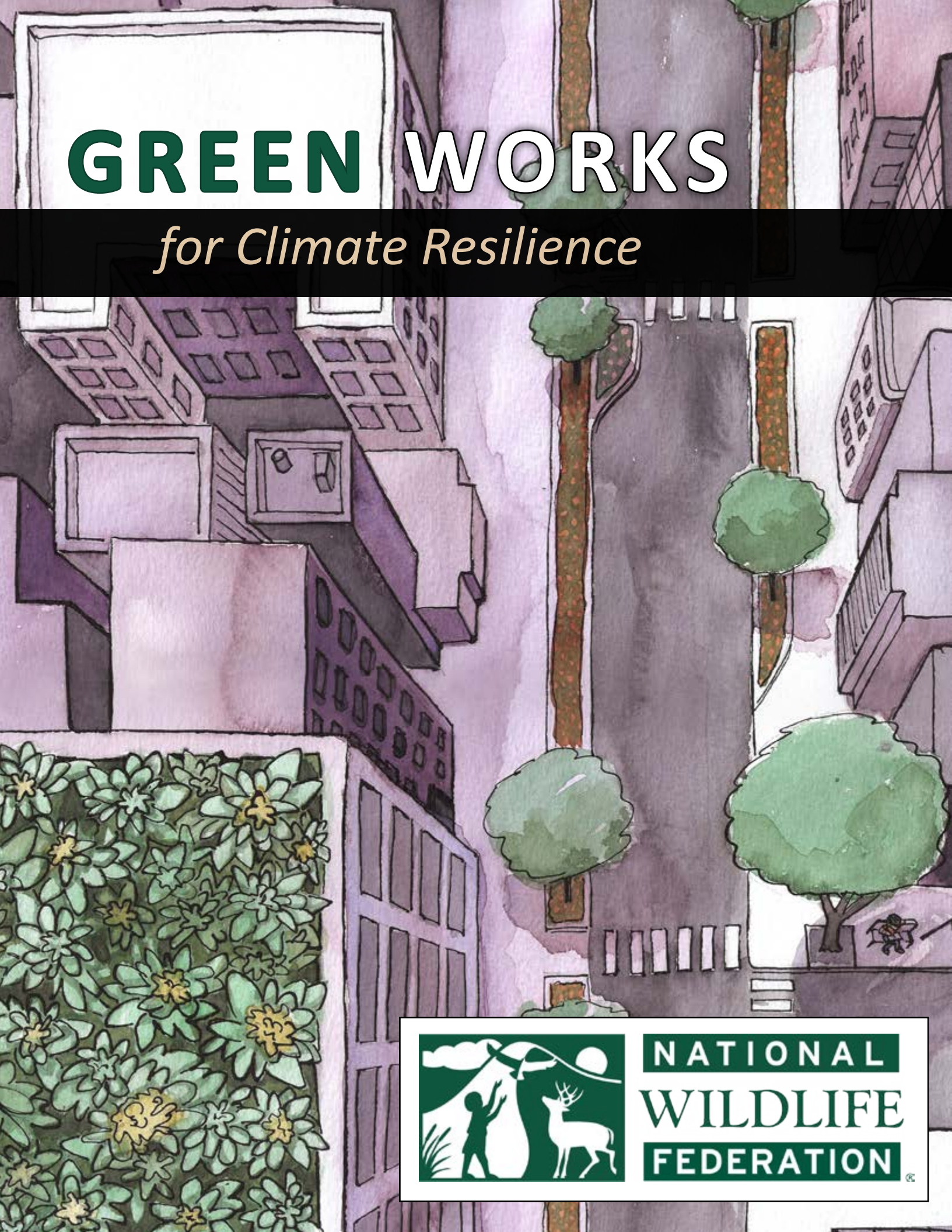
GREEN WORKS

for Climate Resilience



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Green Works for Climate Resilience:

A Guide to Community Planning for Climate Change

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Credit: Phil Whitehouse (flickr.com)

Introduction

Today, more than half of the people in the world, and 80% of the U.S. population, live in urban areas; UN-Habitat estimates that 70% of humans will live in cities by 2050 (U.S. Census Bureau, 2010; UN-Habitat, 2008). Cities are on the frontlines of climate change impacts, such as sea-level rise (SLR) and coastal flooding, drought, and extreme weather – all of which are exacerbating existing urban challenges, including resource degradation, economic downturns, affordable housing crises, and others. The ability of cities to thrive in the face of rapid growth and a changing climate will depend on the ways in which we plan, develop, and manage our cities in the coming decades. Although we need to urgently shift our energy sources away from dirty fossil fuels to cleaner, renewable energy sources to address the root causes of climate change, we also need to prepare for manifest and future climate impacts. At the same time, we must recognize the important role that natural systems can play to safeguard our communities from climate change, while also providing habitat for fish and wildlife.

Although hard armoring, like sea walls, may sometimes be necessary, communities should assess the extent to which nature-based approaches can be prioritized and/or integrated with hard, structural "grey" infrastructure. Nature-based approaches rely on enhancing, protecting, and restoring natural infrastructure, such as coastal wetlands, parks, and tree canopies, as well as features that mimic natural processes, such as rain gardens or green roofs that are used in low-impact development (LID). Nature-based approaches often provide resilience to multiple climate impacts, can help absorb carbon pollution and/or reduce GHG emissions produced by the activities happening in urban areas, typically cost less than structural measures, and provide co-benefits including clean water, fish and wildlife habitat, economic development, and recreational opportunities.

The intent of this guide is to provide an overview of the kinds of nature-based approaches that can be used to respond to and prepare for the impacts of climate change. Although this guide is not exhaustive, it highlights common examples, profiles approaches that communities are already using, and describes strategies that communities can use to implement nature-based approaches.

Credit: K. Reeve

Summary Recommendations for Climate-Smart Community Planning

- Prioritize the use of non-structural, nature-based approaches in recovery, re-building, and resilience activities;
- Assess the extent to which nature-based approaches can be used instead of or in combination with grey infrastructure to reduce the vulnerability of people, built infrastructure, and natural systems;
- Design "hyper-functional" urban landscapes that rely on natural infrastructure for climate resilience, reduce carbon pollution, and provide wildlife habitat and places for people to relax, enjoy, and play;
- Conduct comprehensive vulnerability assessments that include, at a minimum, built infrastructure, transportation systems, natural systems (parks and open space, as well as habitats and species), water resources and infrastructure, and human health;
- Direct development and infrastructure away from environmentally sensitive and climate-vulnerable areas by using land use planning tools, such as zoning and comprehensive plans;
- Incentivize development in less vulnerable areas (for example, through transferable development rights);
- Acquire and protect land in vulnerable areas better suited for wildlife habitat than for development, such as through the establishment of voluntary buy-back programs to purchase properties that are areas at high risk for repetitive floods and/or storms.
- Refrain from adaptation activities that are detrimental or maladaptive for wildlife.

Climate Change is Affecting Communities Now

According to the *Draft National Climate Assessment* Water Resources chapter,[1] sea-level rise (SLR), storm surges, and changes in surface and groundwater use patterns are expected to challenge the sustainability of coastal freshwater aquifers and wetlands (USGCRP, 2013). Flooding events are expected to intensify in frequency and severity in most regions of the U.S., including areas where average annual precipitation is expected to decline, but especially in areas that are expected to become wetter, such as the Midwest and the Northeast. Intense rainstorms can trigger sewer overflows that pose a hazard to public health and aquatic ecosystems, as Superstorm Sandy demonstrated in 2012 (Climate Central, 2013). Meanwhile, the Midwest is threatened with longer, more frequent droughts and higher average temperatures (USGCRP, 2011; Karl et al., 2009, IPCC, 2007). Higher average temperatures also threaten the health

1 The expected release of the final National Climate Assessment is late April 2014: *www.globalchange.gov*

of people and wildlife alike, especially in urban areas where impervious surfaces contribute to the urban heat island effect and fragment wildlife habitat.

Some communities are already carrying out climate change adaptation, which is the process of embracing forward-looking goals and implementing strategies specifically designed to prepare for and adjust to climate change impacts (Stein et al., 2014). The term "resilience" is often used interchangeably with adaptation, and although they are complementary, they are not the same. In ecological terms, resilience refers to the ability of a system to maintain or return to a particular ecological state following a disturbance (Stein et al., 2014). At the community scale, therefore, climate resilience refers to actions taken to increase the ability of cities and towns to return to desired conditions after a disturbance, that is caused (or worsened) by climate change (eg., storm surge in a coastal area). A robust adaptation strategy, therefore, would include actions designed to bolster the resilience of a community.

According to Biernbaum et al. (2013), local adaptation efforts can be implemented though land use planning; efforts related to protecting infrastructure and ecosystems; regulatory approaches focused on the design and construction of the built environment (eg., buildings and roads); and emergency preparation, response, and recovery activities. Some communities are already developing adaptation plans and strategies, but there are few resources that provide guidance specifically about the ways in which natural systems can provide protection for humans, property, and infrastructure. It is important to point out that climate adaptation planning can take many forms, from top-down comprehensive planning to project-scale interventions in which climate information is "mainstreamed" into existing activities. Although holistic, comprehensive adaptation is often favored, communities are encouraged to take the approach that best suits their needs and resources. Instead of developing a broader adaptation plan, some communities may decide to incorporate natural systems adaptation approaches into existing programs or policies, a process known as 'streamlining adaptation' (Stein et al., 2014). For example, some communities are planning for sea level rise by updating zoning policies to require greater setbacks.

Applying Climate-Smart Conservation to Community Planning

The forthcoming *Climate-Smart Conservation guidance* by Stein et al. offers an overview of the ways in which conservation goals and practices can be adjusted in light of climate change. While the focus of the guidance is on wildlife conservation, many of the recommendations can be applied to community adaptation planning. For example, the Climate-Smart Conservation Cycle (page 4) outlines a process designed for restoration or resource management, but can be adapted for use at the community-scale to guide broader community adaptation planning efforts. Although communities can start at any point in the conservation cycle, defining a project's purpose and scope, followed by a vulnerability assessment, are often the first steps in the process. A vulnerability assessment shows the ways in which climate change is and will impact a community, such as how sea level rise will impact coastal areas, how temperature changes may affect public health, or how the hardiness zones of trees may shift. Once a vulnerability assessment is complete, a community can review and revise their adaptation goals and identify possible adaptation options. Climate adaptation and resilience options can then be evaluated and selected based on factors such as cost and co-benefits with other sectors (ie., using nature-based approaches that have both climate mitigation and adaptation value), and then communities can develop

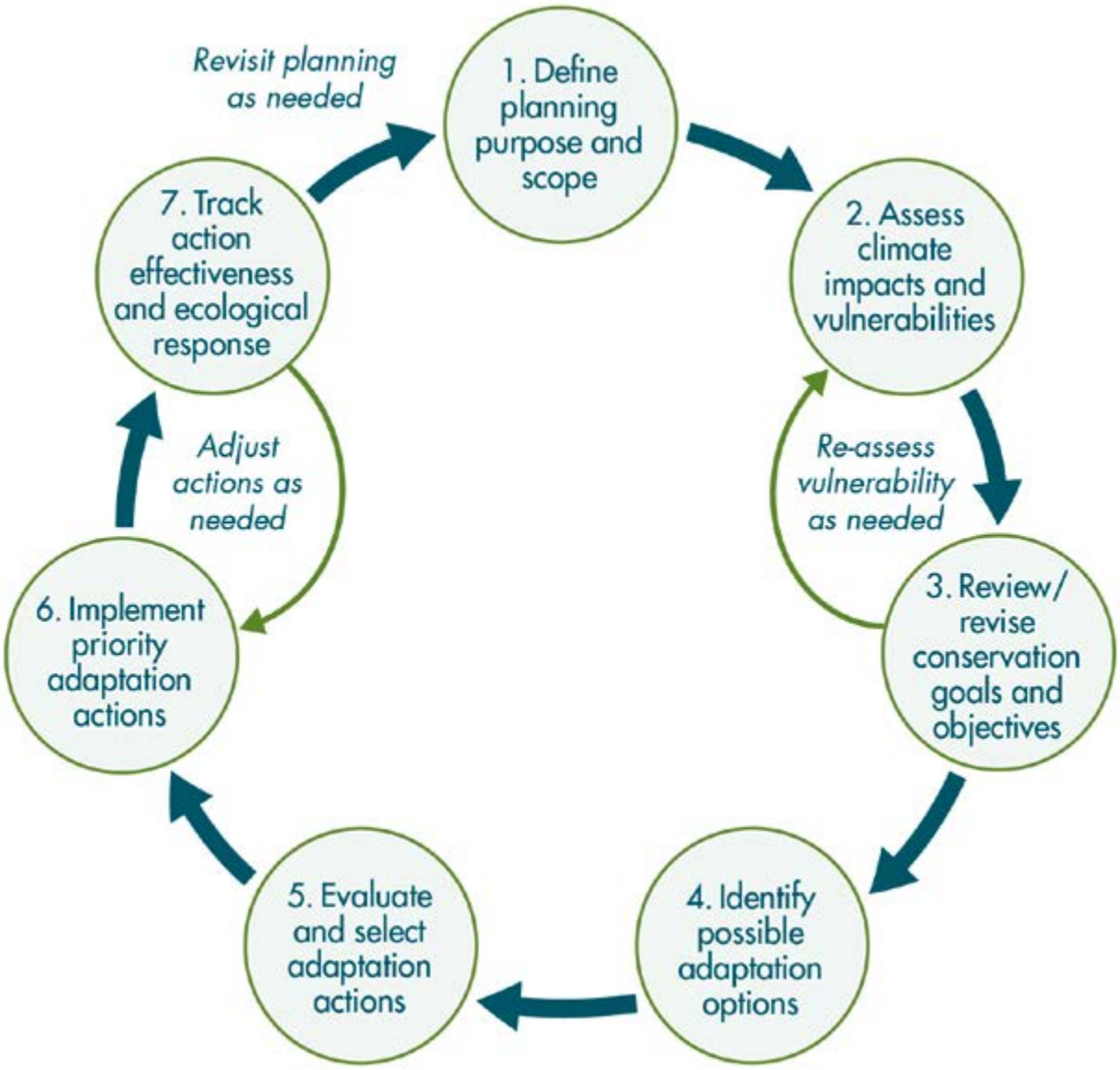


Figure A. Climate-Smart Conservation Cycle.

Figure A is from Stein, B.A., P. Glick, N. Edelson, and A. Staudt (eds.). 2014. Climate-Smart Conservation: Putting Adaptation Principles into Practice. National Wildlife Federation, Washington, D.C.

an implementation strategy. Monitoring and tracking adaptation actions after implementation is needed to determine their effectiveness, and adjustments to actions can be made based on how well they are working and/or based on new science and practices. For example, in the case of an urban forest, active monitoring may reveal that certain species are more prone to pests or disease as the climate warms, and thus different species should be planted to maintain ecosystem values and services. In this way, the adaptation planning process is iterative and adjustments are made to reflect new information about the ways in which climate change is impacting a community.

The Climate-Smart Conservation guidance also includes guidance and resources about

managing uncertainty, tapping into climate data, models, and tools, communicating about climate adaptation, and using policy to enable action. While this guide touches on some of these themes, the Climate-Smart Conservation guidance should be consulted for further information. Communicating climate change, for example, can be a particularly challenging topic as city departments seek to promote adaptation actions both to the public and to elected officials; the Climate-Smart guide's chapter on communication offers advice.

Using This Guide

Numerous communities have begun to plan for and implement nature-based approaches to address some of the major impacts of climate change. For this guide, we divided these impacts into five categories: sea-level rise, coastal flooding, and erosion (includes marine as well as freshwater coasts in the Great Lakes region); drought and increasing aridity; extreme heat and the urban heat island effect; inland flooding and stormwater management; and changes to the natural landscape.

The chapter called, Working with Nature to Prepare for Climate Impacts, begins with a definition and description of each climate change impact (eg., stormwater flooding), followed by the kinds of nature-based approaches that can be used to address each impact (eg., tree canopy improvements). In some cases, additional benefits, such as cost savings, are also mentioned. Longer profiles of select communities are included to describe how nature-based approaches have been planned and implemented. We have also included a chapter, Implementation of Adaptation Actions, that describes approaches to implement nature-based approaches, organized into the following categories: multi-sector adaptation planning, updating existing programs and policies, changes to zoning and land use regulations, creating new programs and policies, and developing public-private partnerships. The last sections of the report include a set of helpful resources for adaptation planning, as well as a list of definitions.

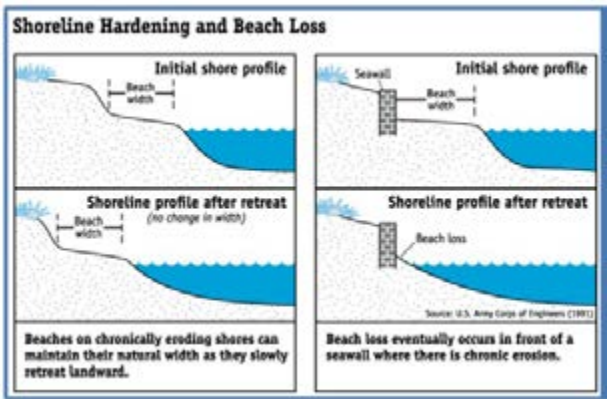
Living shoreline on Lake Huron in Marysville, MI.

Credit: Julie Sobkowski

The examples highlighted in this document include only a fraction of the nature-based approaches that communities are using and we have therefore also compiled a longer set of examples into charts accompanying the text: coastal zone management, urban tree canopy improvements, low-impact development, wetland management, and open space and habitat improvements. We have also included a separate chart detailing coastal strategies specific to the Great Lakes Region. These charts indicate the variety of climate change impacts, as well as some of the additional benefits, that each approach addresses. The primary climate adaptation benefits of each nature-based approach are described and then identified with ✓+, while secondary climate impacts addressed and additional benefits of each strategy, including climate mitigation air quality improvements, are indicated in the chart with ✓.

