's largest open space—is an important component of the Mystic River watershed with significant water resources (Fresh Pond, Alewife Brook, and the Alewife Reservation). The Fresh Pond Reservoir, the terminal reservoir for the City's drinking water supply, is a key asset to protect.

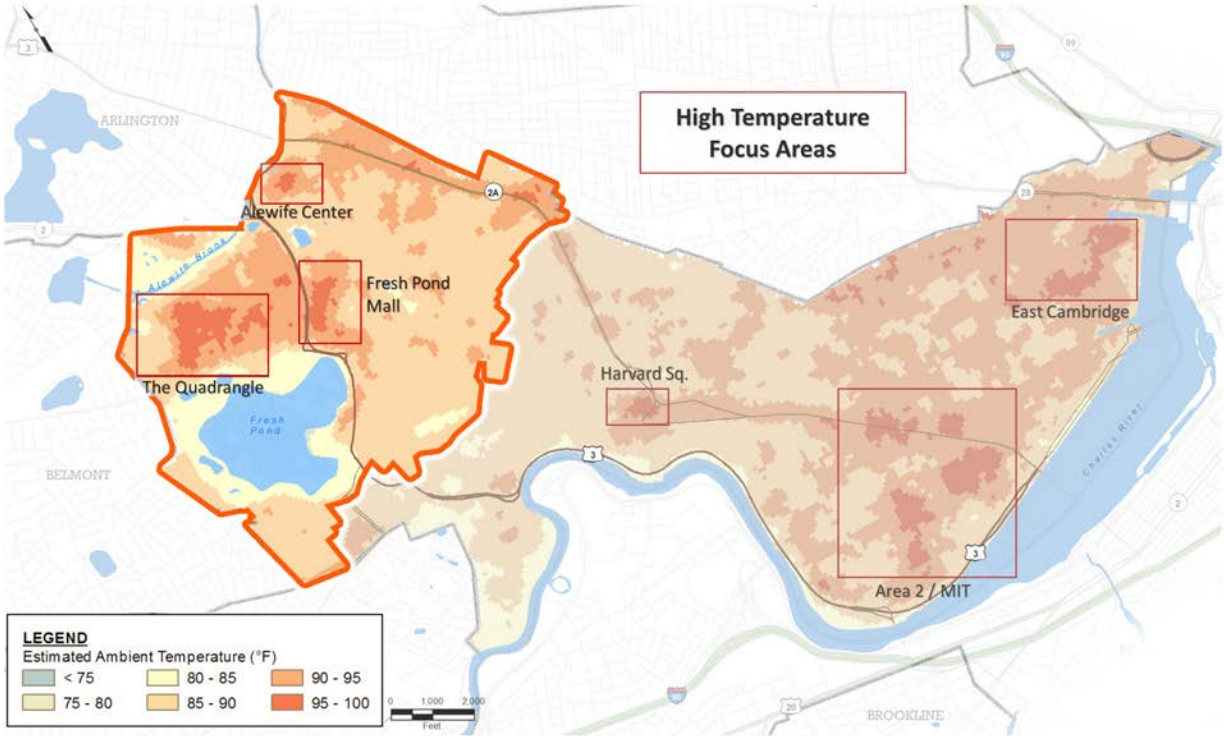

Figure 4: 2030 Ambient Air Temperature with existing tree canopy [Source: Kleinfelder, 2017]

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Figure 5. Alewife area subject to re-development [Source: Envision Cambridge, Utile]

Rapid growth and re-development: Alewife is one of the City's most rapidly developing areas. As illustrated in Figure 5, the existing low industrial use is attractive for re-development. By 2014, re-development surpassed what was anticipated for the period between 2006 and 2024. Re-development has been primarily residential. Under existing climate conditions, the area's resources are already stressed as noted and these impacts will be compounded in the future if no action is taken according to model predictions. Re-development presents opportunities to program early actions and do the "right things."

Critical to the City's economy: Commercial and re-development districts in Alewife are among the most at risk of increased flooding in the City as early as 2030. When projected building damage was analyzed, the northern Massachusetts Avenue commercial district had the most damage and the Concord-Alewife development district had the most building damage for the 100-year event in 2030[2]. This illustrates the importance of developing adequate resiliency strategies for existing and future commercial re-development in the Alewife area to ensure business continuity and minimize economic impact to the City, its residents, businesses, and workforce.

Houses some of Cambridge's most vulnerable populations: The area is also home to a large at-risk population of elderly and young residents, with diverse languages and socio-economic groups. It is important to include preparedness and resilience communication, emergency care, and support to all groups.

2) A complete description of the CCVA economic analysis are available at: www.cambridgema.gov/CDD/Projects/Climate/~/media/8A81573575EB440BA0DBE9421B6AB1B1.ashx

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A COMPREHENSIVE APPROACH TO CLIMATE CHANGE

The City of Cambridge has been a leader in adopting sustainability policies and practices. In 2002, the City Council adopted the Cambridge Climate Protection Plan, which focused on reducing overall greenhouse gas (GHG) emissions. For many years, the City's primary focus was on GHG emissions reduction to minimize Cambridge's contribution to climate change. However, scientists say that despite reduction initiatives, some amount of climate change is "locked in" and will still affect our future. Given this reality, growing public concern, and a strong recommendation from the Climate Protection Action Committee (CPAC)[3] — a local advisory group to the City Manager— the City decided that it is necessary to prepare for climate change impacts while continuing to reduce emissions to avoid the worst effects. The City proceeded first with a Climate Action Plan (CAP) in 2002 that focused on reducing GHG emissions and mitigating climate change. The City completed a Climate Change Vulnerability Assessment (CCVA) in 2017. In 2016, the City initiated the CCPR Plan. This Alewife Preparedness Plan is a first step toward the completion of a citywide plan. The following sections summarize the status and findings of these and related initiatives.

Mitigating GHG Emissions: Climate Action Plan (CAP)[4]

The City's CAP is currently being updated; its revision will focus on strategies and actions to mitigate GHG emissions by incorporating lessons learned from its initial 2002 CAP. The updated CAP will integrate existing and planned programs and actions and coordinate with other ongoing planning initiatives. The City of Cambridge sees its role as a local leader of regional and global coalitions of cities joining efforts to reduce GHG emissions.

Assessing Risks: Climate Change Vulnerability Assessment (CCVA)[5]

The CCVA presents an assessment of risk for the City assuming that no actions are taken. The CCVA report was issued in two parts: Part 1 focused on vulnerabilities to increasing temperature and precipitation, and Part 2 focused on vulnerabilities to rising sea levels and coastal storm surges. The climate scenarios in the CCVA adopted low and high GHG emission scenarios. The low-emission scenario assumed that significant mitigation measures were adopted through implementation of climate action plans that reduced levels of GHG emissions and lessened the overall intensity of events. The high-emission scenario modeled a future where there was no such mitigation and ever-increasing GHG emissions resulted in greater impacts.

> The City of Cambridge wants to integrate adaptation and mitigation efforts as a two-pronged approach to managing short- and long-term disturbances to the climate.

3) The City Manager appoints a standing Climate Protection Action Committee (CPAC) as an advisory committee to assist in the implementation of the Climate Protection Plan.
www.cambridgema.gov/CDD/climateandenergy/climatechangeplanning/climateprotectionactioncommittee
4) The Climate Action Plans and Reports are available on the City's website at:
www.cambridgema.gov/CDD/climateandenergy/climatechangeplanning/climateactionplanreports
5) The full reports and technical appendices are available on the City's website at:
www.cambridgema.gov/CDD/Projects/Climate/climatechangeresilianceandadaptation

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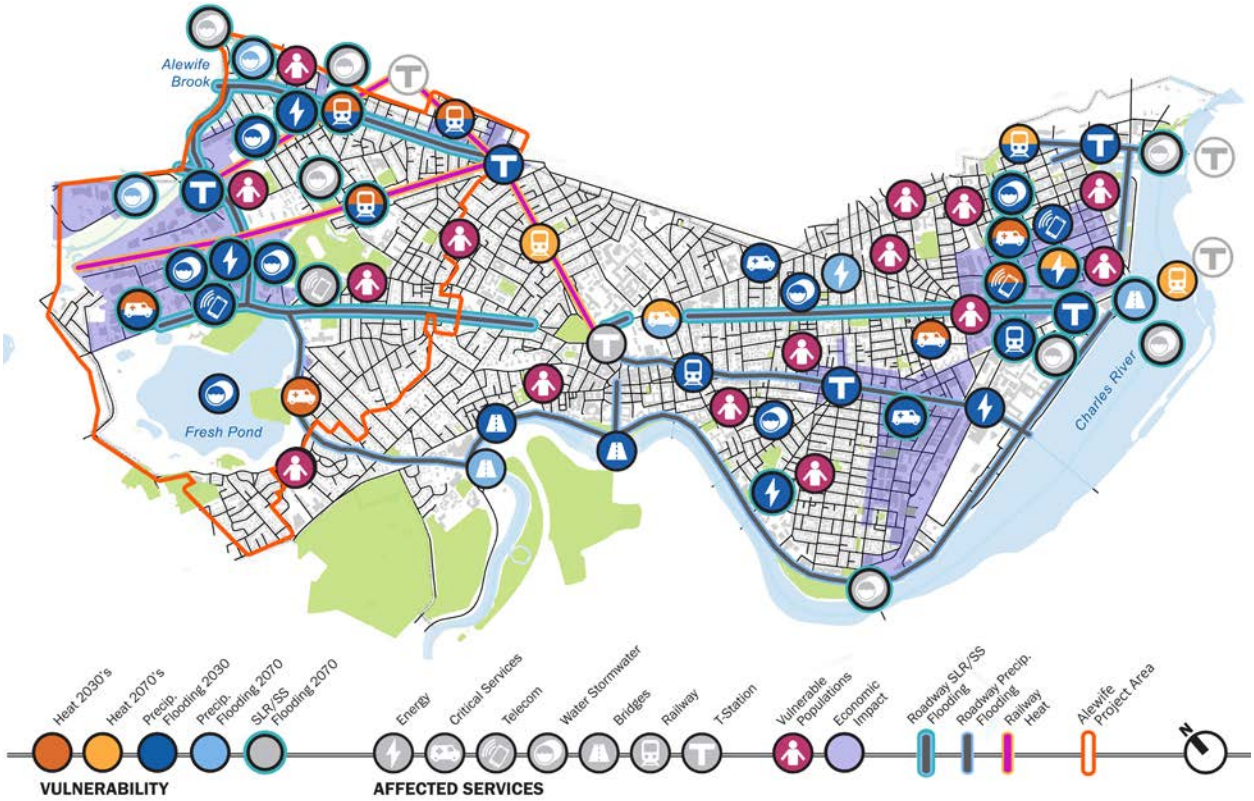

Figure 6. Key physical and social vulnerabilities to projected climate change impacts [Source: CCVA, February 2017]

The CCVA Priority Planning Areas Map (Figure 6) summarizes the most at-risk services and populations, with respect to climate change within the boundaries of Cambridge. The map represents a risk assessment that compares seemingly unrelated resources, such as public health and the transportation system, and the risks within each (what is the greatest public health concern?), as well as between them (how does the risk of an overheated school rate against the risk of a flooded Massachusetts Bay Transportation Authority [MBTA] station?). The map illustrates that the risk from climate change, posed by flooding and increased heat, is not evenly distributed throughout the City: The Alewife neighborhood (northwest Cambridge) displays significant physical and social vulnerability with a cluster of affected services and vulnerable populations affected by heat, precipitation flooding, and SLR/SS flooding. Many of the sites affected by flooding are shown in dark blue icons, such as the Alewife MBTA station and stormwater infrastructure, which means they could be afflicted as early as 2030. Vulnerable populations are the ones most likely to be impacted by flood or heat extreme events, for example young children or elderly, and with the least capacity to recover from these events, as limited by language barrier or living below the poverty line. The area shaded in light purple is at risk for climate change threats, with its economy stressed by loss of business continuity and possible flooding-related structural damage.[6]

6) The complete CCVA Economic Assessment is available at:
www.cambridgema.gov/CDD/Projects/Climate/~/media/8A81573575EB440BA0DBE9421B6AB1B1.ashx

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Preparing Strategies: Climate Change Preparedness and Resilience (CCPR)

The CCVA served as a foundation for the CCPR with the understanding that the science of climate change is evolving, and scenarios might be revised as new information is available. The City is monitoring changing conditions and will integrate new information when available. As illustrated in Figure 7 below, the City of Cambridge is taking a comprehensive approach to climate change by mitigating GHG emissions (CAP), while assessing the City's vulnerability to possible climate change scenarios (CCVA), and preparing for projected impacts (CCPR) for a resilient Cambridge.

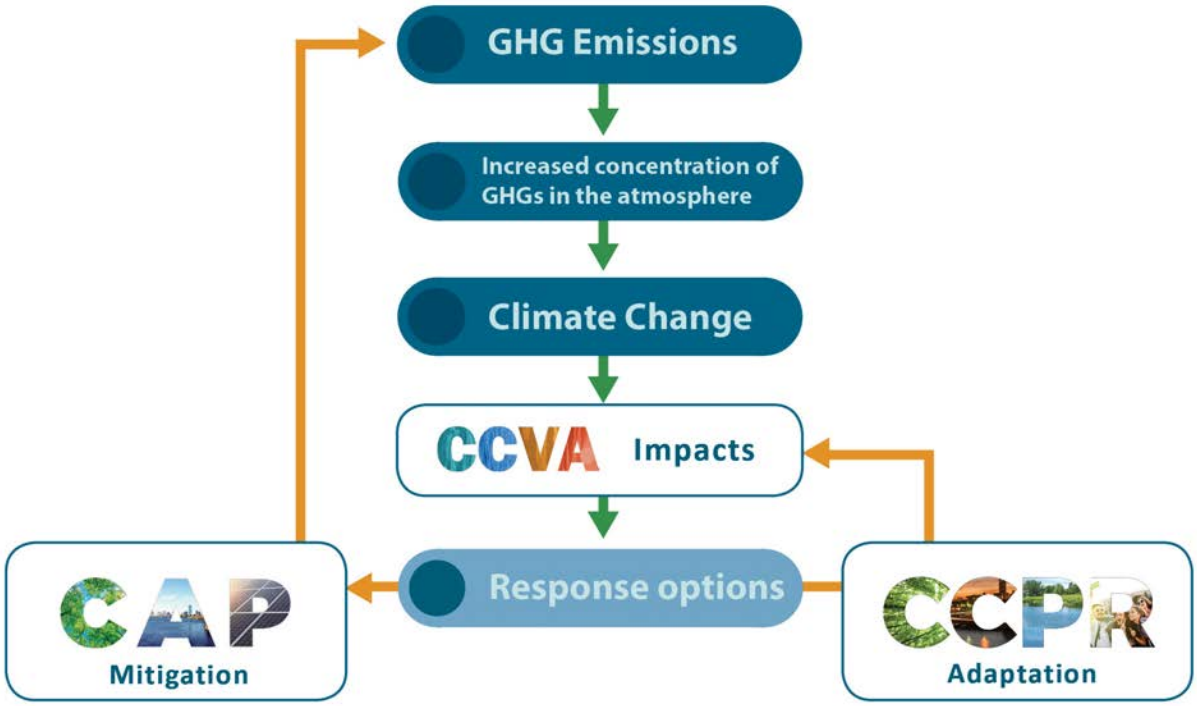

Figure 7. Cambridge Integrated Climate Change Initiatives [Source: Kleinfelder, July 2017]

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Other Planning Initiatives

Climate change is defining a "new normal" that is being integrated into the City's planning and operations. The CCPR is identifying strategies that are informing Envision Cambridge[7], the community-wide process toward developing a comprehensive plan for a more livable, sustainable, and equitable city. The scenarios and alternatives being developed as part of Envision Cambridge will consider the impacts of climate change, as well as proposed infrastructure improvements and policy changes that arise from the CCPR. CCPR and Envision Cambridge are also coordinating with the Net Zero Action Plan[8], which aims to put Cambridge on the trajectory toward becoming a "net zero community" by reducing carbon emissions from building operations. As illustrated in Figure 8, preferred strategies will co-benefit the goals and metrics of these comprehensive plans.

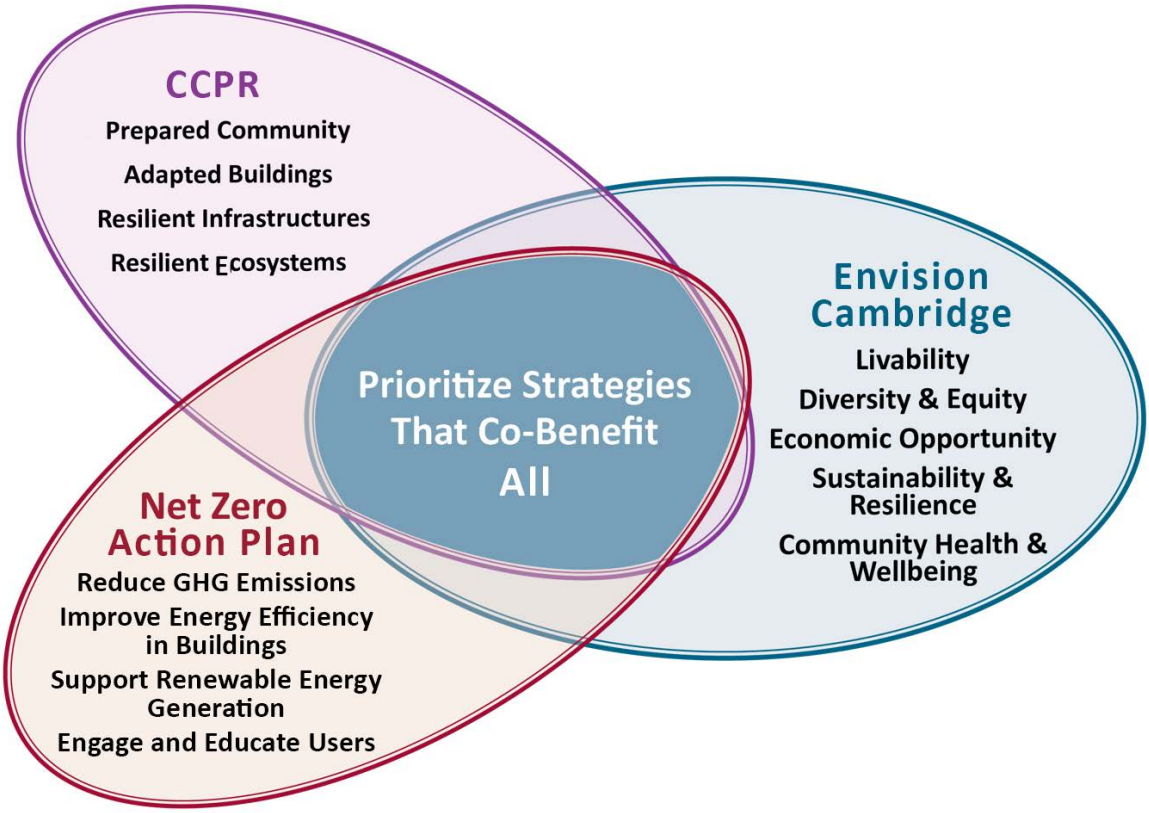

Figure 8. Integration of strategies among the City's comprehensive planning initiatives.
[Source: Kleinfelder, 2017]

7) www.cambridgema.gov/citywideplan
8) The full report is available at:
www.cambridgema.gov/cdd/projects/climate/~/media/D74193AF8DAC4A57AC96E2A53946B96B.ashx

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FRAMEWORK

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Framework

For the CCPR Plan, the framework consists of the vision and the strategies. City and Alewife stakeholders will test the framework to evaluate the plan developed for a resilient neighborhood as aligned with the CCPR vision. The plan will address Alewife's key vulnerabilities identified in the CCVA and recommend strategies for the neighborhood to be prepared and resilient.

CCPR VISION

The Cambridge CCPR Plan will protect the lives and livelihoods of members of the community that are at risk from climate change impacts and, in the process, enhance the well-being of the whole community. A successful CCPR Plan will:

- Propose a realistic set of strategies and recommended actions to guide the City, stakeholders, and community members in implementing the plan's vision.
- Engage the stakeholders, residents, and community members to help them understand the strategies and level of effort needed to create a climate-resilient and prepared community.
- Develop strategies for focus areas, starting with the Alewife Preparedness Plan.

ALEWIFE - KNOWN VULNERABILITIES AND RISKS

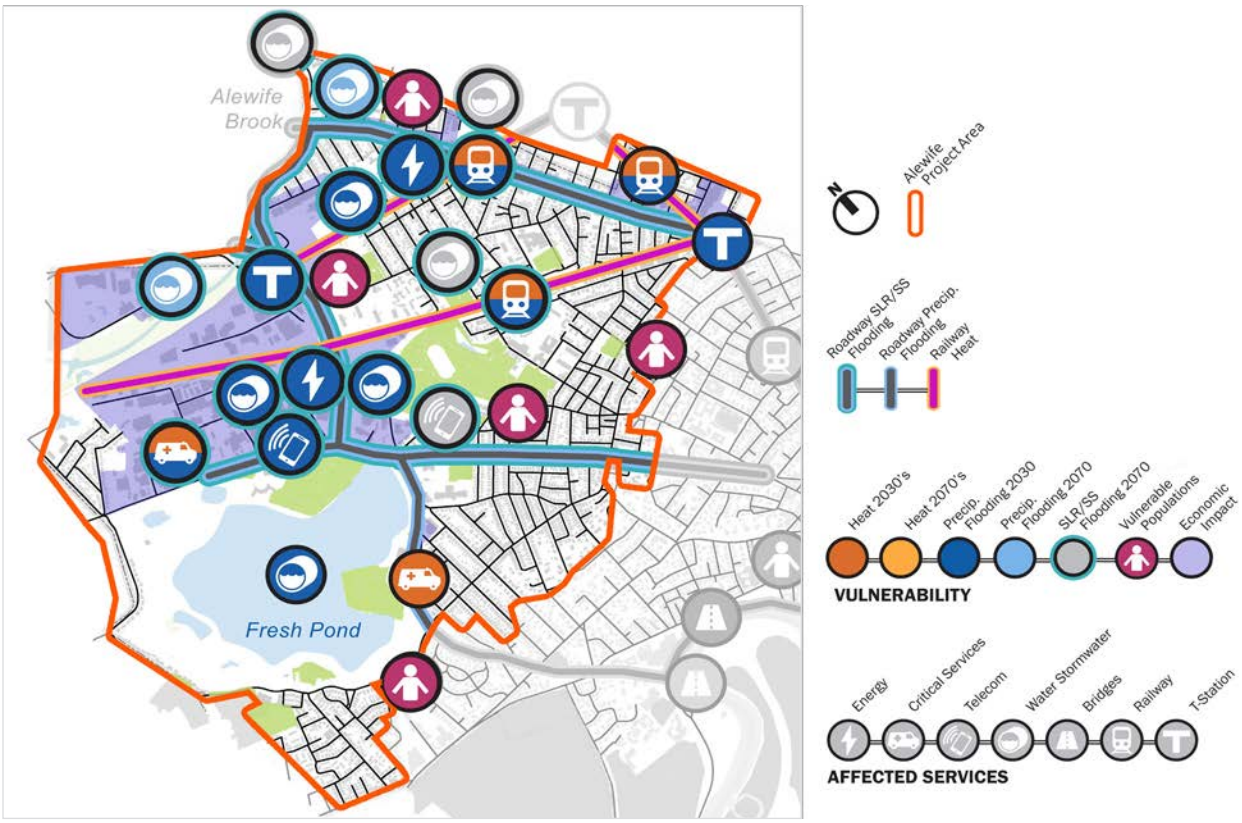

Figure 9. Key physical and social vulnerabilities to projected climate change impacts [Source: CCVA, February 2017]

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The CCVA identified Cambridge's key physical and social vulnerabilities (i.e., the affected services, populations, and economic impacts) with the assumption that no action is taken, based on existing conditions and demographics. For Alewife, specific vulnerabilities have been identified:

- In the near future, the neighborhood will be more vulnerable to increasing heat and precipitation-driven flooding. Heat waves and poor indoor air quality will increasingly challenge public health. Heat waves are likely to have the most immediate and significant impact on Alewife residents. More frequent flooding will lead to poor water and indoor air quality, exacerbating the risk to public health.

- It is projected that the Amelia Earhart Dam will likely be bypassed around 2045. Storm surge flooding, particularly in the Alewife-Fresh Pond area, will pose risks to populations, buildings, and infrastructure. The volume of flood water associated with a storm surge would be immense; conventional flood management techniques, such as storage basins and tanks, would be insufficient to deal with the problem.

- Disruption of critical services and major infrastructure (public transit, electricity, potable water supply, communication, emergency care, transportation, stormwater/wastewater) in Alewife will affect businesses and vulnerable populations with repercussions for the entire City and larger metropolitan area. An unprecedented level of coordination and cooperation among agencies, cities, the state, businesses, institutions, and residents will be required to prepare effectively for acute and chronic climate change conditions.

- Social vulnerability[9] is not evenly distributed among neighborhoods or households within the City, and Alewife is one of the neighborhoods with the highest percentage of vulnerable populations. Residents who are more isolated due to infirmity, age, language, and lower incomes are more vulnerable.

- Economic losses in Alewife from a flood or an area-wide power loss would be significant. Costs from disruption of economic activity will exceed costs of property damage.

STRATEGIES FOR A PREPARED AND RESILIENT ALEWIFE

The CCVA described climate change vulnerabilities in terms of the effects on community, the built environment, and the natural environment. The grouping of preparedness and resiliency strategies builds upon the CCVA to define four categories that address Alewife's vulnerabilities:

- **Prepared Community** providing for increased social and economic resilience.

- **Adapted Buildings** protecting against projected climate-change impacts and/or designing for a speedy return to normal operation.

- **Resilient Infrastructure** ensuring continued service and/or a swift recovery from climate shocks and stresses.

- **Resilient Ecosystems** integrating the built environment with green infrastructure, the urban forest, and natural areas to support a resilient ecosystem.

9) Social vulnerability in the CCVA is based on the identification of at-risk residents based on sensitivity to climate stressors based on income and age and on the ability to adapt based on income, education level, and physical and language isolation. The methodology for assessing social vulnerability is documented in the CCVA technical report at: www.cambridgema.gov/CDD/Projects/Climate/~/media/8FA4C85FCCFA4043B779729B05999361.ashx

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Each strategy group proposes technical, policy, regulatory, or financial actions that address the climate change risks to heat and flooding. The next sections of this report describe each of the four broad groups of strategies in detail and provide the following information:

- Overview of strategies being considered
- Relevance to Alewife
- Actions already being taken by the City and Alewife stakeholders
- Implementation context of the collective impact of the proposed strategies

Qualities of Resiliency

The "qualities of resiliency" are meant to allow the strategies to be compared to one another in terms of effectiveness, feasibility, and contribution to other City goals such as those in Envision Cambridge and the Net Zero Action Plan. The CCPR strategy qualities are:

Impact: Is the strategy technically effective? Which critical assets are protected? How many people will be affected? How will implementation mitigate the risk? The proposed strategies should enable the Alewife community to sustain normal functioning and avoid major repair or replacement costs during extreme events and/or to recover rapidly and operate efficiently afterward.

Cost: What are the estimated capital and operational costs? High capital and/or operational costs will affect the affordability of the proposed strategies. While some strategies might have a low capital cost, they may have significant operating costs. The strategies should yield benefits that exceed the costs, considering that they can save lives, reduce injuries, maintain livelihoods, and keep businesses running. Although they make financial sense, funding and extensive coordination requirements may constrain their feasibility.

Equitability: Will the strategy be fair to all? Proposed strategies for protecting water/wastewater/stormwater, ecosystem energy, and transportation infrastructure will equitably benefit all population groups, businesses, and services. However, strategies improving conditions for the most vulnerable populations may rank higher.

Wellness: Will the strategy help improve overall public health and safety? The strategies proposed will provide informational and educational programs and services on how to prepare for climate change impacts. The proposed strategies will also minimize risk. Some proposed strategies could reduce local temperature, improve water quality, help alleviate public-health impacts and further enable emergency and public safety services to reach areas in need.

Feasibility: Is the strategy technically, politically, legally, and financially realistic? The feasibility of the strategies depends on community buy-in, staffing levels, and technological constraints. These barriers could be addressed through funding allocations, developing new revenue sources, community engagement, innovation, pilot projects, and project phasing. The City will need to evaluate design options competition for the use of public space without compromising, for example, the pedestrian needs, bicyclists' safety and parking requirements.

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Integration: Is the strategy aligned with the Net Zero Action Plan and Envision Cambridge? Aligning strategies with, for example, the Envision Cambridge Plan that is also focusing on community health and well-being will allow for greater acceptance and easier implementation. Closer coordination among the two plans' recommended strategies needs to be achieved once both the CCPR Plan and Envision Cambridge Plan are further developed. The recommended strategies will contribute to the resiliency of buildings and infrastructure services.

Climate Change Mitigation: Does the strategy reduce GHG emissions? Many of the proposed strategies can provide and support reduction in GHG emissions. A resilient system that integrates renewable energy, storage, microgrids, and smart grid technology will be less carbon-intensive. Similarly, a multimodal transportation system that provides mobility options will also reduce reliance on automobiles and mitigate climate change. The increase in tree canopy and green infrastructure solutions will help mitigate GHG emissions by capturing carbon dioxide and indirectly reducing energy demand.

Implementation Context

In developing this plan, the City wanted to develop a broad range of strategies using different types of leadership and drivers across different jurisdictions and at different scales. The following definitions were developed:

The CCPR plan is meant to be an actionable plan to assure the protection of the lives and livelihoods of the members of the Cambridge community.

- *Proponent* is the stakeholder that will spearhead the implementation and who could provide possible financing for implementation or mobilization. Possible proponents are the City, government (other than City), institutions/nonprofits, private corporations, property owners, homeowners, renters, and public-private partnerships.
- *Type* has been defined as whether the intervention is an emergency response to address an extreme event caused by climate change, such as a hurricane, or whether the intervention is a preparedness measure to address a "new normal" caused by climate change, such as much higher average summer temperatures.
- *Jurisdiction* defines the entity who implements and monitors the enactment of the strategy. For example, if the strategy is in the City's purview, can it be made part of the City's regulations or policies? Or is it in the purview of the State as part of a larger facility or infrastructure system? Or can the strategy be implemented and monitored as part of voluntary programs?
- *Scale* can range from a single building or person to the neighborhood, City, or region.

A possible time frame is also being assessed to start discussion on a realistic plan for implementation. Strategies are being sorted according to the following:

- *Near future:* to be initiated soon (start by 2020 or within the next 10 years). For example, higher temperatures and more frequent heat waves have been identified in CCVA as happening in the near future and strategies should be initiated in less than 10 years.

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- *Midterm:* to be initiated between 10-30 years (start between 2030 and 2050). For example, protecting the Alewife electrical substation can start by 2030, since flooding risks at the substation are not likely to be experienced before 2030.

- *Distant future:* to be initiated after 30 years (start by or after 2050). For example, strategies such as using storage in the upstream reservoirs of the Mystic River Watershed to mitigate extreme rainfall flooding can start by 2050, since extreme rainfall flooding will otherwise be exacerbated by 2070.

Some of the proposed strategies might require continuous emphasis—for example, retrofitting existing buildings—and these strategies will be shown as ongoing with no targeted date for completion. On the other hand, some strategies need to be implemented and completed by a certain year. For example, the Fresh Pond Reservoir needs to be protected from SLR/ SS flooding by 2050, since the Reservoir can be flooded once the Amelia Earhart Dam is bypassed by 2045 and overtopped by 2055 from a 100-year flood.

The following sections in this report provide an overview of the four strategy groups, their relevance to Alewife, actions already being taken, and a summary of the implementation context. The Handbook has been crafted with a more detailed description of each strategy's key proponent, type, jurisdiction, scale, and time frame. It also documents best practices that inform the proposed actions.

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STRATEGIES A: PREPARED COMMUNITY

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Strategies A: Prepared Community

OVERVIEW

Strategies for **Prepared Community** range from public health approaches focusing on outreach and education to protection of critical facilities to ensure accessibility in the event of flooding, storm surges, and heat waves. Some are focused on how best to enhance neighborhood services—cooling centers and networks supporting vulnerable populations. Others are focused on protecting the facilities that provide communication services and critical facilities such as local hospitals or ambulatory services. Finally, some propose a more comprehensive approach to strengthen current emergency plans and social networks. Table 1 lists the proposed strategies, and Figure 10 shows the potential locations of the proposed strategies for prepared communities.

TABLE 1: STRATEGIES FOR PREPARED COMMUNITY

STRATEGY	TITLE	DESCRIPTION
A1	NEIGHBORHOOD RESILIENCE HUB	Establish a neighborhood resilience hub to foster community networks on a daily basis and increase preparedness and resilience among residents and businesses through education, training, planning, and implementation of resilience and sustainability measures.
A2	“COOL” COOLING CENTERS	Establish one or more “cool” cooling centers that would be attractive enough to be used during short periods of heat emergencies.
A3	SUPPORT SYSTEMS FOR VULNERABLE POPULATIONS	Establish a program to pre-identify and support individuals who are more vulnerable due to health conditions, addiction, homelessness or social isolation, and develop community support and emergency response systems to ensure their safety and well-being.
A4	EMERGENCY COMMUNICATION SYSTEMS	Develop neighborhood-scale communication systems that are redundant to normal communications systems to provide back-up during outages of telephone, cellular, cable and internet services.
A5	BUSINESS AND ORGANIZATIONAL PREPAREDNESS	Increase business and organizational continuity planning and preparedness including support services such as daycare.
A6	CRITICAL COMMUNITY FACILITIES RESILIENCE	Increase resilience of critical community facilities to climate shocks, prioritizing those with high vulnerabilities identified in the CCVA.
A7	EMERGENCY RESPONSE PLANS	Strengthen existing emergency response plans to include the potential impacts of climate change, including strategies to enable sheltering in place and evacuation when appropriate.