Working With Nature to Prepare for Climate Change

Man-made structures, or "grey infrastructure," such as seawalls, levees, and revetments, are commonly used to protect communities from sea level rise and storm surges, and the resulting coastal flooding. However, these structures can be breached and are often detrimental to fish and wildlife habitats. For example, armored shorelines can disturb sea turtle nesting habitat, prevent coastal wetlands from migrating inland, limit natural sediment buildup, and cause further erosion in unarmored areas (Galbraith et al., 2002; Sea Turtle Conservancy; NWF, 2008). By contrast, natural infrastructure, such as sand dunes and shorelines, can offer many of the same benefits as grey infrastructure while reducing the maladaptive, negative impacts that grey infrastructure can have on wildlife. Building a seawall, for example, can severely damage fish habitat and the associated fisheries, but an oyster reef can also provide protection against storm surge without the negative impacts of a hardened shoreline. Therefore, communities should consider prioritizing and integrating nature-based approaches into their adaptation and resilience planning to the greatest extent possible.



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Coastal Impacts: Sea-Level Rise, Coastal Flooding, and Erosion

Coastal areas are among some of the nation's most productive habitats for fish and wildlife and have long been a magnet for economic activity as well as desirable places for people to live. In fact, over 50 percent of the U.S. population lives in coastal counties, which account for only 17 percent of the country's geographical area (Crossett et al., 2004). Coastal aquatic ecosystems are facing increasing pressure from human population growth and changes in land use patterns. Roads, development, and hard armoring (eg., sea walls) are stressing fragile coastal systems. Although the proportion of people living near coastal areas is expected to remain relatively constant, current projections forecast an overall growth in the U.S. population of nearly 50 percent by 2050 (Crossett et al., 2004). In coming years, coastal communities will need to accommodate a growing population while managing vital natural resources and preparing for coastal hazards compounded by climate change.

According to the Coastal Zone Management Act of 1972, the term "coastal zone" means "the coastal waters (including the lands therein and thereunder) and the adjacent shorelands (including the waters therein and thereunder), strongly influenced by each other and in proximity to the shorelines of the several coastal states, and includes islands, transitional and intertidal areas, salt marshes, wetlands, and beaches. The zone extends, in Great Lakes waters, to the international boundary between the United States and Canada…" Coastal zones in the Pacific, Atlantic, Gulf of Mexico, and Great Lakes vary widely in climate, habitat types, and human impacts. While many coastal communities prepare for sea-level rise, for example, water levels in the Great Lakes are projected to decline (Wang et al., 2012).

Study	Value of Storm Protection Provided by Wetlands (2010 dollars)
Feagin et al. (2010)	Different zones of wetlands near Galveston Island, Texas provide storm protection and reduce damage to shoreline private property: Low Marsh — $5,000 per acre per year Salt Flat — $170 per acre per year High Marsh — $500 per acre per year
Möller (2001)	A salt marsh extending 250 feet in front of a sea wall in the U.K. would reduce the costs of constructing and maintaining the sea wall by about 90 percent, or $3,025 per foot.
King and Lester (1995)	A salt marsh extending 250 feet in front of a sea wall in the U.K. would reduce construction and maintenance costs by $1,800-3,200 per foot or about $300,000-$500,000 per acre of salt marsh.

Source: ECONorthwest, with data from indicated sources.

As global average temperatures warm and the polar ice caps melt, sea-levels are beginning to rise, presenting increased risks from storm surge, flooding, and erosion. Declining water levels in the Great Lakes region present their own challenges, although coastal communities here must still prepare for impacts brought on by fluctuating water levels, including erosion and habitat loss (Flesher, 2013; USGS Coastal and Marine Geology Program). While many coastal communities construct sea walls to defend themselves, these hard structures can be costly to install and maintain, and may fail during intense storms. Conserving and restoring coastal wetlands can reduce climate impacts and provide aquatic habitats, while offering additional community benefits like recreational opportunities and economic development from fishing, boating, and tourism. Wetlands, sand dunes, and barrier islands offer defense from storm surges and habitat for fish and wildlife, for example. These natural structures will migrate inland due to sea level rise, however, and coastal communities must take action to actively protect them as they shift inland.

In 2013, New York's Department of City Planning developed guidance for coastal communities. The report, "*Urban Waterfront Adaptive Strategies*," details a number of adaptation options, including how they work, hazards addressed, costs and co-benefits, and where they would be most applicable. In general, adaptation options for coastal resiliency fall into three categories, first introduced by the *Intergovernmental Panel on Climate Change (IPCC) in 1990*: protection, accommodation, or retreat. The coastal resilience approach that a community decides to take may depend on how much investment already exists in a given location, as well as the amount of risk a community determines is acceptable. For example, in some places, relocation may be an option if the population along the coastline is smaller or if there are lower-risk places inland to accommodate people and assets. In larger, dense cities like New York City, the population and urban investment is too great to re-locate the entire city, so the resilience strategy may include protecting some areas, accommodating coastal flooding in other places where it can be managed without major disruptions, and then retreating, or re-locating, some populations and infrastructure that are very high-risk and cannot be adequately protected. After understanding climate vulnerability, communities must determine the degree

Living Shoreline

Shoreline armoring often results in severe beach erosion requiring expensive restoration, but living shorelines are a nature-based alternative that can prevent this erosion and alleviate future costs. For a low-flow area, such as a creek or a cove, shoreline installation costs run $50-$100 per foot. For a high-energy area, such as the Chesapeake Bay Mainstem, costs are estimated at $500-$1200 per foot (Chesapeake Bay Foundation, 2007). The value of ecosystem services provided by living shorelines helps indirectly offset these costs.

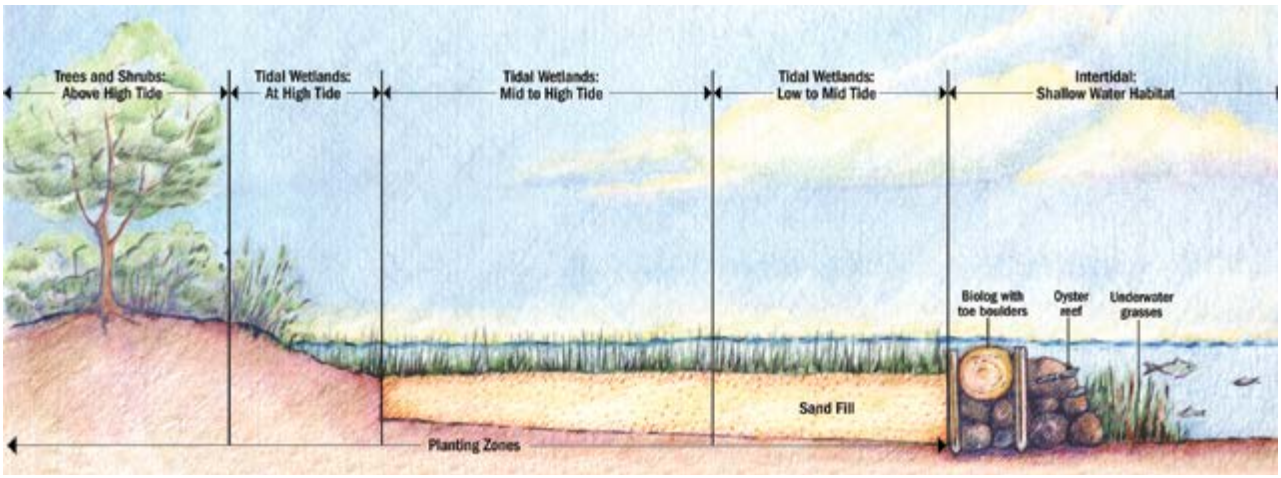
A. Oyster Reef Restoration

In the Gulf of Mexico, a $150 million investment in oyster reef restoration is estimated to increase revenue and sales of fisheries by $6.87 million annually and save property owners up to $150 million on the construction of bulkheads (Kroeger and Haner, n.d.).

B. Coastal Wetlands

In San Francisco Bay, a levee was estimated to cost $12 million to maintain over the course of 50 years. Adding a 25-foot-wide marsh on the bay-side would reduce this cost by over $6 million (Lowe et al., 2013).

Illustration by Amanda Frayer



Credit:Terry Peterson, courtesy of the Chesapeake Bay Foundation

of risk that they are willing to take on and then develop an adaptation plan based on their unique cases, resources, community needs, and other factors.

Protection

"Protection" strategies involve the use of defensive measures to protect against climate impacts such as coastal flooding, erosion, and sea level rise. These options include constructing "hard" structures such as seawalls, breakwaters, and floodgates, or "soft," nature-based structures such as sand dunes. Communities may prioritize one or the other based on costs and community needs, as was done in New York City after Superstorm Sandy. Sand dunes, coastal impoundments, and barrier islands that protect communities from storm surges and sea-level rise also provide vital habitat to fish and wildlife. Coastal impoundments, for example, are areas of upland or wetland habitats where dikes have historically been constructed to restrict, retain, or exclude water over a selected area. While many were created to protect major thoroughfares, these areas are now home to a diverse range of fish and wildlife.

While states and the federal government are often the entities responsible for policies related to coastal structures, local governments can pass stricter regulations on their own. In some communities, the most effective protections against sea-level rise and erosion require a combination of man-made and natural structures. Living shorelines, unlike natural wetlands, are man-made coastlines that include green and grey building materials, such as stone, sand, grasses, and native plants. Living shorelines are preferable over hard surfaces, such as concrete seawalls, as they provide habitat for wildlife, maintain shoreline dynamics, improve water quality by filtering pollution and settling sediments, and limit erosion (Kane, 2011). Coastal erosion and storm surge can also be managed through the creation of off-shore oyster reefs. Once established, an oyster reef can reduce incoming wave energy and enhance shoreline accretion while providing habitat for a number of economically valuable species (Cheong et al., 2013). The creation of oyster reefs can be carried out through partnerships with federal agencies and nongovernmental organizations.

- Mantoloking, NJ, is especially vulnerable to coastal erosion given its location on a thin barrier island. Since 1999, the city has had strict regulations to protect coastal dunes from the impacts of development. Like other coastal communities, the city also regularly plants native plant species to limit dune erosion. By actively managing dunes on the barrier island, the island community is protected, and the island itself can continue

to protect the mainland from storm surges and erosion.

- Communities along the Chesapeake Bay, particularly in Maryland, are using living shorelines to protect against erosion, restore marsh habitat, and protect water quality. Although SLR projections should be incorporated into the design of living shoreline projects to improve their longevity and success, only one living shoreline project in MD (at Gunston School, Centreville) has incorporated SLR projections for the Bay. The *Chesapeake Bay Foundation* offers loans and grants to communities and nongovernmental organizations to create living shorelines in this region.
- The Nature Conservancy received a grant from the National Oceanic and Atmospheric Administration and partnered with the Dauphin Island Sea Lab (DISL), the Alabama Department of Conservation and Natural Resources State Lands Division, and the National Wildlife Federation to create an oyster reef breakwater off the coast of Mobile County, Alabama. The project created 30 jobs, protects 1500 meters of shoreline, and promises to improve water quality and wildlife habitat.

Using Natural Systems to Build Resilience in New York City

In conjunction with the release of the Urban Waterfront Adaptive Strategies report, Mayor Bloomberg announced the release of "*A Stronger, More Resilient New York*," a comprehensive report offering recommendations to rebuild areas impacted by Hurricane Sandy and increasing the resilience of these coastal zones. The plan includes the following:

- Explains that while large-scale engineering projects such as seawalls may seem like simple, attractive methods of improving coastal resilience, other options prove more cost-effective and are less likely to fail in the event of an extreme storm.
- Outlines strategies the city can take to protect specific areas from sea-level rise and storm surges, as well as a number of initiatives that can be taken to implement the strategies.
- Highlights how "soft" structures, such as sand dunes and green space can be used in conjunction with "hard" structures to effectively protect coastal zones while providing other benefits, such as recreation. The plan also outlines opportunities to work with the US Army Corps of Engineers to improve existing "soft" and "hard" structures, including replenishing beaches and raising bulkheads, in vulnerable areas.

Accommodation

Strategies that fall under "accommodation" require advanced planning and acceptance that some coastal zones will be impacted or lost, and people and wildlife must cope with those impacts. Accommodation strategies often require changes to zoning and land using planning practices, as well as acceptance that in some places, we will be living with water instead of fighting against it. For example, to counter rising sea levels, building codes that require houses to be built on stilts or at higher elevations can be adopted. Zoning can also be altered to allow wetlands to migrate inland. Rising sea-levels are also rapidly increasing the rate of erosion along coastlines, threatening people, wildlife, habitat, and infrastructure. Shoreline protection through the use of hard structures may also unintentionally worsen the rate of erosion. While it is impossible to completely prevent erosion in the long-term, many cities are using nature-based approaches instead of or in combination with

Climate-Smart Profile: Preparing for Sea-Level Rise in Chula Vista, CA

Chula Vista, CA, has been working to mitigate greenhouse gas emissions since the early 1990s by adopting renewable energy and energy efficiency standards for new and existing buildings and raising public awareness. In 2011, the city published an Implementation Plan to pursue additional mitigation and adaptation measures. The plan focuses on 11 strategies, including conserving more open space, wetlands preservation, and sea-level rise & land development codes. These measures fall largely under the 'accommodation' and 'retreat' categories, mainly by managing wetlands and open space so they may continue to provide valuable ecosystem services.

Wetland protection is a major component of Chula Vista's open space and sea-level rise adaptation strategy. The city is working with public agencies such as the US Fish and Wildlife Service to monitor wetland ecosystems to track climate impacts. New habitat restoration plans and non-native plant removal guidelines are also being adopted to ensure these ecosystems continue to provide valuable functions. By acquiring upland habitats, the city will also allow wetlands to migrate inland in response to sea-level rise. Protecting coastal wetlands and upland habitat will give local fish and wildlife the opportunity to cope with climate change, while preventing construction in areas at risk from sea-level rise and storm surge.

Chula Vista's adaptation plan offers three additional strategies to cope with sea-level rise: 1) update its grading ordinance to consider a project's vulnerability to sea-level rise; 2) modify the Subdivision Manual to ensure stormwater infrastructure can address future sea-level rise and flooding; and 3) ensure that environmental review procedures are consistent with these changes. The revised ordinances require developers to plan for 1.5' of sea-level rise over the next 50 years, with the ordinance being revised regularly to reflect new findings. The ordinance will discourage construction in flood-prone areas, and accommodate sea-level rise in areas where construction does occur.

For more information, see NWF's community profile:
http://www.nwf.org/pdf/City-factsheets/chula_vista.pdf

grey infrastructure to at least slow the process. In northern states, coastal salt marshes offer similar ecological benefits as mangrove forests in southern regions. Salt marshes serve vital ecological functions for both marine and terrestrial food chains, acting as nurseries for several fish species and acting as habitat for birds and shellfish. These marshes also serve as a transition zone between land and sea, acting as buffers against storm surges and sea-level rise. Communities are taking these marshes into consideration in their development plans as they require buffer zones around the coast and inland wetlands.

- Cities like Chula Vista, CA, and counties like Miami-Dade, FL, are managing for wetland migration by protecting areas immediately inland and uphill of existing wetlands to allow sea-levels to rise and wetland boundaries to shift, ensuring wetlands remain healthy and able to absorb storm surge and floodwaters.
  - Chula Vista's conservation policy is driven by its climate adaptation plan. This plan directs the city to conserve coastal wetlands and update land development codes to allow wetlands to migrate inland.

- Miami-Dade updated its zoning requirements in much the same way, partnering with the *Southeast Florida Regional Climate Change Compact* to determine best practices.

- Mangrove ecosystems that serve as breeding, feeding, and nursery grounds for fish and wildlife also offer natural protection from storm surge and erosion thanks to their intricate root systems.

  - In Broward County, FL, cities are restoring and replanting historical mangrove forests to anchor shoreline and act as buffers against storm surge at the recommendation of the county's climate action plan. Hollywood, a city in Broward County, has already recognized the importance of these habitats and has restored mangrove forests in a coastal estuary. Broward County is actually part of the *Southeast Florida Regional Climate Change Compact*, a joint commitment of Broward, Miami-Dade, Monroe, and Palm Beach counties to partner to reduce GHG emissions and adapt to the impacts of climate change.

- Seabrook, NH, references the need for a transition zone between flood-prone areas and developed areas. This transition zone would remain as open space, allowing flooding to occur naturally and providing space for the natural migration of wetlands as they move inland.

- *A cost/benefit analysis of tidal marsh restoration in San Francisco Bay* compared this adaptation technique to traditional methods of storm surge protection. After reviewing a number of sources that estimate the value of storm protection offered by wetlands, the study compares the cost of a levee maintained over 50 years to the cost of a levee with an adjacent salt marsh. The researchers estimated that a levee alone would cost $12 million over its 50 year lifetime, but with a marsh just 25 feet wide on the bayside, this cost would be reduced to just over $6 million. This cost reduction alone makes marsh restoration appealing before taking into account additional benefits such as fish and wildlife habitat and associated recreational activities.

Managed Retreat

Similar to "accommodation," the "retreat" approach acknowledges that climate impacts will occur regardless of protection measures. Retreat, however, involves no effort to protect a coastal zone. In extreme cases, this may mean entirely abandoning specific areas (IPCC, 2009). Zoning policies can be altered to allow retreat to occur and flood plain maps can be updated to prohibit construction in vulnerable areas, while state and local governments may also opt to buy-out property in flood zones. These properties can then be converted to green space that can absorb storm surge and prevent property damage.