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TABLE 1: STRATEGIES FOR PREPARED COMMUNITY *(CONT.)*		
STRATEGY	TITLE	DESCRIPTION
A8	HEALTH-CARE CONTINUITY AND ACCESS	Work locally with key healthcare service providers and with the regional health and medical coalition to ensure capacity, continuity and access to medical services including pharmacies, dialysis, mental health, and addiction treatment.
A9	STRONGER SOCIAL NETWORK	Develop a neighborhood resiliency social network in partnership with community leaders and organizations.

Figure 10. Potential locations of "Prepared Community" strategies [Source: Kleinfelder, 2017]

RELEVANCE TO ALEWIFE

As previously presented, residents of the Alewife neighborhood are more vulnerable to flood and heat impacts as other parts of the City. As identified in the CCVA Vulnerable Population Assessment[10], the vulnerability index identified at-risk residents as residents more sensitive to extreme heat or flooding including children younger than 5 years old, people older than 65, and residents living below the poverty line. The vulnerability index also takes into account the residents that are likely to have the most difficulty in adapting to extreme conditions including residents living alone or below the poverty line, or with limited education and language barriers. At-risk residents, as identified by a high vulnerability index and as illustrated in Figure 11 on the following page, might be disproportionately affected by climate change, and preparedness measures need to be developed to address their specific needs. The Alewife area is comprised of the following census tracts as identified in Figure 11: North Cambridge; Neighborhood Nine; Cambridge Highlands;

10) The Vulnerable Population Ranking Memorandum is available at: www.cambridgema.gov/CDD/Projects/Climate/~/media/8FA4C85FCCFA4043B779729B05999361.ashx

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West Cambridge; and Strawberry Hill. Alewife is one of the neighborhoods in Cambridge with larger areas of at-risk populations, underscoring the importance of developing specific strategies for a **Prepared Community.**

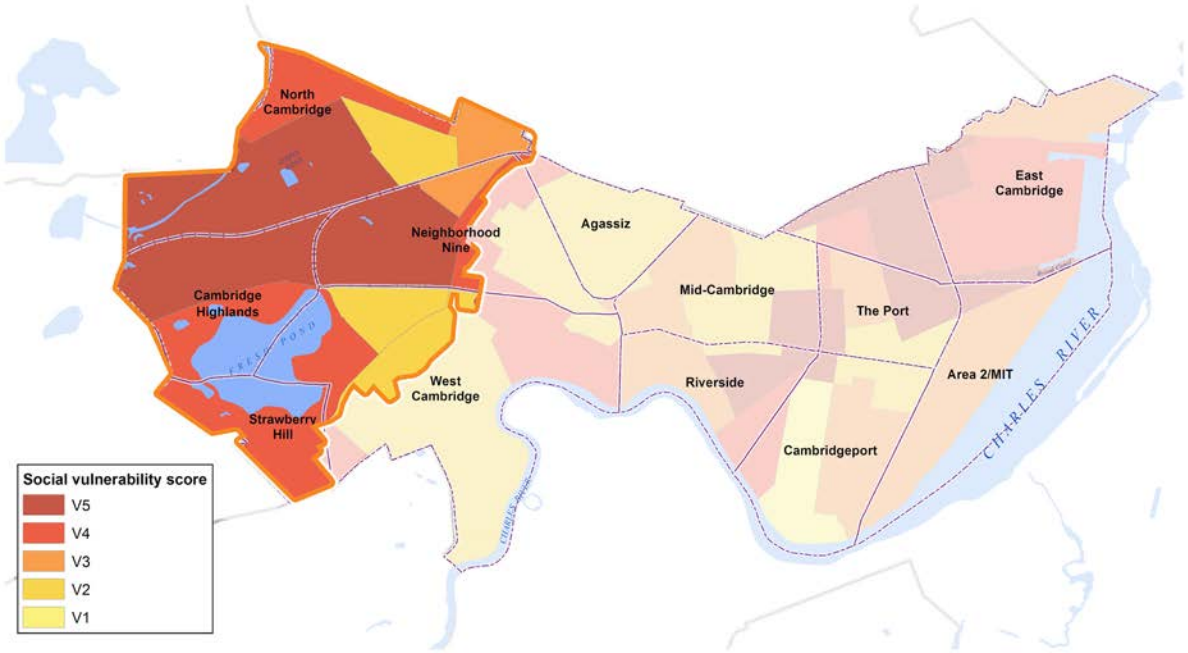

Figure 11. Vulnerable populations per census tracts. Final Vulnerability Scoring: Low – High Vulnerability: Score 1 -5. [Source: Kleinfelder, May 2015]

Projections in the CCVA Economic Vulnerability Assessment show significantly high negative employment and economic-value impacts. The Alewife area is most at risk for structural damages to its entire building portfolio and commercial and development districts as summarized below:

- Analyzed by commercial district, the northern Massachusetts Avenue district had the most structural damage for the 100-year event in 2030.
- Analyzed by development district, the Concord-Alewife district had the highest amount of building damage for the 100-year event in both 2030 and 2070.
- Analyzed by census tracts as illustrated in Figure 12, Alewife showed the greatest structural damage to buildings for the 100-year event in 2030.

The more severe the extent of damage to buildings, the more time needed to recover; jobs and homes will be disrupted, and a return to normalcy will take a long time.

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Estimate of Structural Damage to Buildings by Census Tract from 24-Hour 100-Year Rainfall Event in 2030

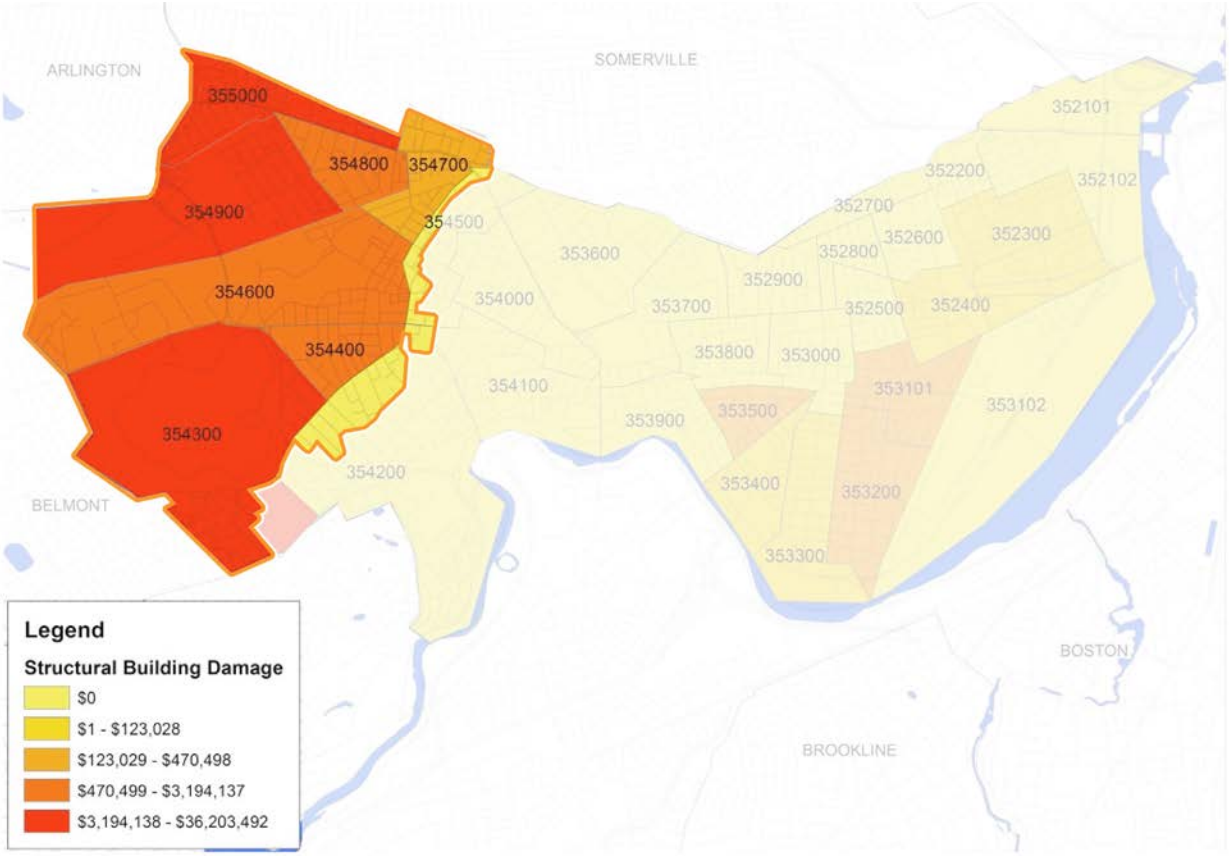

Figure 12. Estimate of structural damage to buildings by census tracts from 24-hour 100-year rainfall event in 2030 [Source: Catalysis Adaptation Partners, February 2015]

ACTIONS ALREADY BEING TAKEN

The City has already set in place many measures to support all members of the Cambridge community during extreme events. The ***City's Combined Emergency Communications and 911 Center (ECC)*** manages the coordinated dispatch of police, fire, emergency medical service (EMS) and other resources[11]. The Community Development Department is providing a small business continuity toolkit documenting measures and available resources for preparedness to extreme events[12].

The community expressed concerns for the long-term health and well-being of their children and their community as affected by climate change.

The City has also set in place programs for building a stronger community. The ***Cambridge Community Response Network (CCRN)*** has been created to help build a more resilient city by creating a strong community in which neighbors feel connected to and responsible for each other[13]. Recognizing the power of grassroots and locally-based connections, the Cambridge Peace

11) www.cambridgema.gov/Departments/EmergencyCommunications
12) www.cambridgema.gov/CDD/econdev/resourcesforbusinesses/smallbusiness/emergencypreparednessforbusinesses
13) www.cambridgema.gov/Departments/peacecommission/CCRN

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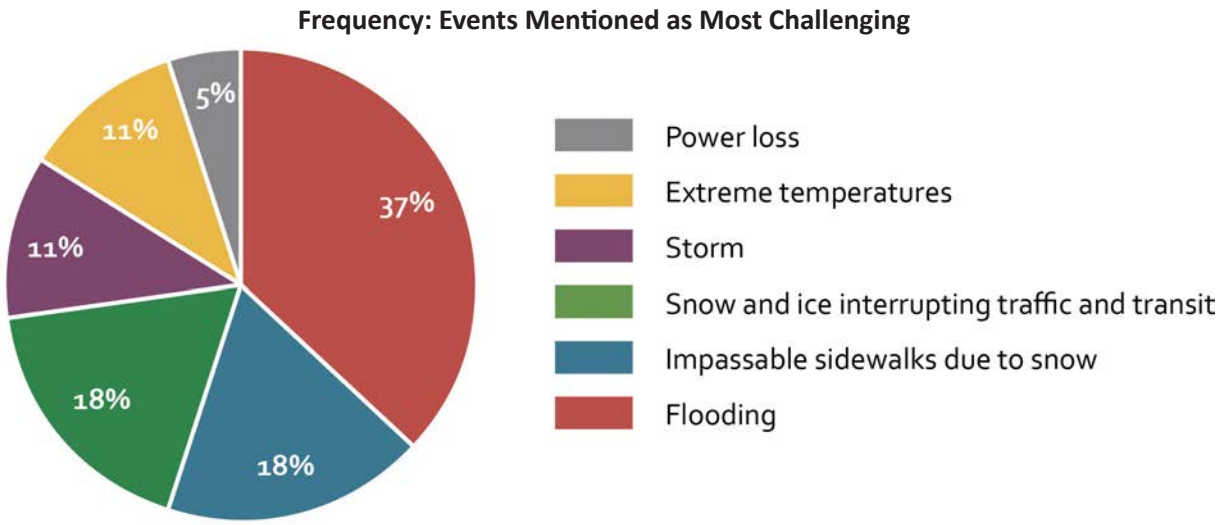

Figure 13. Sample results of survey conducted by UMass Boston, 2016

Commission organizes a ***Meet Your Neighbor Day*** cosponsored by the Citizen's Committee on Civic Unity for a Cambridge-specific approach to building connections and community[14].

To further inform community resiliency for the CCPR Alewife Plan, the students and faculty from the University of Massachusetts-Boston's Program in Urban Planning and Community Development conducted interviews in the fall of 2016 with organizations that provide direct services to populations at risk in Alewife. It also organized two focus groups in the area and "interceptor interviews" in few strategic locations. In total, 92 interviews with residents were completed. Participants identified climate events they found the most challenging (see Figure 13) and flooding and extreme temperature are of most concern. Key findings are documented in the *Local Perceptions of Disaster Preparedness in the Alewife District* included in Appendix C.

IMPLEMENTATION CONTEXT

The aim of the strategies for **Prepared Community** is to enhance social cohesion, increase the resilience of critical facilities, establish and enhance support systems, and promote advanced planning and preparedness. Taking into account that extreme heat is a risk likely to occur in the near future and that Alewife is a community with high-risk populations, there is a sense of urgency to implement some of the proposed strategies within the next 10 years. The organizational structure already exists since City departments, public health organizations, and community organizations would spearhead this effort. As drafted, the jurisdiction of most actions is within the City's Public Health and Inspectional Services departments, so implementation in the near future may be possible. Cost, however, needs to be considered.

As illustrated in Figure 14, a possible time frame for implementation has been developed, staggering strategies to start with a few that could have the most impact and others that would develop over time. Strategies addressing extreme heat are shown as starting in the near future because heat is identified as an imminent risk and has been the largest single weather-related

14) www.cambridgema.gov/Departments/peacecommission/meetyourneighborday

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cause of death in the US[15]. Strategies to build support for vulnerable populations—for example, enhancing access to medical services or education—have also been identified as starting in the near future because they provide critical support to populations experiencing flooding damage to their homes or businesses and loss of revenue due to disrupted access to jobs. Strategies for more extensive emergency measures that take into account possible evacuation or a major collapse of communication systems are delayed to the mid-term because they provide preparedness for more extreme events such as projected flooding from SLR/SS.

The proposed strategies for **Prepared Community** are detailed in the Alewife Preparedness Handbook.

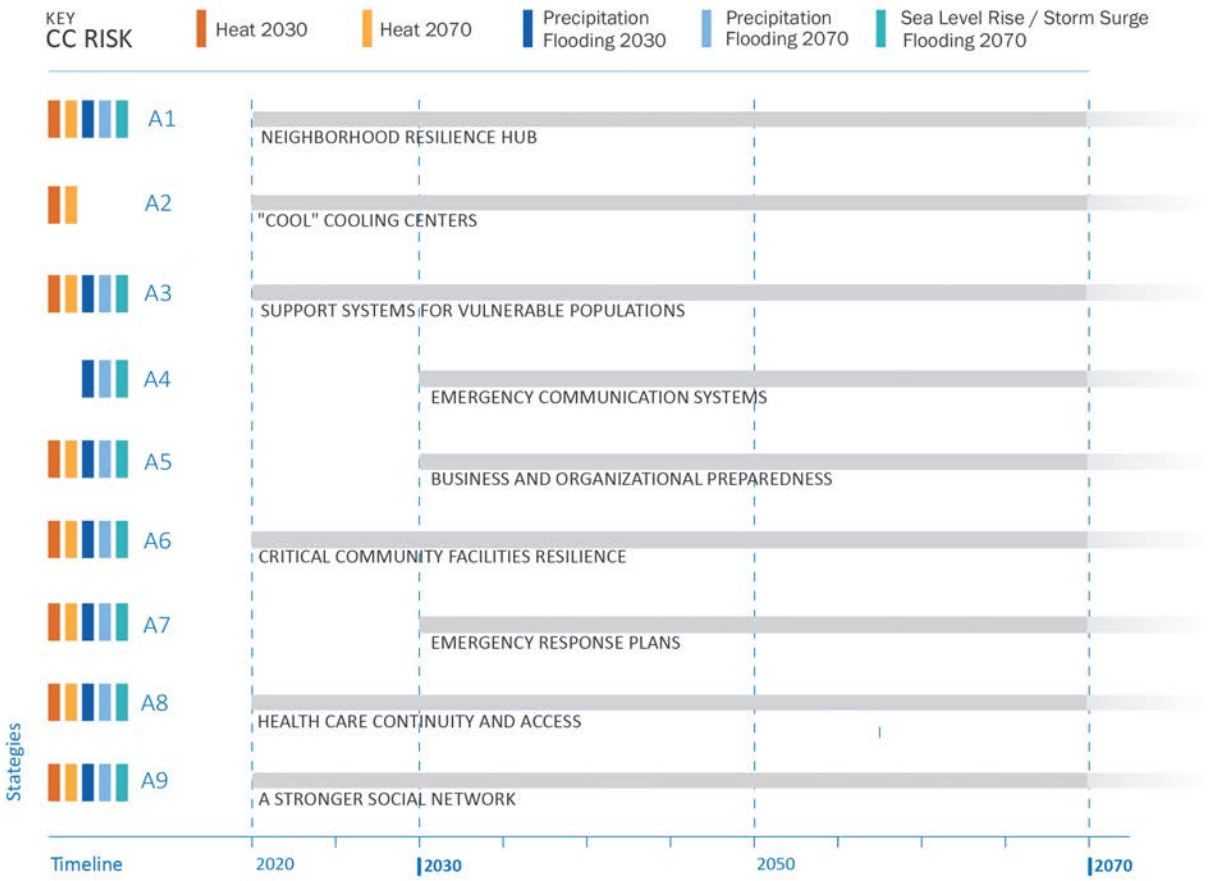

Figure 14. Implementation timeline for "Prepared Community"

15) As reported by NOAA, the National Oceanic and Atmospheric Administration www.nws.noaa.gov/pa/fstories/2005/0105/fs11jan2005a.php

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STRATEGIES B:
ADAPTED BUILDINGS

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Strategies B: Adapted Buildings

OVERVIEW

The overall benefit of the strategies for **Adapted Buildings** is to develop a resilient neighborhood that is protected from climate change impacts and designed for a speedy return to normal. Strategies for flood and heat resiliency have been developed separately for new and existing buildings because different approaches and means are needed for each. Table 2 lists the proposed strategies, and Figure 15 shows the potential locations of the proposed strategies for **Adapted Buildings**.

TABLE 2: STRATEGIES FOR ADAPTED BUILDINGS

STRATEGY	TITLE	DESCRIPTION
B1	FLOOD PROTECTION FOR NEW BUILDINGS	Establish regulations and design guidelines for new buildings and re-development to be resilient to future flood risks identified for the neighborhood.
B2	HEAT PROTECTION FOR NEW BUILDINGS	Establish regulations and design guidelines for new buildings and re-development to be resilient to future heat risks identified for the neighborhood.
B3	FLOOD PROTECTION FOR EXISTING BUILDINGS	Establish a program to support retrofitting of existing buildings and re-development to be resilient to future flood risks.
B4	HEAT PROTECTION FOR EXISTING BUILDINGS	Establish a program to support retrofitting of existing buildings and re-development to be resilient to future heat risks.
B5	BUILDING MANAGEMENT FOR FLOOD AND HEAT PROTECTION	Develop a program to enable building residents and occupants to effectively manage and operate resilient buildings.
B6	SITE GREEN INFRASTRUCTURE	Implement green infrastructure (GI) at the parcel level to improve water management and reduce heat-island effect.
B7	ADAPTED ZONING, POLICIES AND REGULATIONS	Revise zoning to factor in Climate Change risks, such as flooding and extreme heat and adjust building requirements to take into account new constraints such as revised flood elevation.

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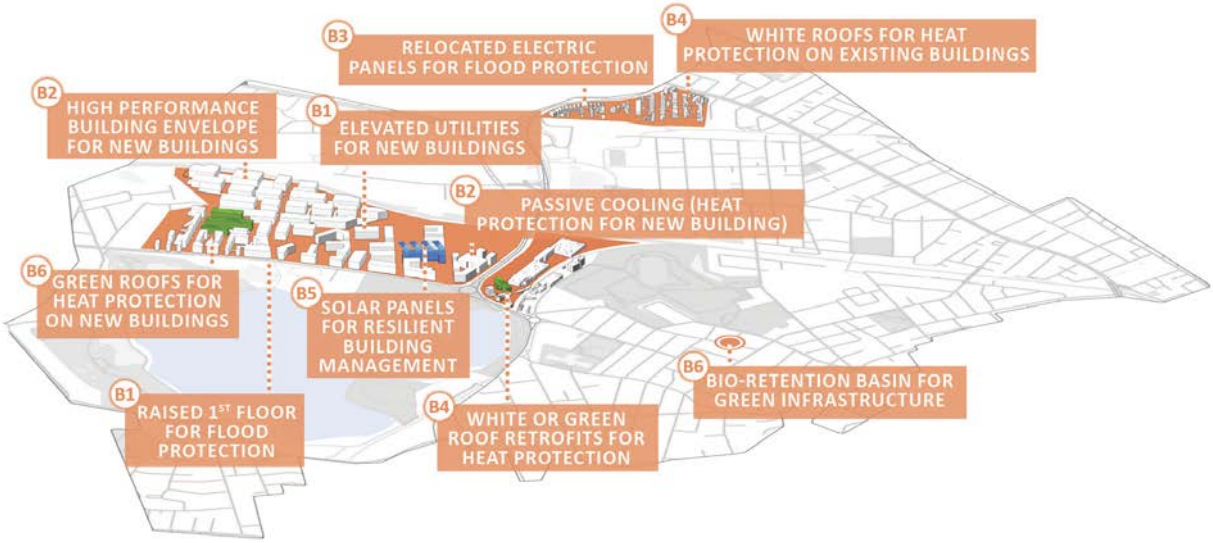

Figure 15. Mapping the potential locations of Adapted Buildings strategies

RELEVANCE TO ALEWIFE

Heat Impacts

By 2030, annual days over 90 degrees Fahrenheit in Cambridge may triple. By 2070, Cambridge may experience nearly three months over 90 degrees Fahrenheit compared with less than two weeks today. Essentially, Cambridge weather could feel like Northern Virginia's by mid-century and South Carolina's by the end of the century.

Sustained exposure to extreme heat affects the health and safety of building occupants and damages critical equipment and roof membranes. A high proportion of older housing may be poorly adapted to hot weather due to a lack of adequate natural ventilation or air conditioning, too many heat-absorbing surfaces, and inadequate insulation.

Flooding Impacts

The Alewife area already experiences significant flooding from extreme precipitation. Figures 16 and 17 show flooding impacts in this area from two heavy rainfall events in 2014 and 2010, respectively. The projected change in flooding for the 10-year storm will define a new normal for Alewife, considering that a 10-year precipitation storm has a 10 percent probability of occurring every year and a 65 percent chance of occurring over a 10-year period.

It is important to note that by 2070, the number of properties that could experience flooding from the 100-year sea level rise and storm surge flood is halved compared to the 100-year precipitation event (see Table 3). Open spaces in the Alewife area are more affected by sea level rise and storm surge flooding, whereas more properties are affected from piped infrastructure flooding due to precipitation. The duration of flooding for both precipitation and sea level rise and

Adapted Buildings are critical to protect households and businesses.

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TABLE 3. ALEWIFE AREA STORM EVENT FLOODING			
YEAR	STORM EVENT	% FLOODED LAND AREA	% FLOODED PROPERTIES
Present	10-year 24-hour precipitation event	3%	5%
	100-year 24-hour precipitation event	11%	18%
2030	10-year 24-hour precipitation event	5%	7%
	100-year 24-hour precipitation event	13%	21%
2070	10-year 24-hour precipitation event	6%	9%
	100-year 24-hour precipitation event	19%	**28%**
	10-year SLR/SS event	31%	12%
	100-year SLR/SS event	34%	**14%**

Figure 16. Fawcett Street Flooding summer 2014
[Source: Fresh Pond Residents Alliance]

Figure 17. Urban Flooding
City of Cambridge July 10, 2010

storm surge is determined by the efficiency of the pumps at the Amelia Earhart Dam, as well as by how quickly the City's piped infrastructure can drain the flood waters away. However, the nature of flooding in the Alewife area from both precipitation and SLR/SS is stillwater flooding with no velocity effects.

Frequent exposure to flooding degrades buildings through structural damage and poor indoor air quality. People spend on average 90 percent of their time indoors; therefore, the quality of indoor air has a large bearing on health. Any residential or commercial structures that experience frequent or sustained flooding, particularly from contaminated floodwaters, may face long-term challenges related to mold and bacterial growth, which could cause respiratory problems. This risk is exacerbated in buildings that are adjacent to poorly drained soils, have poorly sealed windows and roofs, and those that

Based on the current pace of renovation, it is estimated that it will take 50 years to retrofit the existing building portfolio for preparedness. New construction is likely to have more near-future resiliency.

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utilize forced hot-air heating and cooling since this type of system can convey moist air from damp basement areas.

ACTIONS ALREADY BEING TAKEN

Participation in the Community Rating System (CRS): The City of Cambridge's participation in the Flood Emergency Management Act (FEMA)-sponsored CRS Program provides incentives for activities that reduce flood losses and support the sale of flood insurance. The Cambridge Department of Public Works (DPW) is designated as the City's lead agency and CRS coordinates their program. Part of the program's goal is to actively involve City departments and agencies in the development, advertising, and enforcement of any activity that would reduce property damage and residential liability in the event of flooding. Participation in the CRS Program includes annual review and revision of the floodplain management plan for the City, which may include a public hearing process, citywide mail-outs, and other forms of public advertisement.

Re-development Requirements: The Massachusetts State Building Code (780 CMR 120.G) requires all new residential buildings in areas prone to flooding to be elevated. Buildings not used for residences are required to implement floodproofing measures. Existing developments are exempt unless more than half of the perimeter of the building foundation is to be repaired or replaced. Additionally, areas below flood level are limited to storage or parking. Requirements within the Cambridge Floodplain Overlay District—defined by the FEMA 100-year floodplain[16] — include a special permit to be granted by the Planning Board for any structure or building erected, constructed, expanded, substantially improved, or moved, and for earth or other materials dumped, filled, excavated, transferred, or otherwise altered in the Floodplain Overlay District. The procedure for such a permit includes detailed landscape plans showing elevations, documentation of the base flood elevation data if not provided on the Flood Insurance Rate Map (FIRM), and certification by an engineer that any encroachment upon a floodway will not increase flood levels during a 100-year event.

The City is proposing that re-development build/protect to the 2070 10-year flood elevation[17] from precipitation or SLR/SS, whichever is higher, and recover from the 2070 100-year flood elevation from precipitation of SLR/SS, whichever is higher.

The City of Cambridge also has a stringent stormwater management policy in place for re-development, referred to as "25:2." Under this policy, all re-development must store the difference in stormwater volume between the pre-development 2-year, 24-hour storm event[18] runoff and the post-development 25-year, 24-hour storm event[19] runoff. The City is considering if this requirement can be modified to include climate change impacts by updating the present design storm criteria to the 2030 criteria.

Flood Risk Tool: With the understanding that FEMA mapping is based on past events and no longer relevant to the risks posed by climate

With the understanding that FEMA mapping is based on past events and no longer relevant to the risks posed by climate change, the City has created a database at the parcel level to identify projected flood elevations.

16) The FEMA 100-year floodplain is defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year.
17) 2070 10-year flood elevation is the flood elevation that has a 10-percent chance of being equaled or exceeded by 2070.
18) 2-year 24-hour event is a rainfall event that occurs over 24 hours and has a 50-percent chance of being equaled or exceeded in any given year. Rainfall depth is 3.1 inches.
19) 25-year 24-hour event is a rainfall event that occurs over 24 hours and has a 4-percent chance of being equaled or exceeded in any given year. Rainfall depth is 6.1 inches.

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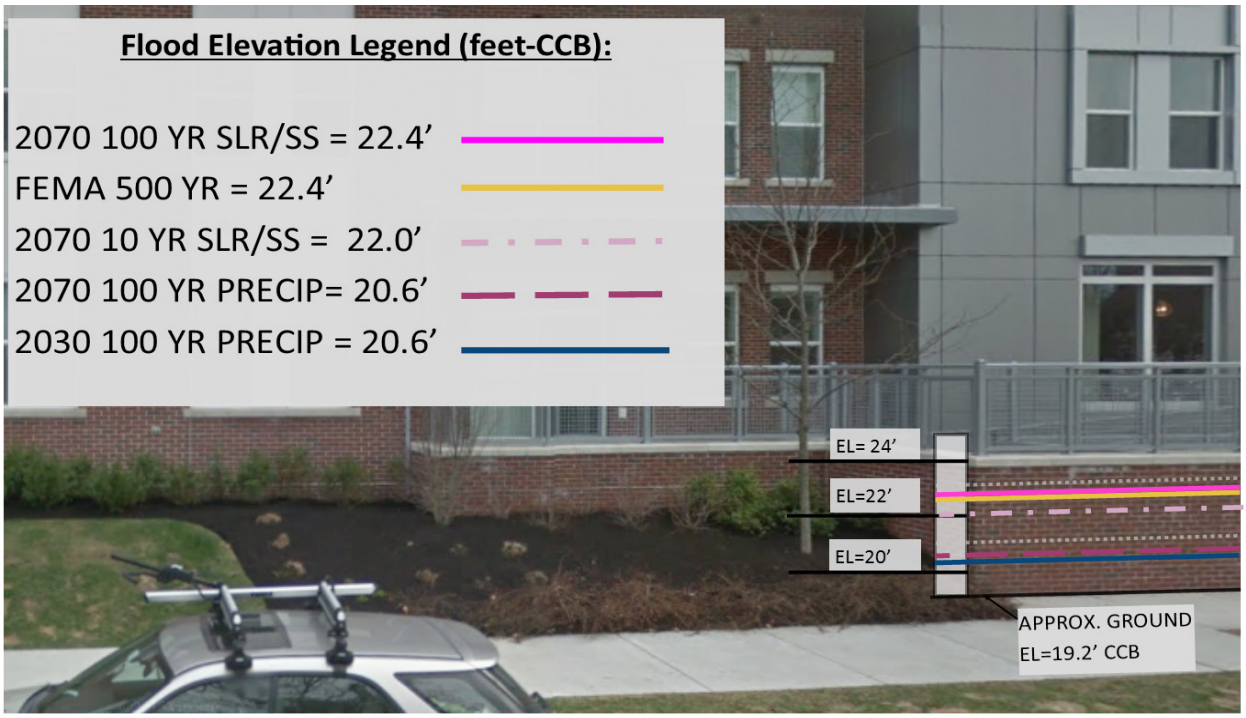

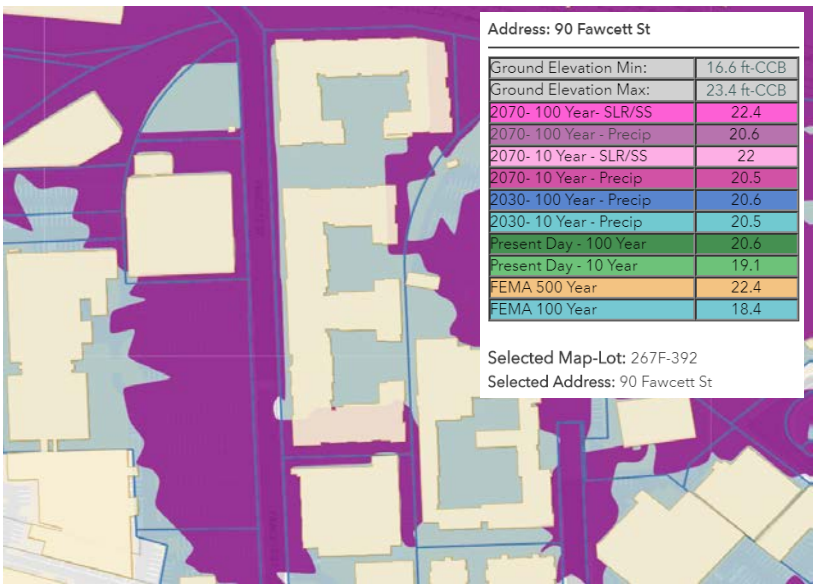

Figure 18. Flooding risk tool (left) developed by the City on a parcel basis to guide re-development. Picture rendering (above) of the different flood elevations for an existing building.
[Source: Kleinfelder for the City of Cambridge, November 2017]

change, the City has developed a geospatial flood-risk tool, which can be used at the parcel-level to identify projected flood elevations and flood depths. The City will make this tool publicly available to inform residents about the risk and vulnerability of specific facilities. As a test case, the DPW is using this tool to provide the proposed design elevations for new buildings to developers. When it becomes publicly available, existing property owners can use it to better understand their flood risks and account for these risks when considering any major retrofits to their property. Figure 18 illustrates the information made available from the flood-risk tool. Since the tool has both maps and call-out text boxes that lists the flood elevations and depths for each parcel, the City is able to communicate the projected flood risks to developers and key stakeholders, allowing buildings to be designed to be resilient to their specific risks.

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IMPLEMENTATION CONTEXT

By retrofitting existing buildings or requiring re-development to meet enhanced resiliency standards, owners and developers can serve as leaders of these measures. A few strategies, such as updating the Massachusetts State Building Code to reflect new flooding requirements and in anticipation of more frequent extreme heat events, require partnerships with State agencies to change regulations. Consequently, the scale of implementation is most often the single building or the parcel; however, several buildings could transform a neighborhood. This is why areas of projected growth carry the potential of transforming entire neighborhoods; one example is the Quadrangle area east of Concord Avenue, which is likely to experience substantial re-development.

As illustrated in Figure 19, strategies for **Adapted Buildings** are staggered between short-term and midterm time frames for implementation. Strategies that provide flood protection for new buildings or major renovations are recommended to start in the short-term, taking into account that the life expectancy of buildings ranges from 25 to 50 years[20] and anticipating that buildings constructed or renovated today will have to sustain the climate risk horizons of 2030 and 2070. Strategies that have more flexibility in their time of implementation, as for example "Heat Protection for Existing Buildings" (B4) or "Building Management for Flood Protection" (B5), are identified to be initiated midterm. Strategies for "Adapted Zoning and Regulations" (B7) is shown to start later as it will require further research and would benefit from learning more on how other cities currently experiencing severe flooding at unprecedented levels revise their zoning and regulations.

The proposed strategies for **Adapted Buildings** are detailed in the Alewife Preparedness Handbook.