Key For Chart 1: **Coastal Zone Management Strategies**

- Coastal Impacts: Includes marine coastal impacts: sea-level rise (SLR), coastal flooding, and erosion
- Drought/ Aridity: Includes drought and increasing aridity
- Extreme heat/ UHIE: Includes extreme heat and the Urban Heat Island Effect
- Inland flooding/SW: Includes floodplain and stormwater flooding and associated waterway pollution
- Landscape/ Habitat Change: Includes changes to the landscape or habitats due to climate change

Chart 1: Coastal Zone Management Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitiga-tion
Strategies							
Mapping sea-level rise projections	✓+				✓		
Natural shoreline restoration	✓+				✓		✓
Living shorelines	✓+				✓		
Managing for migration	✓+				✓+		
Coastal impound-ments	✓+	✓+			✓+		
Restore and protect coastal ecosystems	✓+			✓	✓+		✓
Increase coastal edge elevations	✓+						
Oyster reef creation	✓+				✓+		
Expand ecological buffers around developments	✓+			✓	✓+		✓

Details	Example	More info
Maps of present and future conditions will be necessary to avoid development in at-risk areas, namely in coastal areas and floodplains. Communities can use existing tools or partner with state and federal agencies to carry out these studies.	Various	*NOAA Coastal Services Center*
Restoring dunes, wetlands, and other natural features along coastlines can help cities be more resilient to the effects of climate change while providing habitat for wildlife. Hollywood, FL, has restored mangrove forests in a coastal estuary to maintain water quality and help guard against sea level rise.	Hollywood, FL	*Project Profile - West Lake Park*
Living shorelines are made up of plants, sand, and limited amounts of rock to stabilize and protect stretches of shoreline and provide natural habitat. By using native plants instead of hard structures, erosion can be more effectively prevented.	Various	*NOAA Habitat Conservation*
As the sea-level rises, coastal marshes may migrate inland as long as they are not blocked by development. Conservation efforts can protect and restore lands immediately inland or uphill from wetlands to ensure these habitats can cope with sea level rise and continue to provide protection from storm surges.	Chula Vista, CA	*Chula Vista Climate Action Plan*
Coastal impoundments provide fresh and brackish water to fish and wildlife while acting as protection for the coast against sea-level rise and storm surges. Restoration projects are being conducted in Delaware to prepare these ecosystems for the impacts of sea level rise, namely saltwater intrusion, to ensure they can adapt to climate change.	Delaware	*NWF's Climate Smart Conservation*
Mangrove forests in Florida provide fish and wildlife habitat as well as protection from erosion and storm surges. Communities throughout Broward County have begun planting and protecting mangrove forests in the region.	Broward County, FL	*Broward County Climate Action Plan*
Raising the elevation of vulnerable areas can enhance their resilience to storm surges and sea level rise. This can be accomplished through a variety of methods, such as filling in beaches. New York City developed a strategy outlining how coastal areas can be protected, including details on how some areas can be elevated.	New York City, NY	*A Stronger, More Resilient New York*
Off-shore structures, such as sea walls and groins, are designed to attenuate wave strength, protecting the coast from erosion and storm surge. Natural structures such as oyster reefs serve the same function while providing habitat for fish and wildlife, namely shellfish. Communities can partner with research and conservation organizations to identify and implement offshore projects such as these.	Mobile County, AL	*Oyster Reef Breakwater Restoration on Alabama's Gulf Coast*
Miami-Dade County is working with a regional planning group and updating its zoning requirements to increase the buffers required for developments near coastal wetlands areas. This will preserve habitat, allow for wetland migration, and keep infrastructure away from areas prone to flooding.	Miami-Dade, FL	*Southeast Florida Regional Climate Change Compact*

Chart 1: Coastal Zone Management Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitigation
Implementation Methods							
City ordinance for dune protection	✓+						
Land easements	✓+				✓+	✓	✓
Loans and grants for living shorelines	✓+				✓		
Transition zones	✓+				✓		
Private property buyout	✓+	✓+		✓	✓		
Voluntary Acquisition Program	✓+			✓	✓		
Update FEMA flood risk maps	✓+			✓+	✓		
Zoning updates	✓+			✓	✓		

Details	Example	More info
Located on a thin barrier island, Manatoloking, NJ, is vulnerable to sea-level rise and coastal erosion. The city recognized the importance of sand dunes to protect the built environment. Although states usually pass laws to limit development and protect coastal dunes, the city passed their own policies in 1999 to ensure their community would maintain protection from storm surges.	Mantoloking, NJ	*Mantoloking beach and dune protection ordinance*
To better manage coastal land, private land trusts, and sometimes local and state governments, can work with private landowners to protect sand dunes through conservation easements. Such easements can be designed to limit development and promote dune restoration, but could also limit public access. Rolling easements (hyperlink here http://papers.risingsea.net/rolling-easements.html), however, can actually ensure that protection structures do not limit public access along a shore, even as shores erode inland, by ensuring that the public access boundary migrates inland with the shoreline.	Mantoloking, NJ	*Borough of Mantoloking*
Maryland and Virginia have a host of financial incentive programs to incentivize the creation of living shorelines along the Chesapeake Bay coastline. Funding is available for private and public lands, and may be available for homeowners, communities, local governments, and non-profit organizations.	MD and VA	*Living Shorelines for the Chesapeake Bay*
Seabrook, NH, released an adaptation strategy in 2009 to address the threat of SLR. One policyrecommendation is defining transition zones between areas prone to flood and areas that are developed. This zone would be protected and remain as open space, allowing wetlands to migrate inland.	Seabrook, NH	*Protecting Areas from Coastal Flooding in NH*
After Superstorm Sandy, NY governor Cuomo created a $400 million voluntary buyback program for flooded communities in the state. The program is intended to take high-risk properties off the market and return them to a more natural state, providing wildlife habitat while reducing damage to properties and the state's future storm liability.	New York City, NY	*New York State Disaster Case Management*
After Superstorm Sandy, NJ created voluntary "Willing Seller Plan" to provide central NJ homeowners with the option to move instead of rebuilding in areas that are at high risk for repetitive flooding. The plan is an extension of the state's existing Blue Acres Program, an acquisition program to purchase homes.	New Jersey	*Blue Acres Floodplain Acquisitions*
Construction in flood-prone areas can be limited by using updated FEMA flood risk maps when revising local zoning ordinances. Local government can choose to ban limit, or alter construction in various hazard areas to accommodate storm surge and flooding. The San Diego Bay Sea Level Rise Strategy outlines options for communities to adapt to coastal hazards, including updating zoning and using updated FEMA flood risk maps.	San Diego, CA	*San Diego Bay Sea-Level Rise Strategy*
Cities are able to update their management zones in many ways (overlay zones, downzoning, restricted development areas, rebuilding restrictions, setbacks, etc.) to prevent development in areas sensitive to sea-level rise and flooding that would also bolster the natural adaptive capacity of the area, as well as provide valuable wildlife habitat.	San Diego, CA	*San Diego Bay Sea-Level Rise Strategy*

A recently released report by Columbia Law School, "*Managed Coastal Retreat: A Legal Handbook on Shifting Development Away from Vulnerable Areas*," details regulatory tools and resources states and communities may use to encourage managed retreat and discourage hard armoring and development in vulnerable areas. The handbook includes lessons learned and recommendations for coastal planning, setbacks and rolling easements, prohibiting coastal armoring, rebuilding restrictions, and acquisition. Several city and state ordinances are highlighted, showing how proper regulation can be used to prepare for coastal hazards that are expected to worsen due to climate change. Despite county and state efforts, however, coastal armoring still occurs, resulting in worsening erosion. Local, state, and federal agencies are continuing to work together to address the growing threat of storm surge and erosion.

- In Keene, NH, flood plain maps were adjusted to prohibit development in vulnerable areas.
- After Superstorm Sandy, New York Governor Cuomo created a $400 million voluntary buyback program for flooded communities in the state funded by FEMA (Federal Emergency Management Administration). The program is intended to take high-risk properties off the market and return them to a more natural state, providing wildlife habitat while reducing damage to properties and the state's future storm liability.
- Using $300 million in FEMA funds, New Jersey Governor Chris Christie created a similar voluntary program, the "Willing Seller Plan," to provide Central NJ homeowners with the option to move instead of rebuilding in areas that are at high risk for repetitive flooding. The plan is an extension of the state's existing Blue Acres Program, which is an acquisition program to purchase, "properties (including structures) that have been damaged by, or may be prone to incurring damage caused by, storms or storm-related flooding, or that may buffer or protect other lands from such damage."
- Miami-Dade County is working with a regional planning group and updating its zoning requirements to increase the buffers required for developments near coastal wetlands areas. This will preserve habitat, allow for wetland migration, and keep infrastructure away from areas prone to flooding.
- On Kaua'i, the fourth largest island in Hawaii, the county government used a combination of set distances and erosion rates to determine the distance a development project must be from the coast.

Managing Coastal Impacts in the Great Lakes Communities

Climate in the Great Lakes region has already been changing, although how and how much are variable from one location to another (USGCRP, 2009; Winkler et al.). Looking ahead, climate models project further changes due to carbon emissions. While most coastal zones must prepare for higher water levels, communities throughout the Great Lakes region must prepare for a decline in water levels. Ice cover has declined by an average of 71% across the Great Lakes, resulting in higher rates of evaporation from the open water (Wang et al., 2012). Lake Superior reached a record low in 2007, and Lake Huron and Lake Michigan hit their lowest levels in January 2013 while the other lakes were well below average (Flesher, 2013). The *Great Lakes- St. Lawrence River Basin Sustainable Water Resources Agreement* and the *Great Lakes-St. Lawrence River Basin Water Resources Compact* are two frameworks that limit water diversions and water withdrawals from the lakes to reduce non-climate stressors likely to interact with climate change.

As water levels continue to fluctuate, coastal erosion will become increasingly problematic. In the past, coastal bluffs would provide a source of new sand as beaches eroded away. Coastal communities have armored these coastlines, however, preventing natural revitalization from occurring and causing the coastline to retreat (USGS Coastal and Marine Geology Program).

Most nature-based adaptation strategies in the Great Lakes coastal zone fall under the "accommodation" approach; as water levels change, communities and ecosystems must adjust. One accommodation approach includes dredging channels and marinas more frequently to allow shipping to continue. Rain storms, sewage, dredging, agricultural runoff, zebra mussel density, and warmer waters have all contributed to the frequency of harmful algal blooms in the Great Lakes, which are now a regular occurrence, especially in Lake Erie. Heavy rainfall also increases runoff of nutrients from agricultural lands into waterways, causing algal blooms that deplete oxygen levels. After experiencing one of the wettest springs on record in 2011, Lake Erie was plagued by an algal bloom covering 3,000 square miles, resulting in huge "dead zones" where oxygen levels were too low for fish and other aquatic life to survive. These dead zones harm not only the local ecosystem, but industrial and recreational fisheries as well. Therefore, increased monitoring of water levels and ecosystem responses may be necessary to protect human health. Although agricultural runoff is the primary cause of algal blooms, stormwater runoff is also a contributor; the urban forestry and low impact development strategies described in this guide can be used to reduce stormwater runoff, and subsequently limit pollution flowing into the Great Lakes. Included on page 20 are some nature-based approaches to prepare for current and future coastal climate impacts in the Great Lakes. A longer list of Great Lakes-specific resources is available on page 63.

- *Restoring the Great Lakes' Coastal Future - Technical Guidance for the Design and Implementation of Climate-Smart Restoration Project with Seven Case Studies* (Koslow et al., 2014) recommends multiple climate-smart solutions to improve the adaptability of coastal regions to climate change:
  - The removal of coastal armoring along lakeshores and riparian habitats will increase connectivity of lakes and streams which may be vulnerable during low level lake events.
  - Depending on future lake levels, gently sloping shorelines can reduce erosion or upland berms can dissipate wave energy and stop water from moving inland during severe weather events.

Key For Chart 2:

Great Lakes Strategies

The following chart includes climate impacts and strategies specific to lake level declines and other coastal impacts in the Great Lakes region.

- Coastal: Includes freshwater coastal impacts in the Great Lakes Region.
- Drought/ Aridity: Includes drought and increasing aridity
- Extreme heat/ UHIE: Includes extreme heat and the Urban Heat Island Effect
- Inland flooding/SW: Includes floodplain and stormwater flooding and associated waterway pollution
- Landscape/ Habitat Change: Includes changes to the landscape or habitats due to climate change

Chart 2: Great Lakes Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitiga-tion
Strategies							
Removal of coastal armoring	✓+			✓+	✓+		
Sloped shorelines	✓+			✓+	✓+		
Reveg-etation of wetland habitat	✓+	✓		✓+	✓+		✓
Variable level fish shelves	✓+				✓+		
Water withdrawl limitation	✓+	✓+					
Invasive species monitoring	✓+				✓+		
Living shoreline	✓+				✓		

Details	Example	More info
Removing coastal armoring along lakeshores and riparian habitats can increase connectivity of lakes and streams that may be vulnerable during low level lake events.	Clinton River Spillway, MI	*National Wildlife Federation*
Depending on future lake levels, gently sloping shorelines can reduce erosion and upland berms can dissipate wave energy and stop water from moving inland during severe weather events.	Clinton River Spillway, MI	*National Wildlife Federation*
Revegetation of wetland habitat can help protect wetland species and habitat types that are vulnerable to extremes in lake levels and altered streamflows. To enable plants to move upland or lakeward, vegetation should be planted across a relatively broad area.	Clinton River Spillway, MI	*National Wildlife Federation*
Fish shelves can be constructed at various depths to provide deeper, cooler water and shelter regardless of water levels.	Lorain, OH	*National Wildlife Federation*
The Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement and the Great Lakes-St. Lawrence River Basin Water Resources Compact are two frameworks that limit water diversions and water withdrawals from the lakes to reduce non-climate stressors likely to interact with climate change.	St. Lawrence River Basin	*Council of Great Lakes Governors*
Communities struggling with invasive species can consider identifying areas at particular risk of invasion by non-native species and set up citizen monitoring and response programs like the Lake Erie Waterkeeper program in Ohio.	Oregon, OH	*Lake Erie Waterkeeper*
Living shorelines can help communities be more resilient to the effects of climate change while providing habitat for wildlife. Aquatic plants and cobble provide habitat in which fish can spawn. Wave breaks will help to minimize erosion and provide a less turbulent environment in which fish can congregate.	Marysville, MI	*City of Marysville, MI*

	Carbon Pollution Storage and Monetary Value from Urban Forestry				
	Chicago	New York City	Philadelphia	San Francisco	Washington DC
Data Year	2007	1996	1996	2004	2004
Number of Trees	3,585,203	5,211,839	2,112,619	669,343	1,927,846
Carbon Stored (MT)	649,336	1,225,228	481,034	178,250	474,417
Gross Carbon Seq/yr (MT)	22,831	38,358	14,619	4,693	14,649
Energy Use Avoided (mBTU)	127,185	630,615	14,695	No Data	194,133
Energy Use Avoided (MWH)	2,988	23,579	10,943	No Data	7,924
Pollution/yr Removed (T)	889	1,997	727	235	489
$/yr Pollution Removed	**$6.4 million**	**$10.6 million**	**$3.9 million**	**$1.3 million**	**$2.5 million**

Chart adapted from Foster et al., 2011.

- Re-vegetation of wetland habitat will help protect types of wetland species and habitat types that are vulnerable to extremes in lake levels and altered streamflows. To enable plants to move upland or lakeward, vegetation should be planted across a relatively broad coastal area.

- In Marysville, MI, an old, failing, and unattractive seawall and sidewalk were replaced with 2.7 acres of beautiful, living shoreline. Living shorelines can help communities be more resilient to the effects of climate change while providing habitat for wildlife. Funding from the U.S. Environmental Protection Agency's Great Lakes Restorative Initiative helped make this project possible.

- Erosion and flooding affected by lake level changes may cause climate-induced shifts in species ranges and movements. The *Climate Action Plan for Nature* in Chicago aims to enhance the resilience of local biodiversity by targeting landscape connectivity and corridors, thus protecting native species and maintaining the health of local ecosystems despite uncertainties in future lake levels.

- Communities struggling with invasive species can consider identifying areas at particular risk of invasion by non-native species and set up citizen monitoring and response programs like the Lake Erie Waterkeeper program in Ohio.

- In the Lorain, OH, fish habitat shelves in the Black River were constructed at various depths to provide deeper, cooler water and shelter regardless of water levels. More information regarding Climate-Smart Habitat Restoration in Lorain can be found on page 48.

Drought and Increasing Aridity

A growing population is putting a strain on the quantity and quality of our water resources, particularly due to the water demand from urban areas. Changes in precipitation resulting from climate change are difficult to predict and will vary from region to region, but there are some agreed-upon trends. Arid regions, for example, are expected to face longer, more frequent droughts. Parts of the Great Lakes may also see a decline in precipitation as lake levels continue to fall (U.S. Drought Monitor, 2013). Though droughts cannot be completely prevented, communities can increase their resiliency by enhancing their urban forests, conserving water, and actively preparing for the increased risk of fire.

Urban Forestry

Urban trees can retain water in their roots and leaves and provide cooling shade, limiting evaporation from the ground. In addition, increasing the amount of green space allows water to enter the earth and replenish groundwater, an important source of drinking water. Over a large enough area, urban trees and open space can alter a region's climate, creating clouds to combat heat and drought (Ban-Weiss et al., 2011). Impervious surfaces, by contrast, keep water above ground where it can quickly evaporate or cause severe flooding and sewer overflows.

- Not all trees are equally valuable in the urban forest. Species should be chosen that are native (or naturalized and adapted to the region's climate[2]) and can withstand the future impacts of climate change. As such, NWF's Forestry CPR Guidebook, *Growing Greener: Eco-Structure for Climate Resilience* (Reeve, 2013), recommends that a community should assess its region's present and future climate and develop a list of native trees that can withstand future conditions.

- Chicago has already evaluated a number of native tree species and developed a planting list of those that can thrive in urban environments with restricted soil and water access. They have also developed a *Wilderness Action Plan for Nature* to guide land management.

- To prioritize species that are drought resistant, communities in the southwest, such as Austin, TX, are using native species lists that include details on water needs of various trees. The Texas A&M Agricultural Extension developed the "*Native and Adapted Landscape Plants: An earthwise guide for Central Texas*" in partnership with the City of Austin to help landowners protect and preserve water resources. Such evaluations ensure that the urban forest can continue to function even under harsher future conditions.