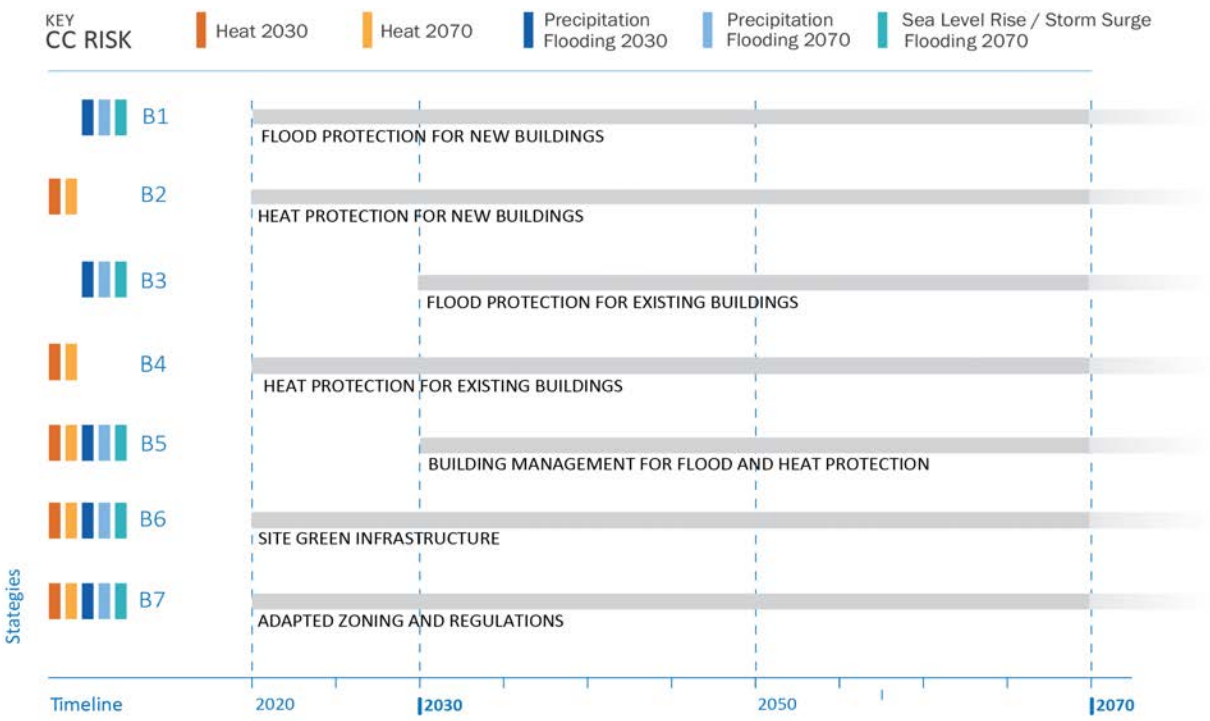

Figure 19. Adapted Buildings strategies timeline from start to effectiveness

20) http://cwc.ca/wp-content/uploads/2013/12/DurabilityService_Life_E.pdf

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STRATEGIES C:
RESILIENT INFRASTRUCTURE

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Strategies C: Resilient Infrastructure

OVERVIEW

The anticipated benefits of **Resilient Infrastructure** strategies are anticipated to prevent damage to critical infrastructure in the Alewife area due to increased flooding and prolonged heat waves. The focus of the proposed strategies is to mitigate economic losses and negative health impacts by making infrastructure more resilient under climate stresses. Mitigating flooding in the Fresh Pond Reservoir will preserve drinking-water quality, which is critical to public health and well-being. Resiliency of the electric grid will help alleviate public health impacts caused by extreme heat and potential loss of the water supply and other critical facilities requiring power. Resiliency of the transportation system enables emergency and public safety services to reach areas in need. The collective benefits of these strategies will improve public health and wellness in the Alewife community and citywide.

Strategies for **Resilient Infrastructure** range from parcel- to regional-scale solutions for protection of critical infrastructure and mitigation of the negative impacts from both precipitation and SLR/SS flooding. Table 4 lists the proposed strategies, and Figure 20 shows the potential locations of the proposed strategies for **Resilient Infrastructure**.

TABLE 4: STRATEGIES FOR RESILIENT INFRASTRUCTURE

STRATEGY	TITLE	DESCRIPTION
C1	PROTECT FRESH POND RESERVOIR	Protect Fresh Pond Reservoir, the terminal reservoir for the City's drinking water supply, from future flooding impacts.
C2	RESILIENCY OF ELECTRICAL DISTRIBUTION SYSTEM	Engage with Eversource and the Massachusetts Public Utilities Commission to increase the resiliency of the electricity distribution system, particularly the Alewife substation.
C3	RESILIENCY OF THE TRANSPORTATION SYSTEM	Engage the MBTA and MassDOT to increase the resiliency of major transportation and transit infrastructure to ensure mobility and access to evacuation routes. Complete street grid by adding new local roads for better connectivity to the Alewife train station.
C4	REGIONAL FLOOD RESILIENCY AT AMELIA EARHART DAM AND OTHER SITES	Collaborate regionally and with the State on structural and operational improvements at the Amelia Earhart Dam. Plan, design and implement storm surge barriers, "smart" flood prevention systems and conveyance improvements at appropriate sites.
C5	WATERSHED SCALE FLOOD STORAGE	Collaborate regionally to plan and implement watershed-scale flood storage at appropriate sites in the Mystic River watershed.

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TABLE 4: STRATEGIES FOR RESILIENT INFRASTRUCTURE *(CONT.)*		
STRATEGY	TITLE	DESCRIPTION
C6	SUB-NEIGHBORHOOD SCALE FLOOD PROTECTION	Create a neighborhood solution for sea level rise/storm surge flooding for the extended Quadrangle area and Fresh Pond.
C7	COMBINED SEWER SEPARATION	Continue combined sewer separation in the Alewife area to reduce adverse public-health impacts during flood events and to protect water quality.
C8	STORMWATER STORAGE	Evaluate the collective benefits of adopting updated stormwater storage requirements at the parcel scale to mitigate flooding at the sub-neighborhood scale.
C9	CLEAN-ENERGY FACILITY	Establish a neighborhood-scale clean energy facility in the Alewife Quadrangle area.

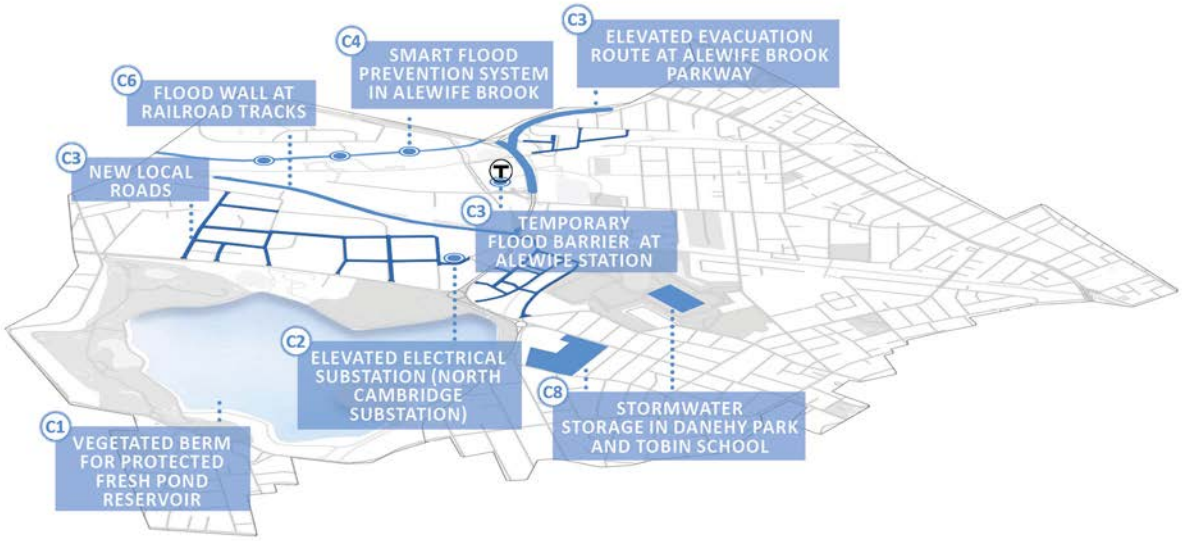

Figure 20. Mapping the potential locations of the Resilient Infrastructure strategies

RELEVANCE TO ALEWIFE

Climate change impacts will have an adverse effect on infrastructure, both in terms of its integrity and operations. Infrastructure is designed based on historic weather conditions. The City of Cambridge is already at risk from precipitation-driven flooding, particularly in the Alewife area. Many homes experience flooding today from both short- and long-duration storms. The Alewife area is one of the most vulnerable areas of Cambridge, with a relatively high population of elderly and low-income residents. Flooding will severely affect these vulnerable populations. There are many negative health impacts associated with inland flooding, especially in areas where sewer systems are still combined. The Alewife area has 17 miles of combined sewers and 20 miles of stormwater pipes. Increased precipitation alone or in combination with SLR/SS can cause street

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flooding from manhole overflows or basement flooding from sewer backups, resulting in untreated sewage on streets and properties and exposing residents to adverse public health effects. Untreated sewage from streets will eventually discharge into surrounding water bodies and degrade water quality.

Amelia Earhart Dam

The Amelia Earhart Dam currently provides adequate protection for storm surge flooding up to planning year 2030. As sea levels continue to rise, the protection provided by the dam will diminish over time. Some key strategies need to be implemented by 2050, since the Amelia Earhart Dam is likely to be bypassed by a 100-year flood by 2045, which would cause significant damage to the functioning of critical infrastructure. After 2055, the probability of SLR/SS flood events flanking and overtopping the dam increases significantly with profound flooding in upstream areas, such as the Alewife area.

The protection of drinking water sources is a particular concern.

Fresh Pond Reservoir

SLR/SS flooding is also a concern for the Fresh Pond Reservoir. Fresh Pond is the terminal reservoir for the City's drinking water supply, and stormwater discharges to it are regulated by the State's water quality standards. Such flooding could potentially introduce salt-laden ocean water, as well as other pollutants, into the reservoir since it would no longer be isolated by existing berms. The normal operating level of Fresh Pond is 16 feet-CCB[21], with the maximum level being at 17 feet-CCB. If Fresh Pond is above 18 feet-CCB, it is no longer isolated, whereas the 2070 100-year SLR/SS flood elevation is 23 feet-CCB. The untreated discharges from overland flooding as a result of SLR/SS would compromise the water quality of the City's drinking water and impact the operation of the treatment plant.

Electrical Distribution System

Climate change will also have adverse effects on the City's electrical distribution system and various transportation modes. The system is one of the most critical infrastructure elements that contributes to a community functioning effectively. Strain on Cambridge's electrical grid will increase if resiliency measures are not taken, as increased energy demands from extreme heat will affect peak energy loads. Vulnerable populations such as seniors who do not have access to air conditioning due to a power outage are more likely to experience negative health impacts. Additionally, given the location of the Eversource electrical substation, power outages from extreme flooding are likely and will have an adverse economic impact.

Transit and Transportation

Many residents rely on public transit as their primary means of transportation. The Alewife MBTA station was not designed to cope with significant exposure to inland flooding. Similarly, the MBTA commuter rail tracks are at risk of buckling under extreme heat. The rail used in MBTA subway lines is conditioned to operate optimally at maximum ambient temperatures of around 80°F[22], above which the risk of buckling or "sunk kinks" increases as heat rises.

Finally, many roadways and intersections in the Alewife area are at risk of flooding, which will restrict access for law enforcement and public safety services in Cambridge.

21) CCB stands for Cambridge City-Base datum, which is vertical reference datum that the City uses. The CCB datum is 11.35 feet above the mean sea level in Boston.

22) Maximum MBTA neutral rail temperature is 110°F (Massachusetts Bay Transportation Authority, Maintenance of Way Division. 2000. Green Line – Light Rail Transit Track Maintenance and Safety Standards: CWR Installation Guide and Track Buckling Countermeasures. Pages 47-52. Accessed November 2014. www.mbta.com/uploadedfiles/Business_Center/Bidding_and_Solicitations/Design_and_Construction/Track-MaintandSafety-Standards-Green-Line.pdf).

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ACTIONS ALREADY BEING TAKEN

The City has been integrating climate change considerations by establishing new design standards and policies. The following examples are ongoing initiatives to enhance preparedness.

Regional Coordination: Cambridge is a signatory to the Metro Mayors Climate Commitment, which is an agreement among 14 cities and towns to work together to make the region more resilient. One initiative was developing a grant application to reduce flood risk along the Mystic River and Alewife Brook at a regional-scale, working with Boston, Chelsea, the Mystic River Watershed Association, and the Metropolitan Area Planning Council. Another was to coordinate with the University of Vermont and communities in the taskforce to conduct tree canopy mapping, which will help communities better understand their urban heat island impacts.

Policy to Promote Resiliency: The City has a "25:2" stormwater management policy for re-development that mandates storing the difference in volume between the 2-year, 24-hour storm event runoff and the 25-year, 24-hour storm event runoff. The City is considering modifying this requirement to include climate change impacts by using the 2030 design storms criteria. Additionally, the City encourages incorporation of green roofs under Zoning Ordinance, Article 22[23]; these roofs are not counted against a building's Gross Floor Area, which provides an incentive for contributing to stormwater management and reducing UHI.

Construction Projects and Infrastructure Programs: To protect Fresh Pond Reservoir from the effect of SLR/SS, the City modified a project under the Fresh Pond Master Plan by raising the hummocks in the Fresh Pond Community Gardens to the 2070 100-year SLR/SS flood elevation of 23 feet-CCB. To reduce adverse public-health impacts during flooding and protect water quality that could be compromised from discharges from the combined sewer system, the City continues to separate sewers, perform remedial reconstruction of storm sewer and drainage infrastructure, and conduct reviews to check on the physical condition of underground infrastructure. The City develops, maintains, and monitors its 5- and 10-year capital infrastructure program objectives for municipal stormwater infrastructure, including combined sewer separation projects, with climate change considerations in mind.

To protect Fresh Pond Reservoir, the City raised the hummock in the Fresh Pond Community Gardens to the 2070 100-year sea level rise/ storm surge flood elevation.

Modeling Future Flooding Conditions to Assess Impacts: The City has developed a unique regional hydraulic model that includes real-time operations of the Amelia Earhart and Charles River dams, the upstream Mystic River watershed up to the confluence with the Aberjona River, and the Malden River. This is the first time that a regional model at this scale and level of detail has been developed. This integrated hydraulic model has been coupled with a sophisticated SLR/SS model developed by the Massachusetts Department of Transportation (MassDOT) and is able to factor in the impacts of flooding from both SLR/SS and increased precipitation. This has provided the greater metropolitan Boston region with a better understanding of the magnitude and timing of flood risks. The City continues to update its model with the

23) www.cambridgema.gov/~/media/Files/CDD/ZoningDevel/Ordinance/zo_article22_1397.ashx
Rail temperature is assumed to be 30°F higher than the ambient temperature in hot weather (Federal Railroad Administration, Office of Safety Analysis. 2013. Continuous Welded Rail Generic Plan: Procedures for the Installation, Adjustment, Maintenance and Inspection of CWR as Required by 49 CFR 213.118. Page 15. Web, Accessed November 2014. http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/cwr/).

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best available information, such as recent infrastructure improvements at the Craddock Bridge. Additionally, the City has been the first in the region to evaluate the benefits of additional pump capacity at the Amelia Earhart Dam, which demonstrated that increasing pumping capacity results in significant flood reduction in the Alewife area.

Resiliency efforts outside the City: Both the MBTA and MassDOT have ongoing efforts to increase the resiliency of Cambridge's transportation system. The MBTA provides shuttle buses and/or single-track trains, allowing for trains traveling in both directions to share the same track as a resiliency measure when a section of rail is shut down. MassDOT and the MBTA are in the process of identifying their most vulnerable transportation and transit assets/infrastructure and developing their own resiliency plans.

IMPLEMENTATION CONTEXT

Key proponents for implementation of the proposed strategies are a combination of City departments collaborating with other government agencies at the State and local level, private institutions, and developers. Public/private partnerships with the City and state agencies such as MassDOT or private utility companies such as Eversource should also be considered.

Strategies can be implemented at different scales. For example, protecting the North Cambridge electric substation or the entrance to the MBTA Alewife train station is at an asset- or building-scale. Building a flood wall south of the railroad line along the Alewife Quadrangle will protect the Quadrangle and the Fresh Pond areas and is therefore a neighborhood-scale strategy. Elevating the Amelia Earhart Dam or building berms on its north and south side to reduce flooding flanking the dam are regional-scale solutions.

As illustrated in Figure 21, a possible time frame for implementation has been developed, staggering the strategies to start with a few that could have the most impact and others that would develop over time. For example, increased stormwater storage requirements (C8) for re-development is a strategy that can be initiated in the near future (by 2020), such that re-development in the Alewife area can mitigate the risks from extreme precipitation, which is more imminent now and projected to exacerbate by 2030. Strategies to protect the Fresh Pond Reservoir (C1), the Alewife electrical substation (C2), and the MBTA Alewife train station (C3) are mid-term (start by 2030). These strategies also need to be implemented by 2050, since the Amelia Earhart Dam is likely to be bypassed by a 100-year flood by 2045 and overtopped by 2055, which would cause significant damage to the functioning of critical infrastructure. Watershed-scale flood storage (C5) to mitigate the risks of both extreme precipitation and SLR/SS flooding can start in the distant future (by 2050), since this strategy will need more analysis and require significant regional coordination across communities in the watershed.

The increased demand on the electric grid is a concern for the community as the number of elevated heat days increases and residents turn on their air conditioning more often. Can the City plan for this increase by exploring and investing in renewable energy, distributed generation, microgrids, energy efficiency retrofits, and incentive structures for reducing electricity use?

The proposed strategies for **Resilient Infrastructure** are detailed in the Alewife Preparedness Handbook.

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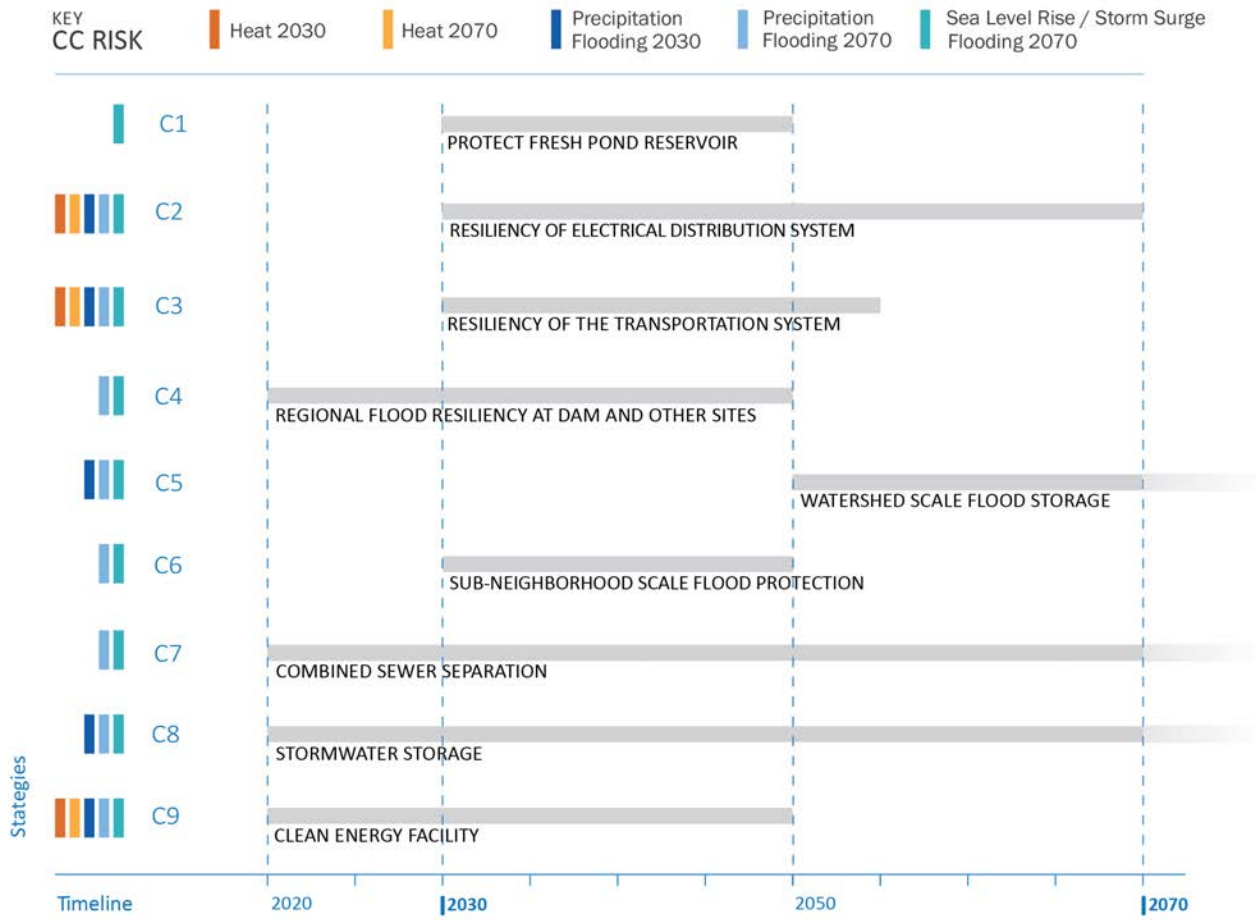

Figure 21. “Resilient Infrastructure” strategies timeline from start to effectiveness

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STRATEGIES D:
RESILIENT ECOSYSTEMS

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Strategies D: Resilient Ecosystems

OVERVIEW

The anticipated collective benefits of the strategies for **Resilient Ecosystems** are to reduce the urban heat island (UHI) effect, preserve air quality, improve water quality, and provide additional stormwater storage capacity. The collective benefits do not necessarily imply that all of the listed strategies need to be implemented at the same time. However, a collective group implementation approach would be more beneficial than any one of the individual strategies.

Strategies for **Resilient Ecosystems** are closely aligned with one another and focus on mitigating the UHI effect to protect vulnerable populations from the negative health impacts of extreme heat, improve water quality, and reduce flooding impacts from smaller storm events. Table 5 lists the proposed strategies, and Figure 22 shows their potential locations in the Alewife area.

TABLE 5: STRATEGIES FOR RESILIENT ECOSYSTEMS

STRATEGY	TITLE	DESCRIPTION
D1	RESILIENT URBAN FOREST	Reduce the urban heat island effect by increasing the urban forest canopy, developing a comprehensive urban forest management plan, and continuing urban forest maintenance efforts.
D2	ENHANCED OUTDOOR THERMAL COMFORT	Develop “cool corridors” aligned with bike and pedestrian routes and MBTA bus stops to enhance outdoor thermal comfort for transit users.
D3	REDUCE IMPERVIOUS AREA	Reduce impervious area of upstream parcels to limit flooding at downstream parcels. Evaluate the implementation of a combination of grey and green infrastructure in parcels upstream of flood-prone areas to reduce runoff from impervious areas.
D4	GREEN INFRASTRUCTURE OPPORTUNITIES	Implement Green Infrastructure (GI) to improve water quality and reduce flooding impacts from smaller rainfall events and mitigate urban heat islands (UHI)

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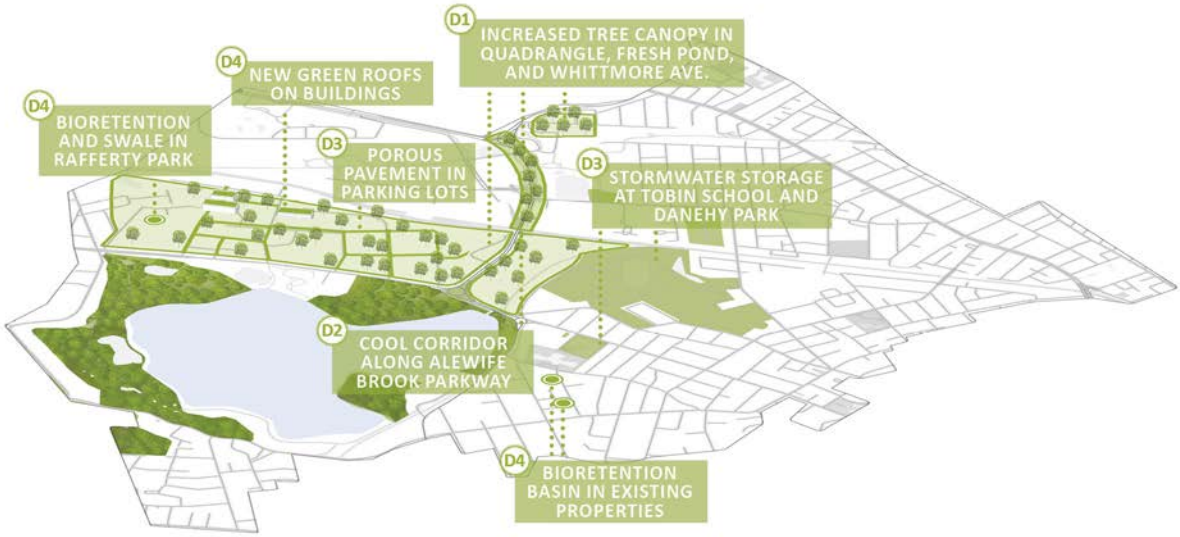

Figure 22. Mapping the potential locations of the "Resilient Ecosystem" strategies

RELEVANCE TO ALEWIFE

Climate change will have negative impacts on the built, natural, and social environment in the City of Cambridge as flooding increases and the UHI effect intensifies. Resilient ecosystems can offer cost-effective and aesthetically pleasing solutions to reduce the UHI effect, preserve water quality, and provide stormwater storage. The number of days over 90 degrees Fahrenheit are projected to nearly triple by 2030 from present conditions of approximately 11 days per year to around 31 days per year[24]. Parts of the Alewife area that lack vegetation will experience heat vulnerability exacerbated by the UHI effect. People with chronic respiratory and heart problems are more vulnerable to the effects of heat. A 1 degree Fahrenheit temperature increase yields an increase of 0.12 ambulance transports per month[25] for heat stroke per 10,000 people[26 27]; this would translate to an additional 1 to 2 transports per month in Cambridge (2016 population: 110,651). A similar temperature increase adds 1.5 to 2 percent to peak electricity demands for air conditioning[28]; this could cause outages that have both negative health and economic impacts.

Travelers are exposed to heat regularly through transit use and at bus stops. Pedestrian networks and bike routes in the Alewife area are directly exposed to heat. Increased tree canopy and other engineered green infrastructure solutions, such as bioretention basins, rain gardens, and green roofs have been shown to reduce the UHI effect.

Green infrastructure solutions, when appropriately designed and integrated as part of the natural ecosystem, also mitigate flooding from smaller storms by providing stormwater storage benefits. The Alewife area already experiences flooding problems caused by heavy rainfall. This is primarily

24) CCVA Temperature and Precipitation Projections, Appendix B, November 2015 www.cambridgema.gov/cdd/projects/climate/~/media/A9D382B8C49F4944BF64776F88B68D7A.ashx
25) The numbers were calculated during the month of August 2010 for 47 prefectures in Japan.
26) Li et. al. Li, T., R.M. Horton, D.A. Bader, G. Huang, Q. Sun, and P.L. Kinney, 2015: Heat-related mortality projections for cardio-vascular and respiratory disease under the changing climate in Beijing, China. Sci. Rep., 5, 11441, doi:10.1038/srep11441
27) Murakami, The relation between ambulance transports stratified by heat stroke and air temperature in all 47 prefectures of Japan in August, 2009; Environmental Health and Preventive Medicine, January 2012, Volume 17, Issue 1, pp 77–80.
28) Reducing Urban Heat Islands: Compendium of Strategies Urban Heat Island Basics. Draft report published by EPA, 2014-06, available at: www.epa.gov/sites/production/files/2014-06/documents/basicscompendium.pdf

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from two causes: 1) overbank flooding from the Alewife Brook due to capacity constraints within the Mystic River watershed, and 2) street flooding due to municipal drainage pipes being overwhelmed. Flooding from combined sewers is also a public health concern in some areas of Cambridge. Reducing impervious surfaces by designing green infrastructure solutions offers a relatively easy solution to reduce flooding from smaller storm events, improve water quality of the runoff ultimately discharging to water bodies, and reducing the UHI effect. Also, green infrastructure solutions can be integrated in re-development opportunities to meet the City's stormwater storage and quality requirements; these requirements are likely to become more demanding to address the growth and re-development in the City and reduce future flooding impacts.

Green infrastructure can play a significant role in adapting to projected increases in extreme rain events by being able to capture as much as 60 percent of the projected increase in extreme precipitation for the 2070 10-year storm. However, green infrastructure cannot address SLR/SS flooding once the Amelia Earhart Dam is overtopped, since the volume associated with this type of flooding is orders of magnitude greater than precipitation flooding.

ACTIONS ALREADY BEING TAKEN

Resilient Ecosystems have been integrated by the City in establishing new designs and policies that support resiliency to climate change. The following are a few examples of ongoing initiatives.

Short-Term Adaptation: To reduce passenger wait time and, therefore, reduce heat exposure at bus stops, the MBTA provides a website that can be downloaded as a cell-phone application that provides global positioning system (GPS) tracking of buses enroute. This helps to minimize outdoor waiting time. In addition, the City of Cambridge offers free access to pools and other waterplay areas, which helps with short-term cooling.

Promoting Urban Forestry: The City has been recognized by the Arbor Day Foundation for its successful urban forestry program. The foundation has awarded Cambridge Tree City awards for 24 consecutive years and Tree Growth awards for 9 consecutive years. As part of the urban forest program, the City maintains a tree inventory to track more than 19,000 publicly-owned trees in the City. This comprehensive inventory contains information on the species, size, and location of all public trees, as well as site characteristics and planting information. The tree inventory was initiated in 2005, and the first inventory was completed in 2011. The City updates the tree inventory whenever a new tree is planted or an old tree is removed or remeasured.

The City of Cambridge is committed to maintaining a healthy urban forest and has been awarded a Tree City USA award from the National Arbor Day Foundation for 24 consecutive years.

In 2016, the City developed an urban forest management plan that contains the City's present policies and guidelines, goals, objectives, and targets for its urban forest future and strategies to achieve these. This plan serves as a guide to integrate the City's urban forest activities with its other policies and planning efforts, including climate change resiliency planning. In addition, the DPW has a variety of programs available for owners interested in adding trees to public spaces around their buildings and homes. For example, a resident can request a replacement tree at no cost if one was removed in front of their property. If there is no space for a tree well on the sidewalk, a resident can request a tree be planted on their own property, or a resident can request to have a well installed. A resident can also pay to have a tree planted to honor a person or significant life event.

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Ongoing Green Infrastructure Projects: The City has designed and commissioned several green infrastructure amenities, such as porous pavement, rain gardens, and bioretention basins especially as part of the Huron A, B, Concord Avenue, and Western Avenue sewer separation projects. The most notable of the City's green infrastructure projects is the 3.4-acre wetland (Figure 23) in the Alewife Reservation area constructed in 2013. This is one of New England's largest constructed wetlands, and it stores and treats stormwater runoff and improves water quality in the Little River and the Alewife Brook. This construction project was a key element of the Alewife Sewer Separation Project that separated the combined sanitary wastewater and stormwater infrastructure in the Huron Avenue and Concord Avenue neighborhoods east of Fresh Pond as part of the Massachusetts Water Resources Authority's (MWRA) Long-Term Combined Sewer Overflow Control Plan for the Alewife Brook.

Figure 23. Alewife Constructed Stormwater Wetland [Kleinfelder, 2013]

Partnership Development: Partnerships and collaboration with key players in the watershed are essential for managing the changing and urbanized Stony Brook watershed, where the City's water supply reservoirs are located in adjacent towns. The Cambridge Water Department (CWD) is continuously reaching out and fostering new partnerships with such parties as the United States Geological Survey (USGS); MassDOT; the towns of Lincoln, Lexington, and Weston; the City of Waltham, and other private entities that are interested in maintaining watershed quality.

The DPW and CWD are involved with current and future re-development, which helps to ensure that green infrastructure solutions such as infiltration basins, rain gardens, and constructed wetlands for stormwater control and treatment are implemented throughout the City and the watershed. Some of the recent partnership projects include constructing a retention pond (Figure 24) and an underground infiltration basin (Figure 25) at Waltham's Polaroid re-development site.

Figure 25. Retention Pond at the Waltham Polaroid redevelopment site [Source: Cambridge Water Department]

Figure 24. Underground infiltration basin under construction at the Waltham Polaroid redevelopment site [Source: Cambridge Water Department]

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IMPLEMENTATION CONTEXT

Key proponents for the implementation of the proposed strategies include City departments collaborating with other government agencies at the State and local level, private institutions and developers, as well as public-private partnerships with City and state agencies such as the Department of Conservation and Recreation (DCR) and the Massachusetts Department of Transportation (MassDOT).

Strategies are implementable at different scales. For example, providing shaded structures at bus stops is a resiliency strategy at an asset-scale. Some of the strategies for **Resilient Ecosystems** are feasible for individual residents, but collective implementation at a larger scale will have the most benefits. Increasing street trees in the Quadrangle is at a neighborhood-scale. Using green infrastructure solutions upstream in the Mystic River watershed, such as at Spy Pond or the Upper Mystic Lakes to reduce runoff to downstream areas in the City from heavy precipitation events, are examples of regional-scale solutions.

As illustrated in Figure 26, a possible time frame for implementation has been developed, staggering the strategies to start with a few that could have the most impact immediately versus others that would need to develop over time. For example, increasing the urban tree canopy (D1), developing “cool corridors” (D2) and green infrastructure strategies (D4) can be initiated in the near future (by 2020) to mitigate extreme heat and flooding risks that are imminent now. Strategies to reduce upstream impervious area in the Alewife Brook sub-watershed or in the Mystic River watershed (D3) can be implemented in the mid-term (by 2030). Most of the strategies under this category will be ongoing in the future since the risks from extreme heat and flooding are likely to progressively exacerbate in the future.

The proposed strategies for **Resilient Ecosystems** are detailed in the Alewife Preparedness Handbook.