Water Conservation

Reducing water consumption is one approach for communities faced with frequent drought. In particular, reducing urban outdoor water use, which includes limiting the amount of water that is used for landscaping in our yards, parks, and other green spaces, can help communities meet their water conservation goals. Conserving water by capturing rainfall for re-use, using less water in landscape management, and encouraging landowners to replace lawns with native, drought-resistant plants can also save water in the long run. Xeriscaping, in particular, is a landscaping method developed for use in arid and semiarid environments that uses water-conservation techniques, namely through the planting of native, drought-resistant plants. Reducing water use can also help ease

2 Chicago's "*Climate Considerations for Management of Natural Areas and Green Spaces in the City of Chicago*" notes that while native species may be best adapted to a region's climate, they may not be best suited for future climatic conditions. Non-local species may be necessary to ensure an urban forest survives these conditions.

A. White Roofs

1,000m2 white roof is estimated to save $200 annually in cooling costs (Gaffin et al., 2010).

B. Green Roofs

Green roofs cost $10-$25 per square foot to establish and $.075-$1.50 per square foot to maintain (Peck and Kuhn, 2003). They can reduce annual energy consumption by 15-45% (Foster et al., 2011). A study of a 1,000 square meter green roof was found to have reduced cooling costs by $250 annually (Gaffin et al., 2010). A 21,000 square foot green roof would cost $464,000 to install vs. $335,000 for a conventional roof, but would save about $200,000 in energy costs and stormwater fees over its lifetime (Foster et al., 2011).

C. Urban Forest

Each tree: $50-$500 to establish, $15-$65 annually in upkeep (Foster et al., 2011). A University of California –Davis study estimated that for every 1,000 deciduous trees in CA's Central Valley, stormwater is reduced nearly 1 million gallons, a value of about $7,000 (Stoner et al., 2006). Each tree is estimated to provide $30-$90 annually when considering all benefits, such as interception and filtration of stormwater, improved water and air quality, and regulation of urban heat island effect. Strategically placed shade trees can reduce air conditioning costs by up to 30%. Windbreaks (rows of trees) can save 10-50% in heating costs (Stoner et al., 2006).

D. Reducing Impervious Surfaces

In Philadelphia, managing 50% of all impervious surface runoff through green infrastructure would provide about $2.8 billion in benefits through 2049 thanks to reduced emissions, improved air and water quality, recreational space, reduced heat, etc. (City of Philadelphia, 2009).

E. Green median renovation

Green infrastructure stormwater controls (maintaining native plants, reducing imperviousness, and installing green stormwater controls) on new residential developments were estimated to save $3500-$4500 per half-acre lot compared to traditional stormwater control methods (Stoner et al., 2006).

See Conclusion, page 61, for illustration detail.

Illustration by Amanda Frayer

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National Wildlife Federation's Certified Wildlife Habitat ® program

stress on the sources of water in some parts of the country, like California, which help accommodate fish, waterfowl and other wildlife in the water source areas.

Aside from using water saving-practices to conserve water, communities can re-imagine urban landscapes that include plants more suited for a changing climate and create suitable habitats for wildlife. National Wildlife Federation's Certified Wildlife Habitat ® program includes certifications for backyards, schoolyards, businesses and public spaces and is based on the four essential needs of wildlife: food; water sources; cover; and places to raise young. While the basic requirements are not stringent, many institutions go beyond the minimum standards. Therefore, the Certified Wildlife Habitat® program can provide a pathway for communities to link plants more suited to the climate, and the resulting water savings, with the needs of birds, wildlife and insects. The strategies for water conservation described below are captured in the LID (pages 38-41) and open space and habitat management (pages 50-53) charts.

- Rain barrels can capture stormwater and act as a valuable resource when water is scarce. Several communities, including King County, WA, have developed programs to incentivize or give away rain barrels for the sake of stormwater management and drought preparedness.
- According to Aurora, CO, xeriscape rebate program, a proper xeriscape can survive on

almost half the water as a traditional grass landscape. By planting xeriscapes, water can be diverted away from lawn care to more pressing needs. Peoria, AZ, also incentivizes this type of management through a rebate program.

Fire Preparedness

Drought and higher average temperatures will likely increase the frequency and intensity of wildfires as well. Pests, such as the Mountain Pine Beetle, are also expected to thrive in warmer climates, increasing the vulnerability of forests to wildfire by killing otherwise healthy, resilient trees. The best defense against wildfire is often early detection and suppression, while prescribed burns and thinning projects are used to reduce the chance of a fire occurring. Appropriate management of green space and developed areas is necessary to reduce the impact of fires when they do occur.

- *Cal Fire* and *Fire Adapted Communities* are just two of many organizations offering resources to communities and individuals to protect their homes from wildfires.
- Though the exact management methods may differ from location to location, there are several key concepts that communities can follow to mitigate fire risk.
  - During initial planning and development, hazard assessments can direct development away from vulnerable areas, such as ridge tops where water isn't readily available.
  - Lots can be developed in clusters with breaks for open space that can slow the spread of fire.
  - For existing development, open space can be managed to reduce fire fuel and plant trees resilient to heat and pests, as is being done in Austin. Vegetation in yards can be managed in the same way through incentive programs and tree giveaways.

Extreme Heat/Urban Heat Island Effect

Urban areas tend to experience higher temperatures than rural areas due to a phenomenon known as the *urban heat island effect (UHIE)*. Impervious and artificial surfaces (i.e. buildings, roads, railways) that cover a large percentage of the land area in cities retain more of the sun's energy, raising ground and nearby air temperatures. The high energy usage in cities, from heating and ventilation systems to automobile traffic, also produces waste heat. While extreme heat is regionally variable, climate change will increase annual average temperatures nationwide, exacerbating the already higher-than-average temperatures in cities. Developing a robust urban forest and implementing a number of low-impact development approaches are the most common nature-based approaches to combat such impacts.

Urban Forestry

One of the common ways that cities are combating the UHIE is through urban forestry. Trees provide cooling shade, preventing dark surfaces from absorbing and releasing heat from the sun. Water released from the tree leaves through transpiration also has a slight cooling effect. Over a large enough area, an urban park or forest can significantly cool a city (Ban-Weiss et al., 2011). By planting new trees and improving the health of existing trees, cities are expanding their canopy coverage in order to provide shade and lower temperatures.

- Maryland's Department of Natural Resources estimated that strategically placed trees could lower air conditioning costs of homes by 30%.

- The Center for Clean Air Policy estimated that the net annual economic benefit of a mature urban tree ranges from $30-$90 (Foster et al., 2011).

- Cities nationwide have initiatives to improve their urban forests. New York City, Philadelphia, Chicago, and Houston are just a few examples of cities that have robust urban forestry programs that seek to plant more native trees on both private and public lands.

  - Many of these programs have a goal of planting a million trees, or improving tree cover by a specific percentage, depending on the city's sustainability plan.

Climate-Smart Community Profile: Houston, TX

Houston's climate is generally hot and dry throughout the year, though its proximity to the Gulf of Mexico makes it especially vulnerable to hurricanes and tropical storms. The city must thus cope simultaneously to periods of scarce water availability and periods of torrential rain. In 2008, the Houston-Galveston Area Council released the Foresight Panel on Environmental Effects Report, including a set of adaptation recommendations for the region. Houston has already begun implementing climate adaption initiatives based on this report.

Improving the urban tree canopy provides shade during hot, dry months while offering a natural solution to stormwater management as water is able to naturally penetrate the earth in green spaces. Improving the urban canopy has been a priority issue for the city. Houston's NeighborWoods program provides volunteers with free trees to plant on city right-of-ways. The city has also developed a set of best practices and tips for tree plantings to ensure trees can survive the harsh southwest climate. The Houston Parks and Recreation Department has also partnered with Trees for Houston to plant a million trees in the city.

For more information, see NWF's community profile: *http://www.nwf.org/pdf/City-factsheets/houston.pdf*

Numerous tools exist to assist communities as they improve their urban forests. In partnership with National Wildlife Federation (NWF) and with support from the USDA Forest Service Urban and Community Forestry Program, King County, WA, developed an online tool to help landowners understand the benefits healthy trees can have for climate change mitigation and adaptation, including offsetting the UHIE. *The Forestry Climate Preparedness and Response (CPR)* tool quantifies and explains complex forest characteristics (i.e. total carbon load at a particular site) using an embedded Geographic Information System (GIS).

- NWF developed an accompanying guidebook, *Growing Greener: Eco-Structure for Climate Resilience*, to encourage cities and towns to recognize trees as critical infrastructure for healthy, resilient communities. The guidebook offers a number of recommendations to ensure urban forests are created and maintained in a "climate-smart" way:

  - Understand which trees and plants in your region are appropriate for a changing climate.

  - Develop a climate-smart tree species planting list.

  - Integrate climate change information into pest and invasive species management.

  - Transform yards and vacant properties into wildlife gardens, like through *NWF's Certified Wildlife Habitat® Program*.

- Understand, analyze, and leverage the benefits of urban trees.

Low-Impact Development (LID) & Increasing Pervious Surfaces

Reducing extreme heat in urban areas can also be done using a variety of low-impact development strategies. Traditional rooftops of tar, gravel, asphalt, and plastic create a dark surface that absorbs the sun's energy, heating the surrounding area. Replacing these dark surfaces with more reflective surfaces or upgrading them to a green roof, when technically feasible, can limit the amount of heat retained in the area. Cities can also address the urban heat island effect by expanding open space. While trees provide cooling shade, non-forested natural landscapes in general tend to absorb less heat than developed areas made of asphalt and concrete. LID is an approach that that works with nature to manage stormwater as close to its source as possible and can be applied to new development, re-development, or as retrofits to existing development, (USEPA). LID approaches preserve and mimic natural landscape features and minimize impervious surfaces in a functional and aesthetically pleasing design that treats stormwater as a resource instead of a waste product.

- A green roof insulates buildings and provides a cooling effect to the surrounding air through transpiration. During this process, plants absorb heat and release water stored in their leaves, resulting in a net loss of heat in the surrounding air (Liu and Baskaran, 2003).
  - Green roofs provide effective insulation for the buildings on which they are located. A study in Long Island City in Queens, NY, found that a 1,000m^2 green roof saved roughly $400/year in heating costs and $250/year in cooling costs (Gaffin et al., 2010).
  - A University of Michigan study determined that, while a 21,000ft^2 green roof would cost $129,000 more to install than a traditional roof, it would save the homeowner about $200,000 in heating, cooling, and air quality improvements over the course of its life (Foster et al., 2011).

Key For Chart 3: **Urban Forestry Strategies Chart**

It is important to note that trees can help communities prepare for a number of climate impacts, including UHIE, but also inland flooding and stormwater management, and landscape and habitat changes. Trees also help improve air quality and sequester GHG emissions.

- Coastal Impacts: Includes marine coastal impacts: sea-level rise (SLR), coastal flooding, and erosion
- Drought/ Aridity: Includes drought and increasing aridity
- Extreme heat/ UHIE: Includes extreme heat and the Urban Heat Island Effect
- Inland flooding/SW: Includes floodplain and stormwater flooding and associated waterway pollution
- Landscape/ Habitat Change: Includes changes to the landscape or habitats due to climate change

Chart 3: Urban Forestry Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitigation
Strategies							
Planting on public lands		✓	✓+	✓+	✓	✓	✓
Planting on private lands		✓	✓+	✓+	✓	✓	✓
Implementation Methods							
Tree giveaways		✓	✓+	✓+	✓	✓	✓
Zoning		✓	✓+	✓+	✓	✓	✓
Street tree ordinance		✓	✓+	✓+	✓	✓	✓
Policy changes		✓	✓+	✓+	✓	✓	✓

Details	Example	More info
Planting trees along public right-of-ways and in parks is common practice for many cities looking to improve their urban forest. Chicago is planting and caring for new trees in a wide variety of public spaces including sidewalks, parks, and the grounds of civic buildings.	Chicago, IL	*Chicago Department of Forestry*
TreePhilly (a Philadelphia Parks and Recreation Department initiative) is engaged in extensive outreach to encourage tree plantings on private property. These efforts complement the city's efforts on public lands to further enhance the urban forest.	Philadelphia, PA	*Tree Philly*
Giving away trees to private landowners is a straightforward way to enhance the urban forest on private land. The City of Philadelphia partnered with a local park conservancy group to sponsor a free yard-tree giveaway	Philadelphia, PA	*Tree Philly*
Changes to zoning policy can help ensure green infrastructure, such as trees, is prioritized during new construction projects. Washington DC is updating its zoning requirements to include a mandatory "Green Area Ratio" to ensure any new developments include a certain percentage of green space (including tree canopy).	Washington, DC	*DC Green Area Ration Factsheet*
Street trees are often planted and maintained by cities. By planting native, resilient species, a robust urban forest can be created to provide shade and stormwater management. New York's sustainability plan urges the improvement of its already robust urban forest. An initial ordinance in 2008 directed the planting of a tree every 25 feet along street frontage.	New York City, NY	*NYC street trees ordinance*
Chula Vista is changing policy to ensure the use of shade trees in future municipal improvement projects and private development parking lot projects. They are developing a City Council policy rather than an ordinance, and are reviewing successful urban forestry programs to inform the new policy.	Chula Vista, CA	*Chula Vista Climate Adaptation Strategies*

Chart 3: Urban Forestry Strategies	Details	Example	More info
Additional Implementation Methods*			
Field research	Communities should research urban forests to determine best practices given cities' unique environments and regional climates. NYC in collaboration with the U.S. Forest Service is conducting research to determine tree mortality, urban ecosystem structure, and a number of other factors to determine how to maximize the benefits of urban trees.	New York City, NY	*U.S. Forest Service NYC Field Station*
Research urban ecosystems	Researching urban ecosystems can help determine the best methods of management, habitat restoration, coastal management, etc.The Baltimore Ecosystem Study, funded by the National Science Foundation, is a long-term study meant to help understand major urban regions as ecological systems to better inform city planners.	Baltimore, MD	*Baltimore Ecosystem Study*
Develop online tools	Online tools can provide decision-makers and the public with resources to foster a robust urban forest. King County, Washington has developed an online GIS-based tool to provide property owners information about the climate-benefits (carbon sequestering, habitat, shade, etc.) of trees. The tool provides suggestions of ways to improve properties, and allows land-owners to look up their property by parcel number.	King County, WA	*Forestry CPR*
Re-evaluate tree species for a changing climate	As climate envelopes shift, some tree species may not be able to cope with new conditions. Trees on the southern end of their range, for example, may be extirpated as trees on the northern edge of their range may thrive. The City of Chicago is taking climate change into account by carefully selecting which tree species to plant. They are targeting species that are not only better adapted for the range of future climate projections in the city, but are better able to thrive in urban environments with restricted soil and water access.	Chicago, IL	*Chicago Climate Action Plan*
Education/ Outreach	Education and outreach are necessary to ensure trees on private lands remain healthy. Philadelphia Parks and Recreation Department hosted free workshops for public employees on planting and maintenance of trees. Participants were given a voucher for a free tree at the end of the workshop.	Philadelphia, PA	*Greenworks Philadelphia*
Provide public resources to improve urban forest in face of climate change	Some plant species will thrive under future climate conditions while others will suffer. The urban forest must thus contain species that can thrive under present and future conditions. Developing species lists that includes native, climate-resilient trees provides a simple tool for the public, and decision-makers, to ensure a robust urban forest.	Austin, TX	*Native and Adapted Landscaped Plants: An earthwise guide for Central Texas*

** Indirectly, these methods can be used to address a variety of climate impacts.*


Credit: Charlie Vinz (flickr.com)

- New York City has begun updating zoning codes to encourage the use of reflective roofs and green roofs that mitigate the UHIE. While painting rooftops white is a valid measure to reduce urban heat, the nature-based approach of green rooftops also manages stormwater and provides habitat for urban wildlife. New York City has taken this strategy a step further by encouraging urban agriculture and community gardening. NYC's sustainability plan, PlaNYC, lays out a strategy for working with local nonprofits and schools to encourage green space in the form of community gardens.

- Providence, Rhode Island, is investing in the expansion and maintenance of city parks, community gardens, and other green spaces in order to reduce the amount of heat-absorbing non-natural surfaces in the city.

- Montgomery County, MD, offers rebates to residential and commercial properties that implement eligible rainscaping techniques to reduce stormwater pollution. Techniques include rain gardens, planting a tree canopy, using green roofs and rain barrels, etc. Each technique has a different rate of reimbursement, incentivizing the best techniques. Funding for the rebates comes from the County's Water Quality Protection Charge, a tax property owners pay for the amount of impervious surface on their property.

Inland/Urban Flooding and Stormwater Management

Precipitation patterns across the world are changing drastically due to climate change, and many areas will see great increases in the severity and frequency of large storms. The exact changes in precipitation patterns may be difficult to predict and will vary from region to region, though it is expected that dry areas will become drier, and areas prone to storms will face more severe weather events (IPCC, 2007; NCA, 2009). This presents a number of challenges to heavily developed areas, especially those located along waterways, where impervious surfaces prevent the natural penetration of water into the earth. Aging infrastructure that combines stormwater and sewage, built to handle historic rainfall and smaller populations, is not effective at handling the water flow from increasingly intense storms. As regions experiences wetter weather and more extreme storms, existing stormwater management plans and infrastructure are not designed to account for these changes. Outfall pipes are also often located in places that historically had low water levels, but now are vulnerable to storm surge and sea-level rise. Without proper management, the increased outflow of water from storms, particularly in urban areas with combined sewer systems, can overwhelm wastewater treatment facilities, resulting in sewer system overflows that put human and environmental health at risk (Schwirtz, 2013). An increasingly urbanized population puts further strain on sewage and stormwater treatment infrastructure, much of which is growing outdated and deteriorating (Copeland and Tiemann, 2010). Much of this infrastructure was built as early as the late 1800s, with environmental standards to regulate these systems not established until decades later. With population growth, increased urbanization, and more intense storms, these systems simply cannot handle the current and future climatic

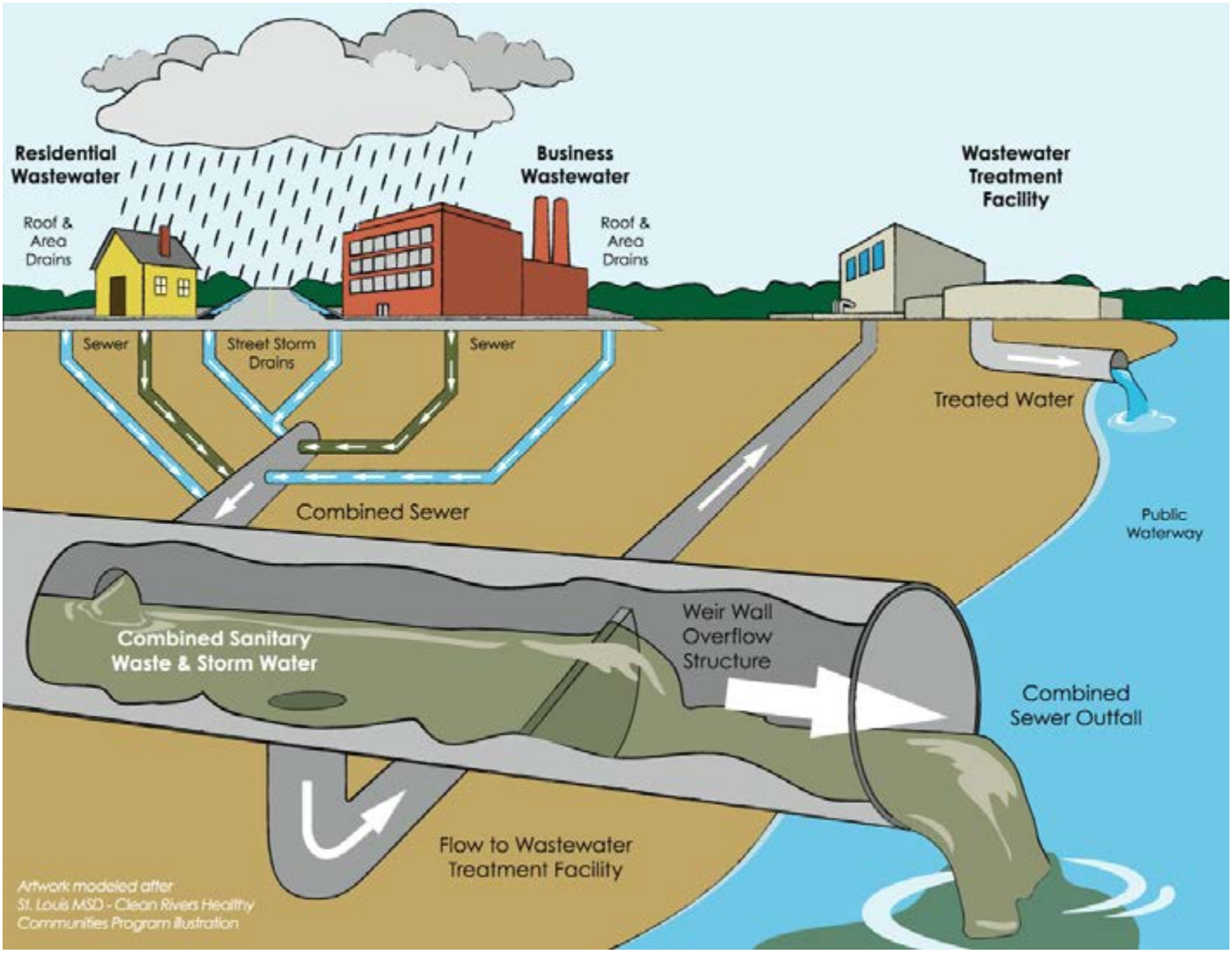


Figure B. Combined Sewer System. Used with permission from Civic Garden Center of Greater Cincinnati

conditions (Kessler, 2011). More intense storm events will also alter and expand floodplains into regions that may contain development, namely along coastlines and near waterways.

Low-Impact Development & Increasing Pervious Surfaces

Updating water treatment plants and grey infrastructure, such as sewer pipes and culverts, to handle the increased demand from growing populations and development is the prevailing method to cope with increased water flow. During extreme rain events, increased stormwater volume overwhelms aging sewer infrastructure, which can result in sewage backups in streets and in the basements of buildings. Further, some communities have already committed to the construction of grey infrastructure interventions to manage stormwater flows, like underground tunnels, which are not designed to accommodate projected increases in rainfall volumes resulting from climate change. Although aging infrastructure needs to be updated, supplementing these upgrades with green infrastructure can assist in stormwater management and provide additional community benefits and cost-savings.

In particular, Low Impact Development (LID) strategies are being used my many communities to manage stormwater. LID is an approach that that works with nature to manage stormwater as close to its source as possible and can be applied to new development, re-development, or as retrofits to existing development (USEPA). LID approaches preserve and mimic natural landscape features and minimize impervious surfaces in a functional and aesthetically pleasing design that treats stormwater as a resource instead of a waste product.

Similar to methods meant to address the urban heat island effect, replacing artificial surfaces with green space allows water to naturally infiltrate the earth instead of overflowing onto streets and into storm drains. A properly managed green roof, for example, can reduce annual stormwater run-off by 50-60% annually (Foster et al., 2011). Communities that are more built-out, or developed, should consider strategies to retrofit existing impervious surfaces, like sidewalks, with green stormwater infrastructure (GSI) to handle current and expected increases in stormwater runoff. Efforts to promote LID range from comprehensive city-wide plans to stormwater policies and regulations to incentive programs for specific interventions, like rebate programs for rain barrels.

- In 2009, the Philadelphia Water Department introduced Green City, Clean Waters, a 25-year plan to protect and enhance watersheds and the city's water supply by managing stormwater with green infrastructure. The plan includes measures to install rain barrels, green roofs, pervious pavement, rain gardens and more. The plan was officially supported by the Environmental Protection Agency which is collaborating with the city on its implementation.

- The City of Seattle offers incentives to homeowners using green stormwater infrastructure, but also requires new projects to implement green infrastructure to the maximum extent feasible. GI is constrained only by physical limitations of a site, practical considerations, and considerations of financial costs and environmental impacts.

- Ann Arbor, MI, is managing stormwater on residential properties by requiring stormwater management plans for new development over 200 square feet and charging annual fees on property with impervious surfaces. Property owners can reduce this fee by implementing stormwater management measures.

- Washington, DC, and Annapolis, MD, are two of countless communities that have incentive programs to encourage homeowners and commercially developed areas to use rainscaping techniques to limit the flow of water off their property.

  - Annapolis offers discounts on their stormwater utility fee for properties that install green roofs and rain gardens.

  - Washington, DC, requires development projects that disturb 5,000 square feet of land or more to retain all the rain from a 1.2 inch storm.

  - The District is also developing a stormwater retention credit trading

Credit: Ralph Tiner (flickr.com)

Climate-Smart Community Profile: Grand Rapids, MI

In June 2011, Grand Rapids finalized its comprehensive Sustainability Plan to manage economic, social, and environmental resources. Included in the plan are efforts to improve the tree canopy, increase green space, and reduce stormwater runoff which all help reduce the urban heat island effect and urban flooding.

The city plans on increasing the tree canopy by 37.5% by June 2015 while requiring landscaping projects that apply for a land use permit to plant at least 70% of plant species native to Michigan. The city is also working to increase the amount of city-owned parks and open space by 10%. One piece of property already acquired, Pleasant Park, followed low-impact design standards.

Grand Rapids has several goals related to stormwater management and reducing overall water consumption. The city has already installed several bi-retention islands along roads to capture stormwater, allowing it to naturally penetrate the earth before reaching surrounding waterways. With an overall goal of improving the quality of the Grand River, the city has begun increasing the number of green roofs within the city and has hosted rainbarrel workshops and distribution programs to reduce stormwater outflow.

For more information, see NWF's community profile: *http://www.nwf.org/pdf/City-factsheets/Grand_Rapids.pdf*

program through which projects can buy and sell credits from the private market to meet those requirements.

- The RainWise program in Seattle, WA, works in much the same way, although the city's Stormwater Code also requires new projects to implement green stormwater infrastructure to the "maximum extent feasible."

- Rain barrels can also be used to limit runoff into sewer systems and waterways. DC's RiverSmart Homes Program estimated that the 739 rain barrels it installed in 2012 are able to retain over 2.6 million gallons of stormwater annually, removing this strain from water treatment plants.

- While DC has made great strides in incentivizing green infrastructure on private property, they have also made progress in public right-of-ways. In 2009, the District was awarded funding from the American Recovery and Reinvestment Act to remove impervious surfaces, renovate green medians, and improve the tree canopy.

  - Their 33 projects ranged from simple concrete removal to complete renovation of sites, and ranged in price from $8 to $44 per square foot, averaging $14.94 per square foot to complete (Washington DDOT, 2012).

- In Virginia, NWF, Rappahannock River Basin Commission (RRBC), and other partners developed a partnership to link NWF's Certified Wildlife Habitat ® Program to the Chesapeake Bay TMDL (total maximum daily load) and RRBC's economic development-based conservation programs. The resulting outcome, called "River Friendly Yards (RFY)," is a multi-phase program to convert conventional lawns in the Chesapeake Bay bioregion to River Friendly Yards that have enhanced wildlife and nutrient reduction capacities.

- In Baltimore, MD, NWF is working with the city to link Certified Wildlife Habitats with water management as part of the *B'More Wild* program. Due to the demands of a growing population and an aging infrastructure, the stormwater and sewage infrastructure often

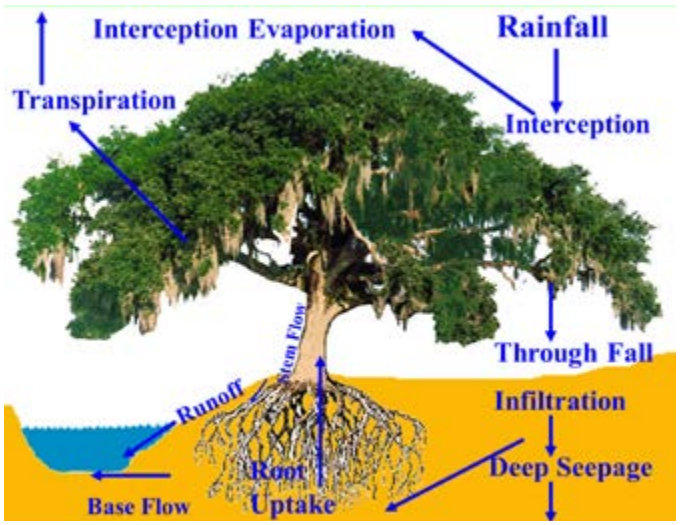


Figure C. Trees Manage Rainfall.

Used with permission from Lawrence Korhnak, UFL IFAS

cannot meet the demand placed on it, resulting in flooding and pollution of the Bay. The B'More Wild program encourages "backyard" practices, such as removal of impermeable surfaces and installation of vegetative buffer zones, to engage citizens, organizations, and municipal leaders in addressing these water issues.

It is important to note that LID strategies can be used to prepare for a number of climate impacts, including primarily stormwater management, the urban heat island effect, and drought. LID approaches can also help with carbon mitigation and air quality improvements.

Economic Benefits of Green Infrastructure for Stormwater Management

While green infrastructure (GI) may not completely replace grey infrastructure for managing stormwater, investments in nature-based approaches can be a cost-effective supplement.

- The national advocacy group Green for All released a report in 2011 to quantify the benefits delivered by green stormwater projects. Based on a $188.4 billion investment over the next five years across the nation, these projects could generate $265.6 billion in economic activities and create over 1.8 million direct, indirect, and induced jobs (Gorden, et al., 2011).
- One study found that new residential developments built with green infrastructure instead of traditional stormwater control cost $3,500-$4,500 less to develop (Stoner, et al., 2006).
- Philadelphia's Green City, Clean Waters plan emphasizes the importance of nature-based approaches as well, allocating 70% of its $2.4 billion budget to GI compared to just 14% for water treatment plant upgrades. They argue that these investments are necessary not just for stormwater management, but climate adaptation in general.

Key for Chart 4: **Low-Impact Development Strategies**

- Coastal Impacts: Includes marine coastal impacts: sea-level rise (SLR), coastal flooding, and erosion
- Drought/ Aridity: Includes drought and increasing aridity
- Extreme heat/ UHIE: Includes extreme heat and the Urban Heat Island Effect
- Inland flooding/SW: Includes floodplain and stormwater flooding and associated waterway pollution
- Landscape/ Habitat Change: Includes changes to the landscape or habitats due to climate change

Chart 4: Low-Impact Development Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitigation
Strategies							
Increase permeable surfaces			✓	✓+			
Green roofs			✓	✓+	✓	✓	✓
Rain barrels		✓+		✓+			
Rain gardens		✓	✓	✓+	✓	✓	✓
White or "cool" roofs			✓+			✓+	
Blue roofs				✓+			

Details	Example	More info
From parks to tree boxes to porous pavement, any surface that absorbs water into the ground rather than letting it run off helps minimize flood risk associated with increased storm events. Providence is taking steps to manage stormwater by increasing green spaces and separating sidewalks from the curb by a permeable strip when possible, allowing for natural penetration of water.	Providence, RI	*Greenprint Providence*
Green roofs reflect the sun's energy better than artificially surfaced roofs, counteracting the UHIE and providing wildlife habitat. This green infrastructure also retains stormwater better than traditional rooftops. DC Greenworks provides resources to encourage the installation of green roofs. DC government encourages this practice through its stormwater fee program.	Washington, DC	*DC Greenworks Green Roofs Program*
King County, WA, is encouraging citizens to use rain barrels to store water to be used in landscaping and gardening during droughts. This relieves stress on the county water system by diverting stormwater, promotes conservation of county supplied water, and helps keep gardens and greenspaces healthy during the dry times of the year.	King County, WA	*King County Rain Barrel Information*
Rain gardens are designed specifically to retain water and prevent storm-water runoff from entering sewers and waterways. The City of Madison, WI passed a code in 2004 requiring that a portion of land in new developments shall be used to infiltrate stormwater into the soil, incentivizing the creation of rain gardens. In addition, the city offers planting plans, guides, and maps in an attempt to increase the number of rain gardens in the city.	Madison, WI	*City of Madison Rain Gardens*
White rooftops better reflect sunlight and reduce energy usage from air conditioning. NYC updated its Construction Codes in 2008 to require most new construction to include rooftops that are 75% reflective or rated "highly reflective" by Energy Star. In addition, NYC Service and NYC Department of Buildings collaborate with volunteers to paint existing rooftops white, reducing the urban heat island effect.	New York City, NY	*NYC Cool Roofs*
Blue roofs are specifically designed to retain stormwater and prevent runoff into sewers and waterways, though not necessary through "green" methods. A proposed method for stormwater management in NYC is to install collars around rooftop drains to help retain stormwater, improving water quality.	New York City, NY	*PlaNYC*

Chart 4: Low-Impact Development Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitigation
Strategies							
RiverSmart Landscaping Incentives		✓	✓	✓+	✓	✓	✓
RainScape Rebates		✓	✓	✓+	✓	✓	✓
Stormwater management requirements and fees		✓	✓	✓+	✓	✓	✓
Stormwater Fee Credit		✓	✓	✓+	✓	✓	✓
Update city codes to require green infrastructure		✓	✓	✓+	✓	✓	✓
Stormwater management ordinace		✓	✓	✓+	✓	✓	✓
Xeriscaping rebates		✓+	✓	✓	✓	✓	✓

Details	Example	More info
Washington, DC offers monetary incentives to homeowners that implement landscape enhancements, such as rain gardens or pervious pavers, that reduce stormwater runoff. Homeowners apply to the program and receive a free audit to determine the best options and incentive amount.	Washington, DC	*RiverSmart Homes*
Montgomery County offers rebates to residential and commercial properties that implement eligible rainscaping techniques to reduce stormwater pollution. Techniques include rain gardens, planting a tree canopy, using green roofs and rain barrels, etc. Each technique has a different rate of reimbursement, incentivizing the best techniques. Funding for the rebates comes from the County's Water Quality Protection Charge, a tax property owners pay for the amount of impervious surface on their property.	Montgomery County, MD	*Montgomery County RainScape Program*
Ann Arbor, MI, is managing stormwater on residential properties by requiring new development over 200 square feet to draft stormwater management plans and charging annual fees on property with impervious surfaces. Land owners can reduce this fee by implementing stormwater management measures.	Ann Arbor, MI	*City of Ann Arbor: Stormwater*
The City of Annapolis raised their Stormwater Utility Fee in 2011, and offers a 50% discount on this fee if residential or commercial properties installed any stormwater management structures or devices on their property. These devices include greenroofs, raingardens, and infiltration trenches.	Annapolis, MD	*Annapolis Stormwater Management*
The City of Seattle offers incentives to homeowners using green stormwater infrastructure, but also requires new projects to implement green infrastructure to the maximum extent feasible. GI is constrained only by physical limitations of a site, practical considerations, and considerations of financial costs and environmental impacts.	Seattle, WA	*City of Seattle Policies Requiring and Related to using GSI*
Several communities have passed ordinances to limit stormwater runoff and capture rainwater as a method of water conservation. Tucson, AZ passed an ordinance in 2008 requiring that 50% of all landscape irrigation uses harvested rainwater. Culpepper County, VA's ordinance on stormwater management sets guidelines for development plans, sets buffer zones for water ways, and offers a number of recommendations for stormwater mitigation.	Tucson, AZ; Cupepper County, VA	*Tucson, AZ Rainwater Harvesting best practices*
Xeriscaping involves the use of drought-resistant plans and management methods to limit water use. In drought-prone areas, xeriscaping allows the creation of robust gardens and habitats despite low water availability. Peoria, AZ incentivizes this type of management through a rebate program.	Peoria, AZ; Aurora, CO; various cities	*Peoria Xeriscape Conversion Rebate Program*

A. Rain Barrels

The operation and maintenance costs for rain barrels are about $3 per unit per year (MMSD, 2011), while a single rain barrel saves about $8 per year in stormwater management costs (Chicago Climate Action Plan, 2008).

B. Bioswale

About $1.5 per square foot per year in operation and maintenance (MMSD, 2011).