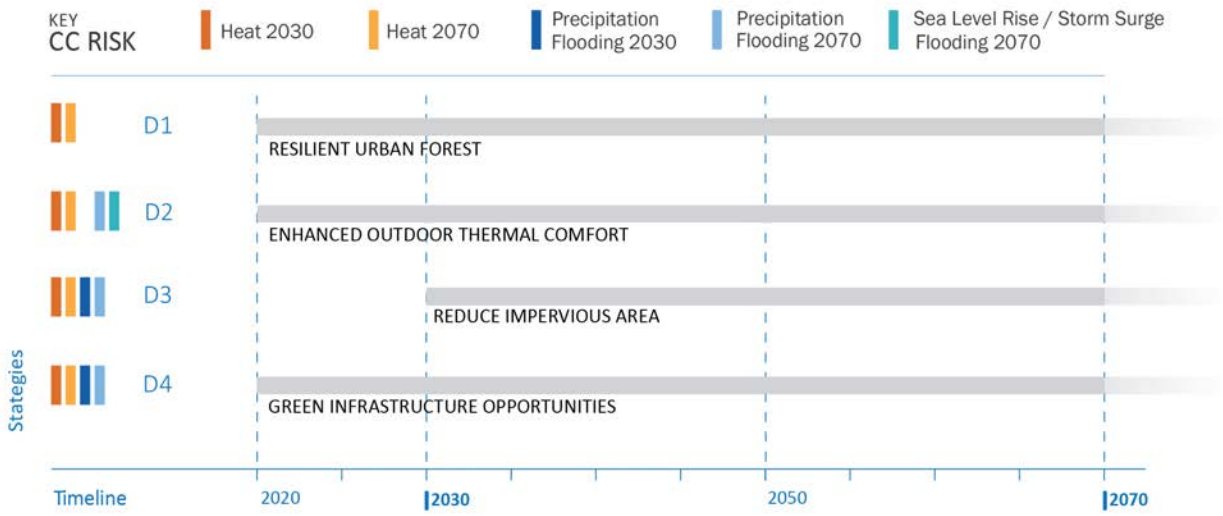

Figure 26. Resilient Ecosystem strategies timeline from start to effectiveness

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CONCLUSIONS AND RECOMMENDATIONS

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Conclusions and Recommendations

Implementation of the strategies for a prepared and resilient Alewife allows for the transformation of the neighborhood. This section presents a discussion on the culmination of the proposed strategies as the proposed strategies will not only protect lives and livelihoods in Cambridge that are at risk from climate change impacts but should also enhance the well-being of the entire community. Three key improvements that will result from developing a more resilient and prepared neighborhood are the following:

- A resilient future for Alewife
- A transformed neighborhood: the Quadrangle as an example
- A hub and connector of regional infrastructure and ecosystems

A RESILIENT FUTURE FOR ALEWIFE

The City's CCVA identified the high priority assets, services, and areas that are predicted to be most at-risk from climate change impacts, assuming no actions are taken toward preparedness or resiliency. Alewife includes the following properties, services, and infrastructure most at risk:

- More than 400 affordable housing units in four locations at risk of flooding as early as 2030
- The City's Emergency Operation Center
- The north Cambridge electric substation
- Key elements of the City's transportation system:
    - ◊ Alewife MBTA subway station with as many as 5,000 weekday entries[29]
    - ◊ Fresh Pond Parkway and Route 60 that exceed 30,000 average daily trips in 24 hours and three of the busiest intersections in the City at Massachusetts Avenue, Route 2, and Concord Avenue, all at risk of flooding

One measure of the plan's success will be determined by the extent to which the recommended strategies reduce the CCVA-identified risks to specific assets identified in the first columns of Table 6. The proposed strategies under each of the four categories, **Prepared Community**, **Adapted Buildings**, **Resilient Infrastructure**, and **Resilient Ecosystems**, are assessed according to their anticipated impact in addressing the identified climate risks: heat and flooding from precipitation and/or SLR/SS. The climate-risk horizons of 2030 and 2070 are also factored in.

The projected change in flooding for the 10-year storm will define a new normal for Alewife.

29) CCVA Technical Report: Critical Assets and Community Resources
www.cambridgema.gov/CDD/Projects/Climate/~/media/13E112045F904992B0953849E9846011.ashx

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	Asset	CCVA Risk					Applicable Resiliency Strategies																													
		Heat		Flood			A Prepared Community									Adapted Buildings							Resilient Infrastructure									Resilient Ecosystems			
		2030	2070	2030	2070	SLR/SS	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	C5	C6	C7	C8	C9	D1	D2	D3	D4
Energy	North Cambridge Substation										●	●						●	●	●	●		●	●	●	●	●	●		●	●			●	●
	Brookford Street Take Station – natural gas										●	●						●	●	●	●			●	●	●	●			●	●			●	●
Roadways and Bridges	Alewife Brook Parkway	●	●								●	●													●	●	●			●		●	●	●	●
	Massachusetts Ave	●	●								●	●													●	●	●			●		●	●	●	●
	Fresh Pond Parkway / Route 60	●	●								●	●													●	●	●			●		●	●	●	●
	Alewife Brook Parkway at Rt.2 and Mass.Ave /Rt.16	●	●								●	●													●	●	●			●		●	●	●	●
	Concord Turnpike / Route 2										●	●													●	●	●			●		●	●	●	●
Transit	Alewife Station (Red)	●	●								●	●						●	●	●	●			●	●	●	●			●	●		●	●	●
	Alewife – Davis – Porter Rail Line (Red)										●	●												●	●	●	●			●	●			●	●
	Fitchburg Commuter Rail Line										●	●												●	●	●	●			●	●			●	●
Water	New Street Pump Station										●	●						●	●	●	●			●		●	●		●	●				●	●
	Fresh Pond Reservoir										●	●											●			●	●	●	●	●				●	●
	CAM 004 (Alewife, Separated)										●	●											●			●	●	●		●				●	●
	CAM 400 (Alewife, Separated)										●	●														●	●			●				●	●
	CAM 001 (Alewife, CSO)										●	●														●	●		●	●				●	●
	D46 (Alewife, Separated)										●	●														●	●			●				●	●
	Alewife Brook										●	●														●	●		●	●				●	●
	CAM 002/002A (Alewife Combined)										●	●														●	●		●	●				●	●
	CAM 401 A/B (Alewife Combined)										●	●														●	●		●	●				●	●
Critical Services	Professional Ambulance Services								●	●	●	●	●	●	●			●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●
	Water Department Bldg. / City's Emergency Operations Ctr.								●	●	●	●	●	●	●			●	●	●	●			●	●	●	●		●	●	●	●	●	●	●
Telecom	BBN Technologies data hub										●	●						●	●	●	●		●	●		●	●	●		●	●			●	●
	Concord Ave Antenna Tower										●	●						●	●	●	●		●	●		●	●	●		●	●			●	●
Affordable Housing	Daniel F. Burns Apt (50 Churchill Ave), 198 units						●	●	●	●	●	●	●	●	●			●	●	●	●	●		●	●	●	●		●	●	●	●	●	●	●
	Briston Arms (247 Garden St), 105 units						●	●	●	●	●	●	●	●	●			●	●	●	●	●		●	●	●	●		●	●	●	●	●	●	●
	2050 Mass Ave/ Leonard J. Russell Apts, 51 units						●	●	●	●	●	●	●	●	●			●	●	●	●	●		●	●	●	●		●	●	●	●	●	●	●
	Neville Center (650 Concord Ave), 57 units						●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Public Schools, Daycare	Tobin School & Daycare						●	●	●	●	●	●	●	●	●			●	●	●	●			●	●	●	●		●	●	●	●	●	●	●

● These specific infrastructure assets were not identified at risk in CCVA. However, within CCPR, the perception of risk has been broaden to factor in heat risk for user groups, e.g. pedestrians, bicyclists and commuters.

Table 6. Alewife's most at-risk assets and application coverage of resilience strategies. See Tables 1-4 of this document for definitions of the strategies.

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Implementation of the proposed strategies for **Prepared Community** will alleviate flooding and extreme heat impacts to critical emergency services and vulnerable populations. For example, establishing neighborhood resiliency hubs at or in close proximity to affordable housing such as the Daniel Burns Apartments, Briston Arms, and Walden Square Apartments will enhance the community network and provide an accessible, usable shelter during extreme events. Similarly, resilience hubs at or in close proximity to the Tobin School and Daycare and the West Cambridge Youth Center can shelter vulnerable young populations. Establishing "cool" cooling centers at other locations throughout the neighborhood such as the Fresh Pond Mall could also provide support to nearby vulnerable populations.

The implementation of resilient strategies for Prepared Community will not only address vulnerabilities to flooding and heat but will also contribute to improved public health and the enhanced well-being of the community.

Implementation of the proposed strategies for **Adapted Buildings** will be critical in developing resilient households and businesses. For example, adopting revised heat resiliency design guidelines for new buildings with passive cooling and high-performance insulation will result in more heat-resilient buildings and neighborhoods in Alewife. Raising buildings' first floors and elevating utilities will result in more flood-resilient neighborhoods. Developing and incentivizing programs, such as weatherization, installing solar panels, painting roofs white, relocating utilities to higher elevation, and installing backwater valves, will also provide buildings' resiliency to both heat and flooding. These strategies will mitigate extreme heat and flooding impacts to several at-risk assets, including affordable housing, critical emergency services, vulnerable populations, as well as protect businesses and maximize business continuity.

Implementation of the proposed strategies for **Resilient Infrastructure**—such as providing for the flood resilience of the electrical substation and the MBTA train station, elevating existing evacuation routes, and developing alternate detour roads for evacuation—will mitigate flooding impacts to several at-risk assets, including energy, transportation, and water/ stormwater/wastewater infrastructure. It will also protect critical emergency services and vulnerable populations. The proposed roads in the Envision Cambridge Plan for Alewife will provide detour routes and serve as a distributed, multimodal transportation network with better connectivity to the MBTA stations, as well as increase redundancies during normal and emergency operations.

Building a flood wall along the railroad tracks would protect the Fresh Pond Reservoir that serves as the terminal reservoir for the City's water supply. It will also protect the Quadrangle area from storm surge. Designing and building microberms at strategic locations along the Alewife Brook that are most at-risk of overbank flooding will mitigate flooding impacts in the Alewife area under extreme precipitation and during extreme storm surge from the Harbor and Mystic River. Finally, the proposed stormwater storage facilities at strategic locations, such as the Danehy Park and Tobin School area, are designed to meet revised storage criteria to mitigate 2030 or 2070 precipitation flooding impacts in the Alewife area.

Implementation of the proposed strategies for **Resilient Ecosystems** include green infrastructure, such as bioretention basins, green roofs and porous pavement, in the Alewife area that have the potential to mitigate both heat and flooding impacts in the Quadrangle, at the Fresh Pond Mall, and some of North Cambridge. Increasing the tree canopy in Alewife will reduce the UHI effect and will contribute to an enhanced urban forest for a more sustainable and vibrant urban

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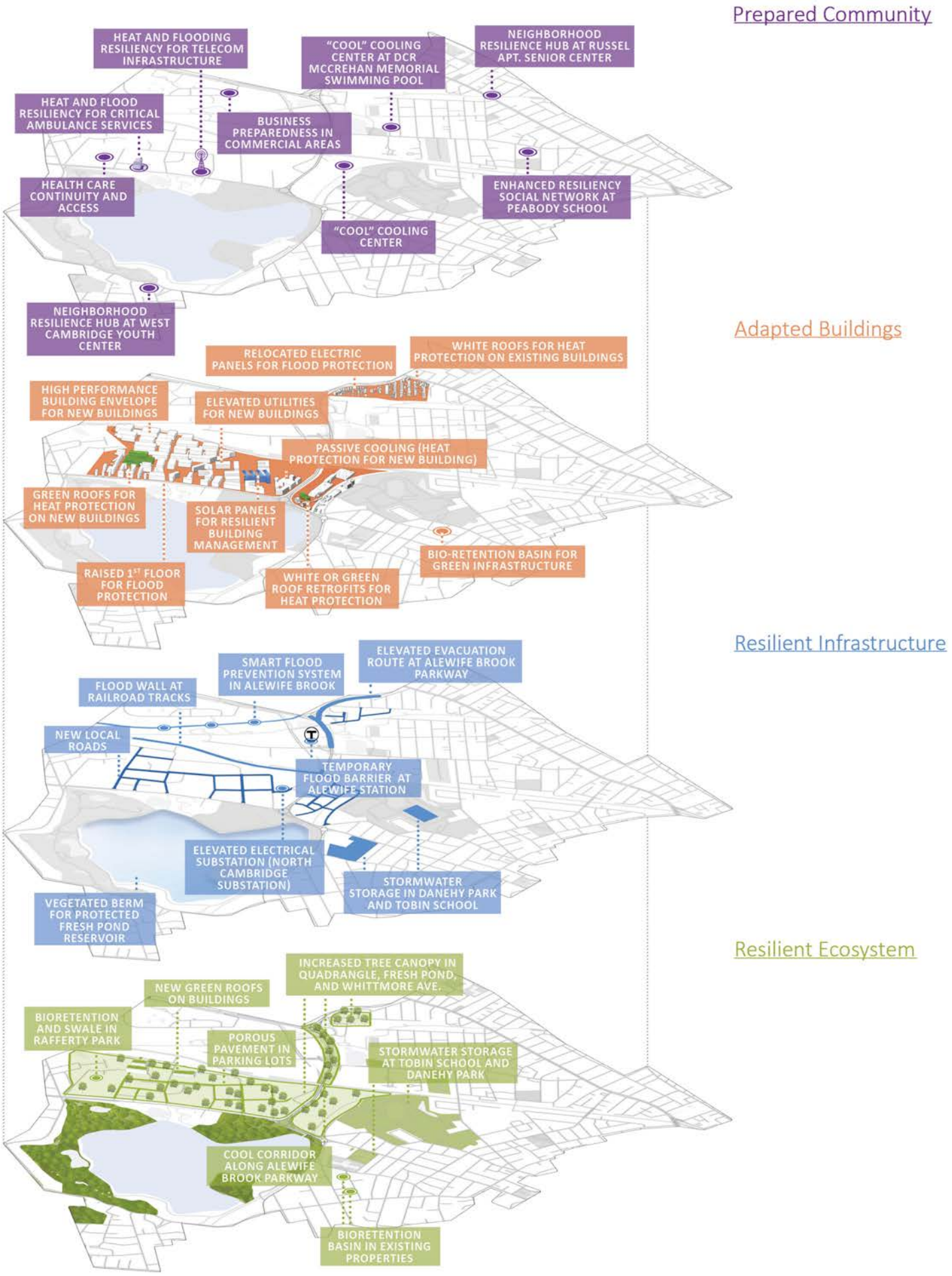

Figure 27. The benefits of the implementation of the preparedness strategies for an enhanced Alewife [Kleinfelder, July 2018]

environment. The Alewife neighborhood has a complex network of ecosystems that consists of waterways, urban forest, and green infrastructure, including large public open spaces. A resilient infrastructure juxtaposed with resilient ecosystems will enhance stormwater management, improve water quality, and reduce the UHI effect. All have the potential to enhance the aesthetics of the Alewife area and improve overall wellness.

Figure 27 illustrates how the proposed strategies provide for a future for Alewife by addressing the vulnerable assets identified in the CCVA for community, buildings, infrastructure, and ecosystems in a comprehensive manner.

A TRANSFORMED NEIGHBORHOOD: THE QUADRANGLE AS AN EXAMPLE

The implementation of the proposed resiliency strategies of a **Prepared Community**, **Adapted Buildings**, **Resilient Infrastructure**, and **Resilient Ecosystems** has the potential to create a transformed urban neighborhood where the built, natural, and social environments are integrated (Figure 28). For the strategies to be most effective, they should be implemented when new infrastructure is built or building re-development occurs. It is equally important that existing infrastructure and existing development are retrofitted to be more resilient.

The scale of re-development opportunities allows for not only having more adapted buildings, but also more resilient transportation, energy, stormwater, and green infrastructure opportunities that could benefit the entire Alewife community.