C. Rain gardens

The cost is about $3-$6 per square foot to install (Foster et al., 2011), and about $1 per square foot per year in maintenance (MMSD, 2011). GI stormwater controls (maintaining native plants, reducing imperviousness, and installing green stormwater controls) on new residential developments were estimated to save $3,500-$4,500 per half-acre lot compared to traditional stormwater control methods (Stoner et al., 2006). For communities with stormwater utility fees, homeowners can be given rebates and save money by installing rain gardens and other stormwater control measures.

D. Native Landscaping

Native plants conserve water because once they are planted, they do not require additional watering. Depending on the climate, soil, and grass type, non-native lawns require about one inch of water per week during the summer – in the Midwest, watering an acre non-native grass lawn for 12 weeks uses about 325,848 gallons of water (Montgomery, 2004). Native landscape installation is estimated to cost $0.10-$5.00 per square foot (Foster et al., 2011). In Chicago, installation of native switchgrass to replace urban sidewalk grass improved water infiltration rate from .29 inches per hour to 7.5 inches per hour.

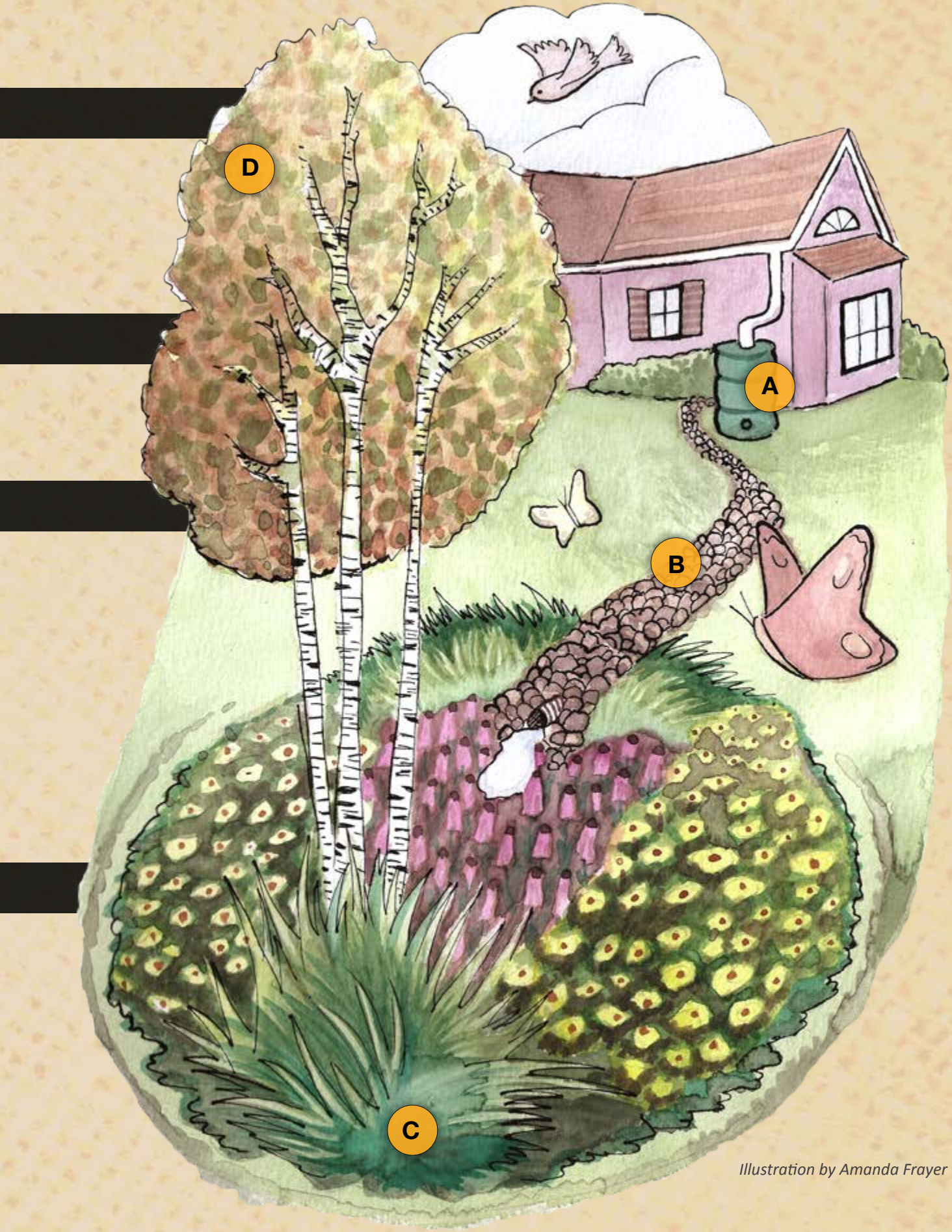


Illustration by Amanda Frayer

A Multi-Faceted Approach to Stormwater Management: Milwaukee, WI

The Milwaukee Metropolitan Sewage District (MMSD) has a long history of using green infrastructure as part of its stormwater management strategy. In 2000, MMSD developed the Greenseams program to purchase land that can capture and store stormwater without the use of grey infrastructure. The Conservation Fund, a national conservation nonprofit, was hired to oversee the program and make voluntary purchases of undeveloped, privately owned properties and open space along streams, shorelines, and wetlands. Since its creation, the program has conserved more than 2,000 acres of land.

Over the course of 13 years, MMSD has partnered with numerous organizations to manage stormwater using low-impact design and green infrastructure. Its rain barrel incentive program began in 2004, followed by a partnership with the Graham-Martin Foundation to promote rain gardens with the intent of protecting Lake Michigan. In 2009, MMSD released "Fresh Coast Green Solutions," detailing the benefits of green infrastructure in managing stormwater. The Regional Green Roof Initiative began the following year, followed by the adoption of several vision statements and partnerships to further promote green infrastructure.

In July 2013, MMSD's Regional Green Infrastructure Plan was approved and will be implemented over the next 20 years. Its efforts are expected to save $44 million in infrastructure costs, create 500 maintenance and 160 construction jobs, increase property values by an estimated $667 million throughout the MMSD planning area, reduce carbon emissions by 73,000 tons per year, save $1.5-$2.1 million in energy costs, and capture 14.8 billion gallons of stormwater that would otherwise flow into sewers and backup sewage treatment facilities. While the plan acknowledges that some green infrastructure may be more expensive to implement than traditional stormwater management techniques, the plan advocates for their implementation due to their multiple benefits and long-term cost savings.

For more information on MMSD's sustainability initiatives, see their website:
http://www.mmsd.com/Sustainability.aspx

Urban Forestry

While many communities develop urban forests for the sake of clean air and urban heat island reduction, not to mention aesthetics and wildlife habitat, urban trees can also help with stormwater management.

- A University of Florida study found that mature deciduous trees can intercept 500 to 700 gallons of water per year, while mature evergreens can capture more than 4,000 gallons per year (Seitz and Escobedo, 2008).
- In 2013, American Forests ranked Seattle as one of the ten best cities in the nation for urban forests. The city's extensive Urban Forest Stewardship Plan provides the framework to expand and improve the health of the urban forest, while empowering citizens to act as stewards. Seattle reLeaf works to engage, educate, and support residents in enhancing the urban forest, namely through tree giveaways and educational programs. The city's RainWise program also encourages homeowners to use green infrastructure, including trees, to manage stormwater, offering rebates to those that do so.

Inland Wetland and Waterway Management

Inland wetland management is another common nature-based approach communities may follow to protect against flooding. One of the many valuable ecosystem services provided by wetlands is floodwater retention. Ensuring the health of wetlands in cities and towns is thus an effective way to protect against flooding. Changes to zoning and building codes may be necessary to ensure the protection of wetlands and prevent construction in vulnerable areas. In New England, the warming climate is expected to decrease snowpack and snowfall during winter months, while increasing non-snow precipitation. These changes will lead to high river flows during storms, but decreased river flows from long periods of drought and minimal melting snowpack upstream. This means cities and towns along rivers and streams could expect longer dry periods, followed by intense storms that lead to flooding.

- Among many other communities, San Luis Obispo County, CA, is working to restore existing wetlands through native plant restoration. The County's Integrated Climate Change Adaptation Plan offers guidance for policy-makers and recommends conserving and restoring wetlands and constructing new wetlands to ensure the ecosystem services from wetlands continue to benefit the community.

- Philadelphia's water department is working to restore rivers, streams, and riparian zones to better manage waterflow during storms. By removing old damns, uncovering culverts, and tearing out pipes that had previously directed water flow below ground, water can flow more naturally and penetrate the earth to restore groundwater and limit urban flooding, while providing freshwater fish with more ideal habitat. Removing these hard structures will allow waterways and associated wetlands to respond more naturally to changes in climate and the expected surges in waterflows.

- In Keene, New Hampshire, public officials worked to redefine their 200-year floodplain, while adjusting zoning regulations to prevent future development in high risk areas. This will prevent future loss of property while allowing rivers and wetlands to function as natural protection against floods, with the added benefit of conserving valuable fish and wildlife habitat.

Key for Chart 5: **Inland Wetland Management**

- Coastal Impacts: Includes marine coastal impacts: sea-level rise (SLR), coastal flooding, and erosion
- Drought/ Aridity: Includes drought and increasing aridity
- Extreme heat/ UHIE: Includes extreme heat and the Urban Heat Island Effect
- Inland flooding/SW: Includes floodplain and stormwater flooding and associated waterway pollution
- Landscape/ Habitat Change: Includes changes to the landscape or habitats due to climate change

Chart 5: Inland Wetland Management Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitigation
Strategies							
Wetland construction	✓	✓		✓+	✓+		✓
Wetland restoration	✓	✓		✓+	✓+		✓
Dam removal				✓+	✓+		
Daylighting rivers				✓+	✓+		
Buffer zones around wetlands	✓	✓		✓+	✓+		
Vulnerability assessments/ Mapping							
Implementation Methods							
Zoning	✓			✓+	✓+		
Restoration incentive programs	✓			✓+	✓+		
Create and protect public parks			✓	✓+	✓+	✓	✓

Details	Example	More info
Wetlands can act as natural stormwater retention areas while restoring groundwater reserves and acting as wildlife habitat. Constructing artifical wetlands can offset impacts to natural ones. San Luis Obispo County (CA) is constructing artifical wetland habitat in anticipation of losing many of its natural wetland areas to drought.	San Luis Obispo, CA	*Integrated Climate Change Adaptation Planning in San Luis Obispo County*
Wetlands (both riparian and coastal) are threatened by human impacts such as development and filling, lessening their capacity to absorb precipitation and cope with rising sea levels. Restoring these wetlands improves water quality and provides habitat.		
The projected increase in the number of severe storms in coming years suggests an increased frequency in floods. Restoring rivers can improve their ability to manage stormwater. Philadelphia is restoring flow to previously dammed rivers and streams in order to make them (and the wetlands associated with them) more resilient to climate impacts to come.	Philadelphia, PA	*Water Dept's Waterways Restoration Tools*
Philadelphia is removing dams, restoring river and riparian ecosystems, and tearing out pipes and culverts to return local rivers to their natural state. These improvements will allow the rivers to better cope with increased runoff and minimize flooding and provide cleaner and healtheir habitat for wildlife.	Philadelphia, PA	*Greenworks Philadelphia*
Limiting development near wetlands will allow them to cope with climate impacts without the threat of other human impacts. Several communities in the Boston metropolitan area recognized the importance of wetlands in stormwater management and as wildlife habitats. They have thus updated their zoning policies to limit development in their associated buffer zones.	Boston metro area	*Boston.com Local News*
Although regulatory tools and strategies exist to protect and restore inland wetlands, mapping and assessing these wetlands should be the first step to identify those that are most vulnerable, which will help determine the appropriate actions to protect them.	Various	*Wetlands-at-Risk Protection Tool*
Miami-Dade County is working with a regional planning body to update its zoning requirements to increase the buffers required around development near wetlands, which will preserve habitat, allow for wetland migration, and keep infrastructure out of flood-prone areas.	Miami-Dade, FL	*Adaptation Task Force Recommendations*
The Hawk Creek Watershed Project in Minnesota developed a watershed basin-wide program to reduce nutrient runoff that contributes to low dissolved oxygen in the Minnesota River. Communities that restore wetlands were given monetary incentives for restoring and protecting wetlands.	Hawk Creek Watershed, MN	*West Central Tribune, Willmar, Minn.*
Greenspaces such as public parks can mitigate the urban heat island effect and manage stormwater. These parks can also contain natural or created wetlands that provide habitat for wildlife. Grand Rapids, MI acknowledges the importance of these green spaces and associated wetlands in its sustainability plan, and plans on increasing its number of public parks.	Grand Rapids, MI	*City of Grand Rapids Sustainability Plan*

Climate-Smart Habitat Restoration: Lorain, OH

Despite the importance of the goods and services inland and coastal wetlands provide, decades of mismanagement have severely degraded these habitats nationwide (Dahl, 1990; Stedman and Dahl, 2008). Extensive habitat restoration projects may be necessary to ensure these ecosystems continue to provide valuable services to people and wildlife.

Located along Lake Erie in Northeastern Ohio, The City of Lorain was developed in the 1800's as a port for shipping and industry. Even today, over 80 percent of the land along the waterfront in Lorain remains industrial. As a result of point and non-point pollution from this development, the Black River watershed was designated as a Great Lakes Area of Concern (AOC), as defined by the U.S. – Canada Great Lakes Water Quality Agreement and Annex 2 of the 1987 Protocol Amendments.

Through the Climate-Smart Restoration Partnership Project for the Great Lakes and Chesapeake Bay (a partnership of NWF, NOAA, and the Kresge Foundation), Lorain and its partners have worked to restore the Black River watershed with future climate in mind. Climate change is expected to cause water levels to fluctuate thanks to heavier rainfall and more severe drought, while increasing overall average temperatures. To facilitate migratory pathways for local fish, shelves were constructed at various depths to provide deeper, cooler water and shelter regardless of water levels. NWF and its partners also developed a native, climate-smart tree species list for replanting along the river banks. These species were chosen to provide cooling shade and combat erosion, and are expected to survive and thrive under future climatic conditions.

Although much work remains to be done, these efforts will help ensure wildlife habitat, and the services they provide, are maintained even as human development and climate impacts continue. For more information, see NWF's Climate-Smart Communities Program: *http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Climate-Smart-Communities/NWF-Programs.aspx*

Landscape and Habitat Change

Nearly every climate impact, from flooding to increased temperatures to sea-level rise, will result in the loss or damage to valuable wildlife, habitat, and ecosystems. Wildlife species in urban areas already face a number of threats; development has fragmented their habitats and destroyed food and water sources, the urban heat island effect causes heat stress, and they can be killed by cars and outdoor cats. Climate change is compounding these problems, increasing the vulnerability of wildlife and their habitats.

Nature-based approaches to climate adaptation, however, can guard human interests and property while also helping plant and wildlife species adapt.

Landscape Connectivity and Habitat Restoration

As regional climates change, plant and animal ranges are expected to shift or expand, often to higher altitudes and latitudes (Kelly and Goulden, 2008). Habitat connectivity is thus necessary to allow wildlife to move in response to changes in climate. Connecting and restoring habitats around and within urban areas can facilitate animal movement and provide valuable habitat while providing services to people, such as stormwater management and recreation.

- Cities like Keene, NH, are managing their lands to ensure that large, suitable areas of habitat remain closely connected to facilitate the migration of species across the landscape.
- The Field Museum in Chicago developed a number of strategies communities can follow to protect and restore wildlife habitat in backyards, namely by planting native, "climate-friendly" plants.
- Coastal and inland wetland restoration and protection policies, in communities ranging from Chula Vista, CA to Boston, MA, provide protection against flooding and sea level rise, while providing a healthy habitat for fish and wildlife.
- *Green Seattle* is a partnership between the City of Seattle and Forterra, the state of Washington's largest land conservation, stewardship and community building organization, formed in 2004 with the goal of restoring and protecting healthy forested parklands throughout Seattle. This group and its volunteers recognize that over 150 years of logging and mismanagement have severely degraded the region's forests, allowing invasive species to take over. These forests, however, can be restored to save the city over $1.5 million in stormwater management benefits and clean air (Green Seattle).
  - The Partnership coordinates weekly volunteer events to remove invasive plants, plant new native species, and perform long-term maintenance with the goal of restoring 2,500 acres of forested parkland by 2025.

Pests and Invasive Species Management

Pests and invasive species threaten a variety of ecosystem types across the country, and as the climate changes these impacts are expected to worsen. Even native species, such as the Mountain Pine Beetle (MPB) in the Rocky Mountains, can become a menace under future climate scenarios. Outbreaks of MPB have become more common and widespread as milder winters fail to kill larvae. Large stands of infected trees become more vulnerable to forest fire, threatening surrounding communities. Invasive plants, such as *Phragmites*, also threaten ecosystem services that wetlands provide. By outcompeting native species, wildlife habitat is lost and the health of the ecosystem suffers. Different regions must

Key For Chart 6: **Open Space and Habitat Management**

- Coastal Impacts: Includes marine coastal impacts: sea-level rise (SLR), coastal flooding, and erosion
- Drought/ Aridity: Includes drought and increasing aridity
- Extreme heat/ UHIE: Includes extreme heat and the Urban Heat Island Effect
- Inland flooding/SW: Includes floodplain and stormwater flooding and associated waterway pollution
- Landscape/ Habitat Change: Includes changes to the landscape or habitats due to climate change

Chart 6: Open Space and Habitat Management Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitigation
Strategies							
Expand green space	✓	✓	✓	✓+	✓+	✓	✓
Community gardens			✓	✓	✓	✓	✓
Corridors		✓	✓	✓	✓+	✓	✓
Manage land to reduce fire risk		✓+			✓	✓	✓
Forest parkland restoration			✓	✓	✓+	✓	✓
Convert conventional lawns to wildlife habitat		✓		✓+	✓+	✓	✓
Manage invasive species					✓+		
Vulnerability assessments	✓	✓	✓	✓	✓+		

Details	Example	More info
Expanding and maintaining parks, community gardens, and other green spaces provides many benefits, from absorbing stormwater to providing wildlife habitat to reducing providing shade and reducing temperatures.	Providence, RI	*Greenprint Providence*
Community gardens expand green space and give residents a greater stake in their community. NYC's sustainability plan outlines several methods to facilitate urban agriculture and community gardening, including working with GrowNYC, a non-profit organization that supports local school gardens.	New York City, NY	*PlaNYC*
Keene, NH has established city regulations to promote connected stretches of natural wildlife habitat. These corridors often link multiple, larger areas of intact habitat and help facilitate the migration of species across the landscape as climate change alters the underlying conditions of an area.	Keene, NH	*Keene, NH - Planning a Climate Resilient Community*
Wildfires are expected to increase in frequency and intensity as summers become drier and hotter for longer periods of time. Extreme wildfires can devastate natural habitats and endanger human lives and property if forests are not managed properly. "Fire Adapted Communities" such as Leavenworth, WA are taking a number of steps to reduce the risk of wildfire	Leavenworth, WA; various	*Fire Adapted Communities*
Forested parks can bolster a community's urban forest, providing benefits in stormwater management and clean air. The Green Seattle Partnership was created in 2004 in response to the degradation of the city's forests. The Partnership now hosts regular restoration projects to remove invasive species and plant natives, with the goal of restoring 2,500 acres by 2025.	Seattle, WA	*Green Seattle*
In VA, the Rappahannock River Basin Commission (RRBC) developed a program to link NWF's Certified Wildlife Habitat ® Program to the Chesapeake Bay TMDL (total maximum daily load) and RRBC's economic development-based conservation programs. The resulting outcome, called "River Friendly Yards (RFY)," is a multi-phase program to convert conventional lawns in the Chesapeake Bay bioregion to River Friendly Yards that have enhanced wildlife and nutrient reduction capacities	Virginia	*Rappahannock River Friendly Yard*
Chula Vista is focusing much of its open space management on removal of invasive species to restore ecosystems to their natural state. These improvements will allow local systems to function at their most robust levels and be better prepared to cope with the new conditions brought on by climate change.	Chula Vista, CA	*Chula Vista Climate Action Plan*
Vulnerability assessments are necessary to understand the ways in which climate change will impact the natural and built environments. While some federal agencies, states, and local governments have completed such assessments, it is advantageous for communities to conduct their own assessments in order to have access to the most accurate and relevant information.	Atlanta, GA	*A Climate Change Vulnerability and Risk Assessment for the City of Atlanta, Georgia*

Chart 6: Open Space and Habitat Management Strategies	Climate impact addressed					Additional benefits	
	Coastal	Drought/ aridity	Extreme heat/ UHIE	Inland/ SW flooding	Landscape & Habitat change	Air quality	Carbon mitigation
Implementation Methods							
Expand waterfront parks and public access	✓+		✓	✓+	✓+		
Water-smart backyard habitats	✓+		✓	✓+	✓+		
Backyard habitats				✓	✓+	✓	
Develop policies to encourage cluster/ high density housing				✓	✓+	✓	
Purchase land for multiple uses	✓	✓	✓	✓	✓	✓	✓
Work with partner organizations to conserve land	✓	✓	✓	✓	✓+	✓	✓
Invasive species control ordinace		✓			✓+		✓

Details	Example	More info
Since 2002, NYC has acquired more than 373 acres of waterfront land for parks. Released in 2011, the Comprehensive Waterfront Plan offers direction for acquiring and restoring shoreline areas for parks, housing, recreation, and natural habitats. Shoreline parks limit development in flood-prone areas, while creating parks and habitat for people and wildlife to utilize.	New York City, NY	*Vision 2020: NYC Comprehensive Waterfront Plan*
In Baltimore, MD, NWF is working with the city to link Certified Wildlife Habitats with water management as part of the B'More Wild program. Baltimore's stormwater and sewage infrastructure often cannot meet the demand placed on it, resulting in flooding and pollution of the Bay. The B'More Wild program encourages "backyard" practices, such as removal of impermeable surfaces and installation of vegetative buffer zones, to engage citizens, in addressing these water issues.	Baltimore, MD	*Baltimore: A City for the Birds*
The Field Museum in Chicago is encouraging the public to plant native, wildlife-friendly species in their backyards to provide habitat and minimize stormwater runoff.	Chicago, IL	*Chicago Wilderness - Climate Action Plan for Nature*
Policies can be enacted and zoning updated to encourage higher density housing, decreasing urban sprawl and encouraging the creation and protection of green space. The City of Homer, AK, adopted a policy of high-density development to avoid sprawl and ensure large tracts of surrounding land remain unfragmented.	Homer, AK	*City of Homer Comprehensive Plan*
Purchasing land for conservation can also provide recreational opportunities and manage stormwater in a more natural way. The Milwaukee Metropolitan Sewage District began the Greenseams program to partner with The Conservation Fund to conserve land that can effectively absorb stormwater.	Milwaukee, WI	*Milwaukee Metropolitan Sewage District: Greenseams*
Cities and towns can identify priority areas through their own open space plans and work with partners to ensure those areas are protected. In southern Maine, numerous local and state-wide land trusts work with communities to acquire and conserve land. Partnerships with national wildlife refuges and state parks provide additional resources to acquire and protect land.	Biddeford, ME; southern Maine; various	*Biddeford 2012 Open Space Plan*
Invasive species, including plants, animals, and fish, are often first established in a community when they are released into the wild by their owners. These species can then throw off the balance of the surrounding ecosystem. Chicago's invasive species ordinance prohibits the importation, sale, transportation, and ownership of invasive plants and animals within the city. The city commissioner is responsible for keeping a list of regulated species.	Chicago, IL	*City of Chicago Invasive Species Control Ordinance*

Credit: Michael McCullough (flickr.com)

cope with different invasive species, but many management options are relevant regardless of the species. The *National Invasive Species Council* provides resources and guidance that all communities may find useful.

- The open space management component of Chula Vista's Climate Action Plan acknowledges that invasive species must be managed and controlled to allow native species to thrive and adapt to climate change.
- In the Great Lakes region, removal of invasive Phragmites has been a restoration priority. For challenging pests, the Climate-Smart Habitat Restoration of the Clinton River Spillway, Michigan guide recommends an integrated pest management approach which includes initial herbicide treatment followed by mechanical removal and annual maintenance.
- The *Pennsylvania Sea Grant* is examining the vulnerability of Pennsylvania's aquatic ecosystems to the threat of invasive species by exploring 3 emissions scenarios and their impact on potential movement of species. This project helps identify the species that have the greatest potential to expand their ranges into Pennsylvania and will assist proactive adaptation efforts.

Implementation of Adaptation Actions

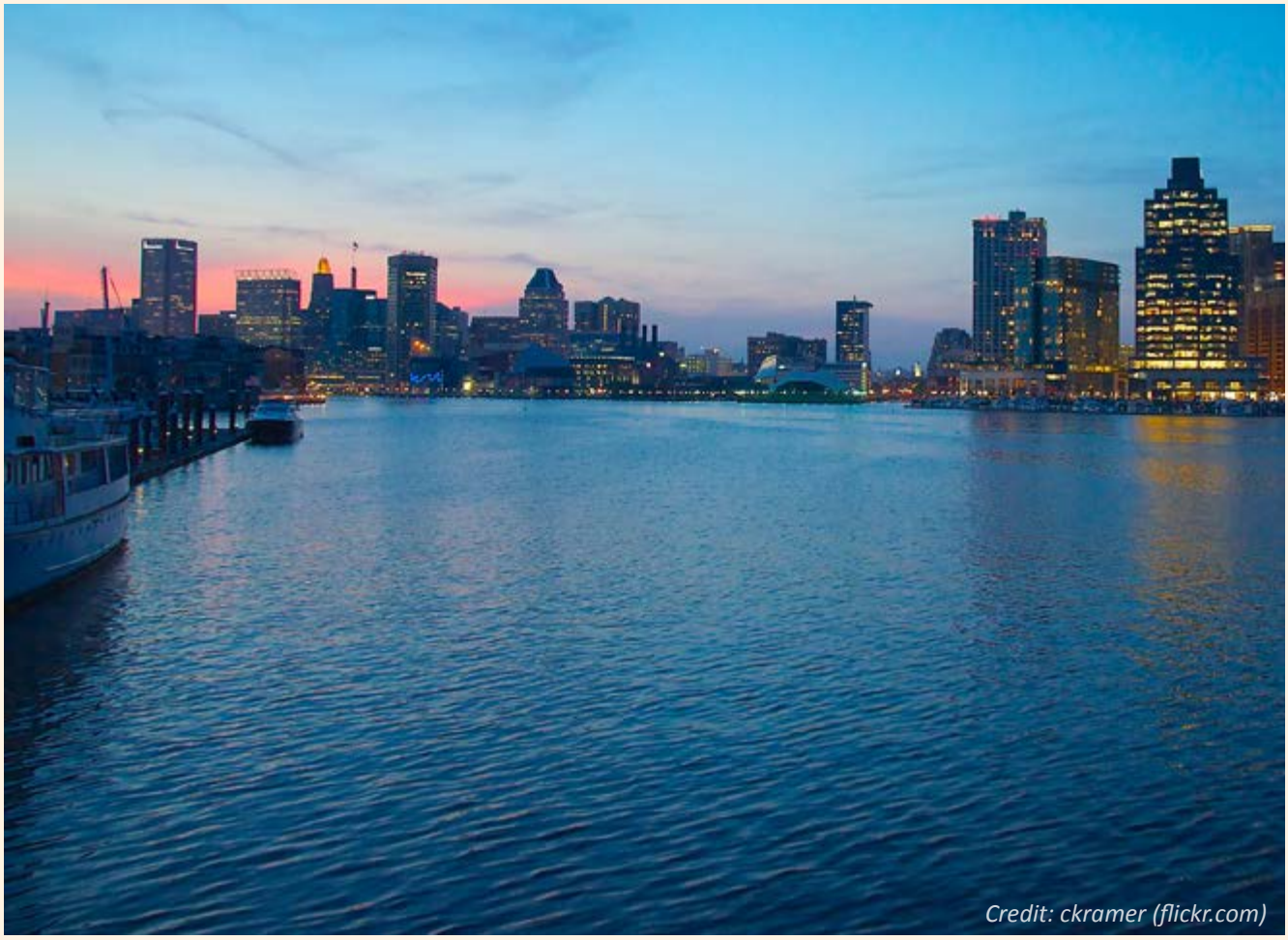
Communities are encouraged to identify and prioritize adaptation options with an eye towards implementation. Cities and towns can implement adaptation actions by creating or updating multi-sector adaptation plans, updating existing programs, changing zoning ordinances, creating new programs and policies, and developing public-private partnerships to advance adaptation activities. Different adaptation strategies may merit the use of one or all of the implementation methods described below.

Multi-sector adaptation planning

Many of the communities referenced throughout this document initiated adaptation planning through the creation of city-wide climate action or adaptation plans. Throughout the planning process, communities should consider the advantages of nature-based approaches over traditional "grey infrastructure," and be specific in their goals. PlaNYC, for example, outlines how New York City can reduce carbon emissions (climate mitigation) and prepare for projected climate impacts (climate adaptation). An executive order or legislation can direct the creation of such an adaptation plan and offer guidance on the process. New York City's adaptation plan began when local law created the Office of Long-Term Planning and Sustainability as part of the Mayor's Office. The Office brought together over 25 City agencies to create a plan that addressed everything from transportation and public health to open space and coastal management. Additional reports have been released regularly as amendments to address specific

Chart 7: Examples for Implementing Nature-Based Approaches

Strategy	Details	Example	More info
Integrate climate change impacts into existing plans	Many existing plans, such as Hazard Mitigation Plans and Emergency Operations Plans, already outline how a city can prepare for and respond to natural disasters. Cleveland, OH's Climate Action Plan recommends conducting a climate change vulnerability assessment and integrating these impacts into existing plans to better respond to heat days, power outages, flooding, and disease outbreaks.	Cleaveland, OH	*Cleveland Climate Action Plan*
Update FEMA All Hazards Mitigation Plan to include climate adaptation	Every local jurisdiction in the US is required to develop a hazard mitigation plan to be eligible for disaster-related assistance from FEMA. In updating its hazards plan, Baltimore included potential impacts from climate change and highlighted adaptation options, including improving urban forestry, using low impact development methods, and utilizing green infrastructure.	Baltimore, MD	*Baltimore Disaster Preparedness and Planning Project*
Construction Code Updates	Construction codes can be updated to require green or reflective roofs, as done in NYC. Codes can also be updated to allow the construction of denser housing or taller buildings, reducing urban sprawl and habitat loss. Areas could also be zoned to encourage the installation of rooftop solar panels.	New York City, NY	*PlaNYC*
Green building legislation	Legislation can be passed to update existing building codes, create incentive programs, and overall promote the construction of green buildings. Washington, DC's Green Building Act of 2006 established a council that amended several existing codes and laws, and created incentives for green buildings.	Washington, DC	*Washington DC Green Building Act of 2006*
Public space design guidelines	Green Area Ratio (GAR) is an environmental sustainability zoning measure that has been proposed for development sites in Washington DC. It is intended to set standards for landscape and site design that contribute to the reduction of stormwater runoff, improve air quality, and reduce the urban heat island effect. The Green Area Ratio model allows a user to choose from a number of optional environmental elements (from landscaping to solar panel installation) in order to achieve an overall GAR score for the site.	Washington, DC	*DC Green Area Ratio Factsheet*
City Ordinance's for LEED Design	Leadership in Energy and Environmental Design (LEED) Certification for buildings increases energy efficiency, encourages low-impact design to benefit green spaces, and improve water efficiency. The City of Annapolis passed an ordinance in 2007 requiring new construction to meet LEED Certification standards.	Annapolis, MD	*City of Annapolis*



Credit: ckramer (flickr.com)

Preparing for Climate Change in Hazard Mitigation Planning: Baltimore, MD

In order for communities to qualify for non-emergency disaster assistance from the Federal Emergency Management Agency (FEMA), state, tribal, and local governments are required to develop *Multi-Hazard Mitigation Plans*. These plans are meant to identify vulnerabilities and reduce disaster losses. Baltimore's 2013 Disaster Preparedness and Planning Project (DP3) takes this planning process a step further by including future climate impacts in its planning process. In this way, the plan is both a Hazard Mitigation and Climate Adaptation plan. Among the recommendations of DP3, Baltimore emphasizes a number of nature-based approaches to adaptation. The city intends to update flood maps to reflect expected changes in hydrology and storm surge, discouraging development in vulnerable areas. Similarly, the plan highlights the need to protect and restore riparian areas and shorelines for the sake of wildlife and the services these habitats provide to protect human health. The plan also recommends continuing to integrate climate change data into existing programs, such as urban forestry management. Their adaptation plan states that high priority should be placed on native trees with high adaptive capacity, meaning they are likely to survive future climatic conditions. By promoting a variety of nature-based approaches such as these, the city will address stormwater flooding, the urban heat island effect, and coastal flooding, while also providing habitat for wildlife.

For more information, see Baltimore's Office of Sustainability: *http://www.baltimoresustainability.org/disaster-preparedness-and-planning-project*

sectors, such as "A Stronger, More Resilient New York" to further guide coastal planning.

Rather than create a new climate action or adaptation plan, communities may update existing comprehensive plans. Comprehensive plans already offer guidance on development and land use, and can be updated to encourage low-impact development, coastal wetland protection, and urban forestry, just to name a few. Washington, DC's comprehensive plan, for example, was updated in 2011 to include goals related to mitigating climate change. The city's 2006 plan already outlines policies to foster the growth of the urban forest, protecting rivers and wetlands, promoting low-impact development, and conserving natural resources.

Baltimore, MD, addressed the need for multi-sector planning by updating its federally mandated Hazards Mitigation Plan (required to qualify for FEMA assistance) to include climate adaptation actions. These plans already assess how natural disasters may impact multiple sectors of a community. By acknowledging future climate impacts throughout the plan, the city can begin to prioritize actions that will remain effective under future climate scenarios.

City-wide adaptation plans, comprehensive plans, sustainability plans, and hazard mitigation plans can all assess climate risks on multiple sectors, identify and prioritize adaptation options, and describe how the plan will be implemented, such as by directing specific agencies to carry out actions to address specific needs. The Chicago Climate Action Plan, for example, directs the Department of Forestry to focus on plantings along the public right-of-way throughout the city while Philadelphia's plan sets a goal of 30% canopy coverage in every neighborhood in the city.

Updating existing programs and policies

Depending on the adaptation action, a program, policy, or plan may already exist that addresses the same threat. Integrating adaptation planning into ongoing efforts, or "mainstreaming" adaptation, takes advantage of these existing mechanisms without the need for new planning efforts or funding streams. By considering climate change throughout the existing decision-making process, or developing adaptation strategies separately and inserting them into ongoing plans, nature-based approaches to adaptation can be integrated and prioritized (Stein et al., 2014). For example, Cleveland's Climate Action Plan includes various actions for the city to adapt to climate impacts while mitigating carbon emissions. One of the plan's recommended actions includes completing a climate change vulnerability assessment for the city, and then integrating strategies to reduce vulnerability into existing plans. For Cleveland, this means not only improving the urban forest to combat the urban heat island effect, but also updating the City's Emergency Operations Plan to better respond to heat days, power outages, flooding, and disease outbreaks that will become more frequent or compounded by climate change.

While states may set minimum requirements for building codes, local governments can amend existing codes to ensure low-impact development methods are used. Cities, such as New York City and Annapolis, MD, have passed legislation requiring or incentivizing the use of green infrastructure and low-impact development techniques to manage stormwater. Similarly, building codes can be altered to require water mitigation measures during times of drought. Kirby, TX, passed an ordinance in 2009 outlining how periods of drought will be monitored and what measures should be taken to mitigate water use, depending on the length and severity

of the drought. Installing new landscapes is also regulated, and the ordinance also requires water mitigation measures to be included in the installation and management plans.