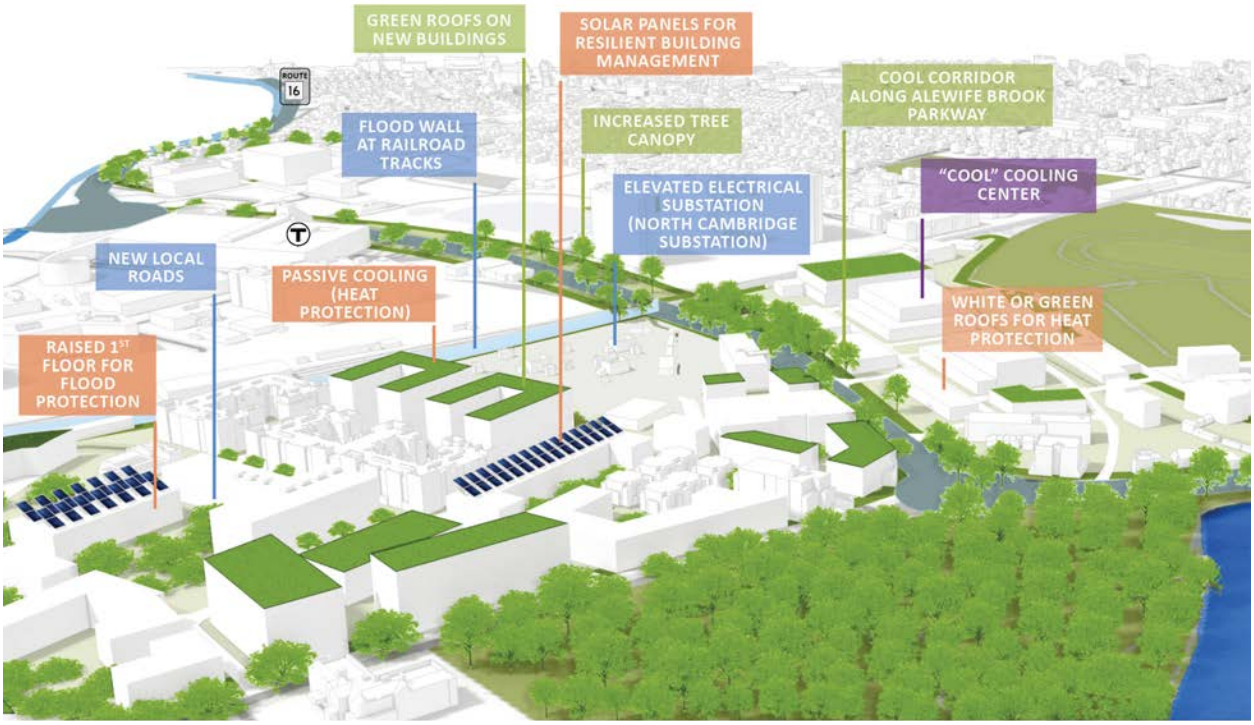

Figure 28. Strategies for a transformed and resilient urban neighborhood [Kleinfelder, July 2018]

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With its projected growth, the Quadrangle area in Alewife provides unique opportunities to implement the proposed resiliency measures by integrating them with future growth scenarios. Coincidently, this area is also projected to be at significant risk of flooding and extreme heat. The proposed scale of re-development allows for having more adapted buildings and more resilient transportation, energy, stormwater, and green infrastructure that could benefit the entire Alewife community. Assuming that the proposed resiliency measures for new infrastructure and re-development can be factored into its future planning scenarios, the Quadrangle area can serve as a model of resiliency for the City. Successful implementation of strategies in this area would also help assess how similar strategies can be implemented in other parts of the City. Strategies for each category are presented below.

Community: Within existing conditions, the Quadrangle area is isolated from the rest of the Alewife neighborhood since it is bordered by the railroad on its north and east edges and by the Alewife Parkway on its south edge. It prevents residents of North Cambridge from accessing the Fresh Pond Reservation. The proposed strategies for neighborhood resilience hubs, redundant communication systems, and increased resiliency of critical services in the Quadrangle will nurture the development of a neighborhood resiliency network that will benefit the Cambridge community at large.

Buildings: The coordination between Envision Cambridge and CCPR Plan has resulted in a proposal that new residential, commercial, and light industrial buildings located in the floodplain be raised 4 feet above ground to minimize flooding risk (Figure 29). Raising first floors allows the public realm to remain engaged with neighborhood life but not be too removed from street life while being flood-resilient. Utilities would also be elevated. New buildings will be resilient to extreme heat due to high-performance building envelopes, passive cooling, and green roofs. These proposed strategies will allow for energy-efficient buildings to pose fewer strains on the energy grid, already identified at risk for increased demand for air conditioning during extreme heat events.

Infrastructure: The proposed street grid to support re-development in the Quadrangle area will increase mobility by providing alternatives to the Alewife Brook Parkway that now acts as a barrier to pedestrians and bicyclists. These roads will provide better connectivity to the neighborhood and could serve as detour routes during emergencies or evacuations. The proposed flood wall along the railroad tracks (Strategy C6), which has the potential to be integrated as part of the new buildings' façade, will enhance resiliency not only for the Quadrangle but will protect the Fresh Pond Reservoir from storm surge and possible salt-water intrusion. In addition, collective implementation of updated stormwater storage requirements for re-development will mitigate how flooding affects physical assets and critical services.

Figure 29. Option for the Quadrangle [Source: Utile for Envision Cambridge. Spring 2017]

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Ecosystems: Re-development opportunities in the Quadrangle also provide the possibility of weaving natural and engineered ecosystems with the built environment. While this area holds some of the largest natural and open spaces in the City, there are large expanses of impervious terrain that create intense UHIs. The proposed strategies to increase tree canopy coverage both on the streets and as part of re-development will significantly reduce localized urban heat. For example, measures to implement green infrastructure in re-development, roads, and open spaces in the Quadrangle, using porous pavement or biorentention basins, will decrease stormwater flooding, improve water quality of the stormwater discharge to the Alewife Brook, and reduce the UHI effect.

ALEWIFE: A HUB AND CONNECTOR OF REGIONAL INFRASTRUCTURE AND ECOSYSTEMS

The Alewife area is part of the 76-square-mile Mystic River watershed, which includes 21 municipalities north of Boston. Cambridge and many of the adjacent coastal communities are vulnerable to changing coastal conditions from sea level rise and projected increases in extreme precipitation. Community resilience will be threatened on a watershed- and regional-scale. These communities are connected by waterways and open spaces. The Alewife area also serves as the regional hub for several key infrastructure systems (energy, transportation, and drinking water), and includes elements of the natural environment, such as the Alewife Brook and Alewife Brook Reservation. The proposed resiliency strategies for infrastructure and ecosystems will not only benefit Cambridge but will increase regional resiliency by mitigating climate change risks to the Mystic River Watershed and the Boston metropolitan area.

The electrical substation in the Alewife area is one of four major substations in the City. Electricity from this substation powers residential, commercial, and public buildings. Although the electric infrastructure is interconnected for redundancy, the Cambridge area can be constrained in its ability to import power because the transmission infrastructure serving the City has limited capacity and redundancy. Therefore, building resiliency for the Alewife substation is particularly important to ensure electric supply for continuity of operations for businesses and households and to minimize economic and social impacts from power outages.

Preparedness strategies for the Alewife area will not only result in this area being more resilient but will provide cascading impacts increasing the resiliency of the built and natural environments in Greater Boston.

The Alewife MBTA Station is the terminus of the Red Line and a multimodal transportation center serving multiple bus lines. This station caters to the Alewife neighborhood as well as the broader region. The MBTA parking garage is used as a park-and-ride facility by commuters and by “feeder” bus routes to and from the station. Portions of Routes 16 and 2 that serve as the City’s evacuation routes are projected to flood under extreme storm events. Protecting the transit station and these major roads is critical. The proposed preparedness measures will aid emergency response services and recovery operations, maintain business continuity, minimize economic disruptions, and contribute to building social resilience.

This plan proposes building micro-berms at strategic locations along the Alewife Brook in the Alewife Reservation. There is also a strategy to enhance the urban forest and to maximize the City’s open spaces and implement green infrastructure. Supplementing these

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ecosystem opportunities with built infrastructure improvements, such as measures at the Amelia Earhart Dam as recommended for "Resilient Infrastructure," will not only benefit Cambridge but will also contribute to regional resilience. The Metropolitan Area Planning Council (MAPC), along with the Cities of Boston, Cambridge, and Chelsea, jointly submitted a proposal for a grant to increase regional and community resilience to sea level rise in the Mystic River watershed. Figure 30 illustrates the joint actions, including key strategies outlined in this report.

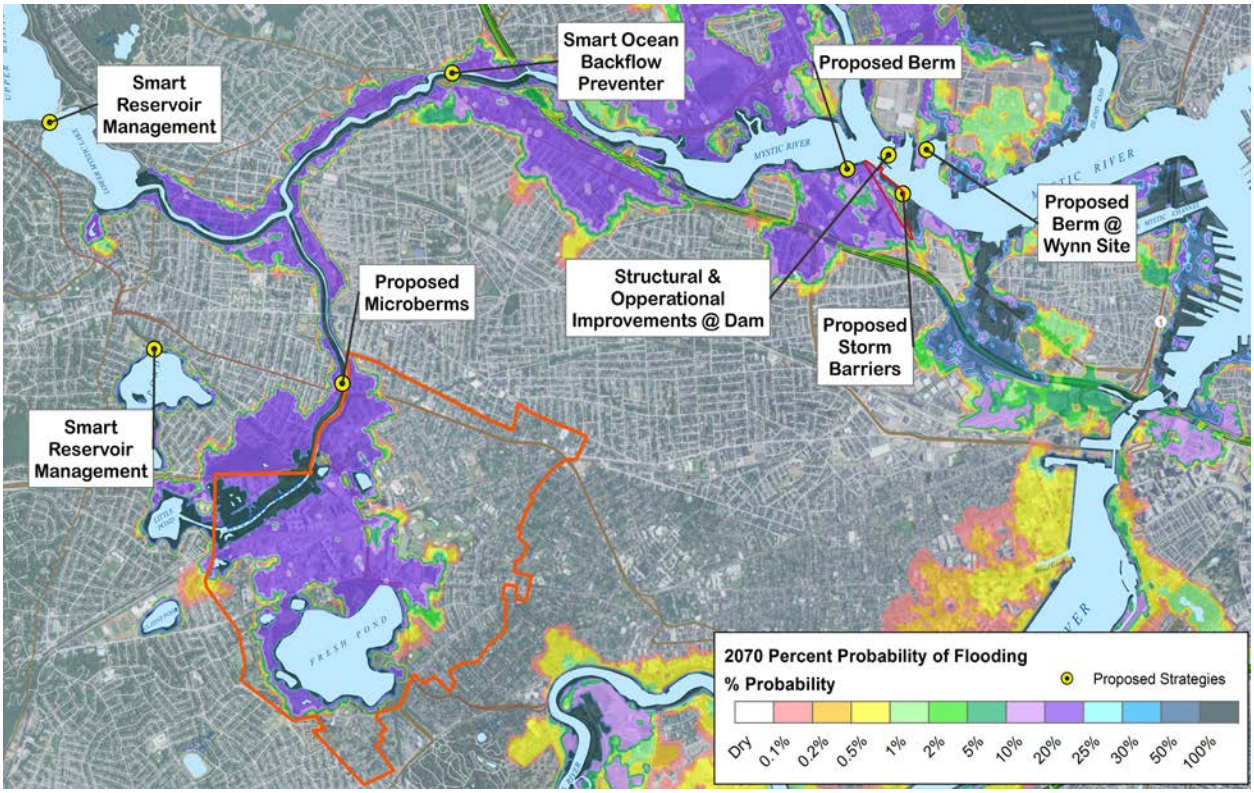

Figure 30. Map of potential regional joint actions for the Mystic River and Alewife Brook [Kleinfelder for the City of Cambridge, June 2017]

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NEXT STEPS

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Next Steps

The Alewife Preparedness Plan is the first step toward developing the City's comprehensive CCPR Plan. Next steps will include considering options for broader climate change risks, quantification of cost and economic opportunities, and a continued robust stakeholder engagement process. As was the case in the development of the Climate Change Vulnerability Assessment, it is recognized that the resiliency strategies herein are based on climate change scenarios developed for Cambridge that are drawn from the best available science but involve ranges of uncertainty. These strategies will need to be revisited frequently to ensure community preparedness plans continue to reflect updated projections specific to local climate change.

BROADER CLIMATE CHANGE RISKS

Aligned with the CCVA, the Alewife Preparedness Plan recommends strategies to address extreme heat and flooding from extreme precipitation and SLR/SS. The changes in risk from vector-borne diseases or drought or more frequent ice storms (Figure 31) are also considered important for the City of Cambridge but were not specifically addressed in the CCVA when published in 2015 because future projections of these risks from climate change scenarios are more difficult to determine. Some of the proposed measures explored in this report will improve resiliency in all sectors, but the need to further develop specific strategies for drought and ice storms will be assessed when the final citywide CCPR Plan is developed.

Figure 31. Increased risk of falls resulting from abundance of snow and ice. Massachusetts snow and ice removal law (February, 2015) http://massrealestatelawblog.com/tag/massachusetts-snow-removal-law/

COST AND ECONOMIC OPPORTUNITIES

A critical next step for implementation of the CCPR is to understand potential costs to the City or government agencies, institutions, nonprofit organizations, private corporations, property owners and residents. The Cambridge community faces two key questions: 1) what is the cost of "doing nothing" compared to the cost of undertaking resilience improvements, and 2) what is the best way to enact these measures and determine who will pay for implementing the proposed strategies?

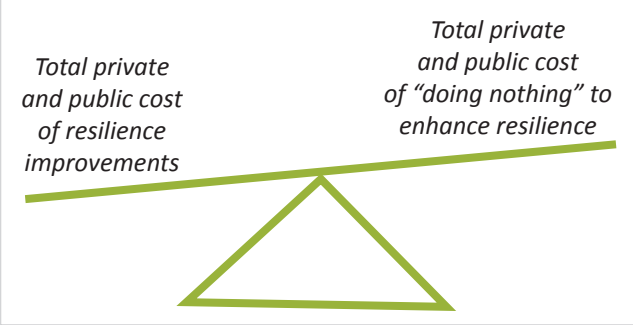

Figure 32. Threshold for action [Source: HR&A]

The Alewife Preparedness Plan is at a preliminary stage, with the most promising resilience strategies outlined. The next step will address the level of protection offered by proposed actions and the cost of these actions. The most technically attractive package of resilience improvements may be a combination of parcel-scale and district-scale actions. It may be possible to capture the cost of necessary improvements on a parcel-level basis for individual homeowners or developers

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and apply those funds to improvements that benefit the district as a whole. Assuming that the improvements that benefit the district as a whole provide the same level of protection at the same cost, private developers should be indifferent between undertaking resilience improvements at the parcel-scale and undertaking them at the district-scale. For example, each project in the Quadrangle can provide for flood-resiliency improvements limited to its re-development or contribute to the construction of a floodwall at the railroad tracks benefiting the district. If district-scale improvements are less expensive than parcel-scale improvements, developers should be willing to contribute via a special assessment district or other mechanism to actions that would not only protect their property but also benefit the larger district. The proposed approaches or mechanisms to be considered are listed in Table 7.

TABLE 7: OPTIONAL IMPLEMENTATION MECHANISMS

OPTIONS	FIRST STEP	ACTIONS/SUB-TASKS
Mechanism 1 Private-market provision through mandatory requirements	City **requires** resilience improvements* from private developers *parcel or district-scale	• Resilience improvements will be "priced into" private re-development • If resilience improvements are too costly, re-development will become infeasible • Land values may decrease to make re-development feasible
Mechanism 2 Private-market provision through voluntary incentives	City does not require, but **incentivizes**, resilience improvements* from private developers *parcel or district-scale	• Developers will implement if cost of resilience improvements is less than value realized • Value created through incentives (e.g., greater density, reduction in stormwater management costs) must be meaningful over and above baseline value
Mechanism 3 Private-market provision through value capture	City enables private developers to fund improvements* through value capture *district-scale	• Developers contribute through increased or incremental tax revenues (special assessment vs. tax increment financing structures)
Mechanism 4 Direct pubic provision	City directly undertakes resilience improvements* itself *district-scale	• City undertakes district-scale improvements because it believes public intervention is necessary to supplement the private market

STAKEHOLDER ENGAGEMENT

It is crucial to underscore the importance of incorporating stakeholder input in developing and implementing resiliency strategies. The stakeholder engagement process that has been established as part of the CCPR Plan supports this purpose. Cambridge's residents, business associations, and regional and local organizations have provided input in defining the vision, framework, and strategies. The intent is to continue this productive exchange and the few examples below identify ongoing initiatives:

- Further coordination with the Cambridge Public Health Department (CPHD) will be required as it is currently developing specific strategies to address increased risks from vector-borne

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diseases, poor air quality, and asthma. Concurrent to development of the CCPR Plan, CPDH will be working with regional health and medical coalitions (i.e., Metro Regional Preparedness Coalition headquartered at Cambridge Health Alliance) on public health initiatives, taking into account the implications of climate change from a health perspective.

- The City is working with regional stakeholders, watershed organizations, and neighboring communities. For example, the Metro Boston Climate Preparedness Taskforce[30], a coalition of 14 metropolitan municipalities that includes the City of Cambridge and regional infrastructure agencies, has been established to coordinate resiliency projects in the region.

- The City will continue having public meetings with the Alewife community to seek input on this Plan and Handbook. The Plan and Handbook are being shared with the community to: 1) confirm that comments received during the stakeholder engagement process have been integrated, and 2) solicit feedback on next steps for further developing the CCPR Plan citywide.

The Plan and Handbook and supporting documentation are available online at www.cambridgema.gov/CDD/Projects/Climate/climatechangeresilianceandadaptation

Figure 33. CCPR Alewife Plan public meeting held in April 2017. [Source: Kleinfelder]

30) On May 13, 2015, the Metro Mayors Coalition convened the first Metro Boston Climate Preparedness Summit and pledged to work together to reduce the region's greenhouse gas emissions and prepare their communities for climate change, launching a taskforce to address the vulnerabilities of the region's interdependent and interconnected infrastructure systems and coordinate on regional resiliency efforts. www.mapc.org/planning101/tag/metro-mayors-coalition-climate-preparedness-taskforce/

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PRODUCED IN COLLABORATION WITH

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