Many communities have already developed extensive open space plans that direct how land is acquired, managed, and used. These plans can be updated to prioritize efforts that also address climate impacts. Coastal lands and low-lying areas can be prioritized for acquisition, for example, to prevent construction in at-risk areas. These plans can also direct a Parks department to plant species that can survive in future climatic conditions, preparing the space for hotter temperatures and changes in precipitation. In the case of Chula Vista, CA, open space management plans also include active monitoring and removal of invasive species to ensure ecosystem functions can be maintained. Similarly, communities can update existing ordinances that direct tree plantings on public right-of-ways. Chicago, IL, and Austin, TX, have both produced lists of trees that should be planted along streets that can both combat the urban heat island effect and can cope with future climatic conditions.

Changes to zoning and land use regulations

Changes to zoning policies can have far-reaching benefits, such as increased green space, protection of inland and coastal wetlands, prevention of construction in areas at risk of flooding, and mitigation of wildfire risk. Communities in the Boston, MA, metropolitan area and Miami-Dade County, Fl, have updated their zoning laws to limit development around inland and coastal wetlands. While States have the authority to regulate wetland protection, these communities recognized the importance of these ecosystems in providing habitat to endangered species and offering additional benefits, such as stormwater management, and have thus passed stricter regulations. In several Boston communities, this meant redefining "significant" wetlands to include a broader range of wetland types, and expanding buffer zones around vernal pools and similar habitat types. Alternatively, communities can redefine floodplains to limit development near waterways, as was done in Keene, NH. The *Georgetown Climate Center Adaptation Toolkit for Sea-Level Rise* offers an array of planning, regulatory, spending, and tax and market-based tools to implement policies that protect coastal areas. Adjusting zoning laws for accommodation or retreat, for example, can be done through updating floodplain regulations, as was done in Seabrook, NH, or requiring setbacks and buffers from specific shoreline features (ie., a high tide mark or projected average sea-levels in future years).

Altering ordinances that guide zoning can protect and expand green space, namely by requiring clustered development. Requiring high-density housing can leave space open for wildlife and recreation, while also providing services such as clean air, cooling shade, and carbon sequestration. Care should be taken in fire-prone areas, however. Communities may opt to adjust zoning to reduce fire risk, namely by preventing development on ridges where fires may easily reach and/or where water is difficult to transport.

Creating new programs and policies

Depending on the adaptation goal, it may be necessary to create new programs, policies, or pass new ordinances. A new ordinance may be as simple as a law passed in New York City requiring a tree to be planted every 25 feet along public right-of-ways, or as complex as a tax-based incentive program to encourage

Credit: Todd Petit (flickr.com)

natural infrastructure to manage stormwater on private land. Aurora, CO, and Peoria, AZ, both incentivize water mitigation measures, such as drought-resistant xeriscapes, by offering rebates to homeowners that take these steps. Aside from updating zoning codes, Annapolis, MD, further incentivizes the use of natural infrastructure by charging a stormwater utility fee on every property. Property owners can reduce this fee by holding water on site through LID, such as green roofs and raingardens. Ordinances such as these require a degree of public education and cooperation from multiple sectors to be successful, as the example from Milwaukee exemplifies (see page 44).

LID can be encouraged through changes to zoning laws, as previously described, but new laws can be passed to achieve similar goals. Washington, DC's Green Building Act of 2006, for example, established new high-performance building standards and established a green building incentive program. This legislation aligns with the city's comprehensive plan and sustainability goals, complementing and improving existing policies.

Improving urban forestry can be done through changes in zoning and updating existing programs, but new programs can further the cause. Many cities across the country have created "Million Trees" programs to promote tree plantings on both private and public lands. These programs often involve tree-giveaways and offering educational materials to the public to incentivize participation. In Denver, Philadelphia, and Los Angeles, just to name a few, these programs have been largely led by the city's parks and recreation department with assistance from volunteers and nonprofit partnerships.

"Creating" new policies or programs may simply mean adopting existing tools for new purposes. The Georgetown Climate Center Adaptation Toolkit for Sea-Level Rise lists a number of spending tools, including acquiring land or granting landowners conservation easements,

that can also be used to promote retreat from at-risk coastal zones. Efforts to streamline the permitting process for the construction of soft armoring (while preventing harmful hard armoring) can promote protection rather than retreat. Such permits allow private developers, rather than government, to implement strategies that protect otherwise vulnerable areas. For coastal adaptation to be successful, a combination of these approaches is likely needed.

Developing Public-Private Partnerships

Adaptation initiatives may not be feasible for some communities to implement due to a lack of resources. Creating an urban forestry program from scratch can be costly, drafting a fire hazard mitigation plan may require technical resources a town lacks, and scientific data on sea-level rise projections may not be readily available for a region. Public-private partnerships are thus necessary to fill in these gaps and ensure successful implementation of adaptation actions.

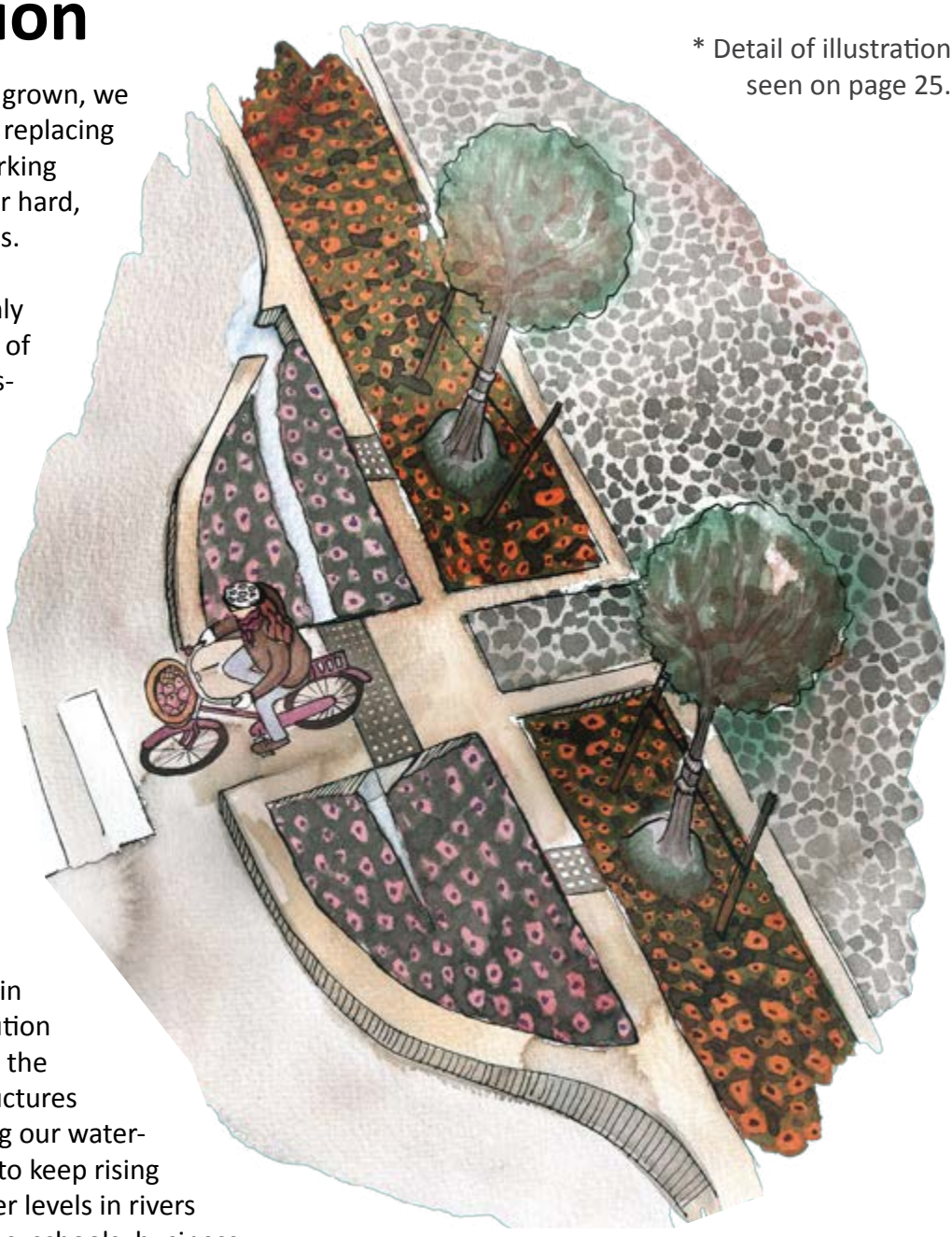
Local nonprofits, businesses, and nongovernmental organizations with parallel goals to a city program can be willing partners that mean the difference between success and failure. Philadelphia's Parks and Recreation Department's Million Trees program, TreePhilly, has been largely successful thanks to partnerships with Fairmount Park Conservancy, Wells Fargo, the Mayor's Office of Sustainability, and numerous local groups, such as Philly Tree People and Northeast Tree Tenders. By offering funding, volunteers, and educational materials, these partners bolstered the city's capacity to implement the urban forestry program.

For communities at risk of fire, partnerships with nearby land trusts and nation-wide fire management organizations are necessary to properly monitor and manage land where fires may originate. Leavenworth, WA, is one of eight pilot Fire Adapted Communities in the nation. Located just south of the 50,000 acre Chumstick Watershed, this community founded the Chumstick Wildfire Stewardship Coalition to reduce fire fuel, carry out restoration projects, monitor fire-prone areas, and educate the surrounding communities on how to prevent and prepare for wildfires. This program was largely successful thanks to National Fire Plan funds and support from the Fire Adapted Communities program.

Similarly, open space plans can be informed by conservation partners as well as state and federal efforts. State Wildlife Action Plans, for example, can identify at-risk species that a city should work to protect. By working with partners, a city can ensure land is conserved without having to acquire the land on its own. Located in southern Maine, the city of Biddeford released its most recent open space plan in November 2012. The plan describes how a number of partner organizations at the private, local, state, and even federal level have worked to acquire land in the region to protect valuable wildlife habitat that the public can enjoy. The city itself has also acquired park land using its own funds in addition to grants from The Nature Conservancy and the Maine Coast Heritage Trust.

State and federal legislation can heavily influence community policies, especially in coastal areas. The Coastal Zone Management Act of 1972 gave authority to states to create and implement their own coastal management programs in order to qualify for federal funding grants. State legislation can then mandate local planning and provide guidance and resources to coastal communities. These mandates can provide structure and facilitation of local plans, offer goals that are clear, specific, and prioritized, and include regulatory tools to ensure local plans are complying with state standards. Coastal communities benefit from the grants and tools these mandates provide in both the planning and implementation of coastal hazard mitigation.

Conclusion



* Detail of illustration seen on page 25.

As urban areas have grown, we have altered nature, replacing it with sidewalks, parking lots, roads, and other hard, man-made structures. Our development patterns have not only led to harmful levels of greenhouse gas emissions in the atmosphere, causing the climate to change, but they have also made our neighborhoods more vulnerable to the impacts of climate change. We've designed our cities to transport storm-water as swiftly as possible away from buildings over hard, impervious surfaces, resulting in flooding in our streets and pollution in our waterways. At the same time, hard structures have been built along our waterways and coastlines to keep rising seas and higher water levels in rivers away from our homes, schools, business, and other built infrastructure. But there are better ways for us to protect our cities as they grow; for example, in some cases an approach that integrates both grey and green infrastructure can actually provide more protection for communities, while also offering us co-benefits like greenhouse gas emissions reductions, fish and wildlife habitat, and recreation opportunities for residents and visitors alike.

Many communities are now working with nature to reduce risk from and build resilience to climate change, often using technology and human engineering to mimic the natural processes that were disrupted with development. To implement these nature-based approaches, communities are using a variety of astrategies, including developing comprehensive

On November 1st, 2013, President Obama signed Executive Order (EO) 13653 on Preparing the United States for the Impacts of Climate Change. The EO calls for better cooperation between federal, state, local, and tribal governments and information-sharing to ensure the built and natural environment can prepare for future climate impacts. The EO also established the *State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience*, which will recommend actions the Federal Government can take to improve resilience of communities. The establishment of this Task Force reinforces the important of identifying, preparing for, and responding to the impacts of climate change and the critical role that local governments have in this process.

multi-sector plans, updating or creating new policies and programs, changing zoning and land-use regulations, and using innovative and cost-saving public-private partnerships.

For example, New York City and Chicago have developed comprehensive, multi-sector adaptation plans that address a variety of climate change impacts. Baltimore, has developed a hazards mitigation plan to qualify for disaster-related assistance from the Federal Emergency Management Agency (FEMA) that includes a plan to adapt to climate-related hazards. Miami-Dade County is updating its zoning policies to include buffers around development areas to allow for wetland migration resulting from sea level rise. Others are taking a hazard mitigation approach. At the grassroots level, Detroiters Working for Environmental Justice formed the Detroit Climate Action Collaborative,[3] which includes diverse stakeholders from many sectors, including environmental NGOs, government agencies, scientists, academic institutions, health practitioners, businesses, and others, all working collectively to develop a plan to reduce greenhouse gas emissions and prepare for the impacts of climate change.

A resilient city is one that is able to respond to, withstand, and recover from the impacts of climate change in ways that enhance economic, social and environmental well-being. As shown throughout this report, using nature-based adaptation approaches can build sustainable and affordable climate change resiliency for people and wildlife by protecting and enhancing natural systems, thereby helping communities thrive in the face of climate change now and into the future.

3 *http://www.dwej.org/do/dcac*

Resources for Adaptation Planning

A number of existing resources are also available to inform adaptation decisions at the local level, which we have compiled and broken down by category.

Climate Adaptation Plans

- State climate action and adaptation plans: *http://www.c2es.org/node/9337*
- Georgetown Climate Adaptation Clearinghouse: *http://www.georgetownclimate.org/adaptation/clearinghouse*
- Communities using nature-based approaches: *http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Climate-Smart-Communities/What-Cities-Are-Doing.aspx*
- CakeX: Climate Adaptation Knowledge Exchange: *http://www.cakex.org/*

Drought Mitigation and Fire Adaptation

- Fire adapted communities: *http://www.fireadapted.org/*
- Cal Fire: *http://www.fire.ca.gov/*
- U.S. Drought Monitor: *http://droughtmonitor.unl.edu/*

General Climate Change and Adaptation Information and Tools

- Climate Change Response Framework: *http://www.climateframework.org/*
- Draft National Climate Assessment: *http://ncadac.globalchange.gov/*
- Intergovernmental Panel on Climate Change: *http://www.ipcc.ch/*
- Tools for Coastal Climate Adaptation Planning: A Guide for Selecting Tools to Assist with Ecosystem-Based Climate Planning: *http://www.natureserve.org/biodiversity-science/publications/tools-coastal-climate-adaptation-planning-guide-selecting-tools*
- The Value of Green Infrastructure for Urban Climate Adaptation: *http://ccap.org/assets/THE-VALUE-OF-GREEN-INFRASTRUCTURE-FOR-URBAN-CLIMATE-ADAPTATION_CCAP-February-2011.pdf*
- ICLE adaptation tool: *http://www.icleiusa.org/tools/adapt*

Great Lakes Coastal Resources

- Chicago Climate Action Plan: *http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINALv2.pdf*
- Great Lakes Coastal Community Climate Adaptation Checklist: *http://map.co.door.wi.us/planning/Mun-Ed/Coastal%20Community%20Adaptation%20Checklist%202012.pdf*
- Great Lakes Restoration Initiative Action Plan: *http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf*

- NOAA Climate Ready Great Lakes: http://www.regions.noaa.gov/great-lakes/index.php/resources/climate-ready-great-lakes/
- NOAA Great lakes Water Level Dashboard: http://www.glerl.noaa.gov/data/now/wlevels/dbd/
- University of Michigan Great Lakes Adaptation Assessment for Cities (GLAA-C): http://graham.umich.edu/glaac
- Technical Guidance for the Design and Implementation of Climate-Smart Restoration Projects in the Great Lakes (with Seven Case Studies): http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Adaptation-Reports.aspx
- Water implications for Michigan communities, landsystems, and agriculture: http://expeng.anr.msu.edu/uploads/files/20/Climate%20Change%20Implications%20for%20MI%20by%20Dr.%20David%20Lusch.pdf
- Wisconsin Initiative on Climate Change Impacts: http://www.wicci.wisc.edu/resources/Climate%20Adaptation%20Memo%20to%20Working%20Groups.pdf

Open Space and Wildlife Management

- State Wildlife Action Plans: http://teaming.com/state-wildlife-action-plans-swaps
- NOAA Habitat Restoration Techniques: http://www.habitat.noaa.gov/restoration/techniques/index.html
- The National Invasive Species Council: http://www.invasivespecies.gov/
- Pennsylvania Sea Grant Climate Change and Aquatic Invasive Species Study: http://www.paseagrant.org/studies/study-2/

Sea Level Rise/Marine Coastal Management

- Achieving Hazard-Resilient Coastal & Waterfront Smart Growth: http://coastalsmartgrowth.noaa.gov/resilience.html
- Analysis of the Costs and Benefits of using Tidal Marsh Restoration as a Sea Level Rise Adaptation Strategy in San Francisco Bay: http://bay.org/assets/FINAL%20D211228_00%20Cost%20and%20Benefits%20of%20Marshes%20022213.pdf
- Georgetown Climate Center Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use: http://www.georgetownclimate.org/sites/default/files/Adaptation_Tool_Kit_SLR.pdf
- NOAA Coastal Services Center: http://www.csc.noaa.gov/digitalcoast/
- Global Change Coastal Resilience Resources: http://www.globalchange.gov/what-we-do/assessment/coastal-resilience-resources
- Guidance for Coastal Climate-Smart Conservation Projects in the Northeast- Coastal Impoundments and Living Shorelines: http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Adaptation-Reports.aspx
- Managed Coastal Retreat: A Legal Handbook on Shifting Development Away from Vulnerable Areas: https://web.law.columbia.edu/sites/default/files/microsites/climate-change/files/Publications/Fellows/ManagedCoastalRetreat_FINAL_Oct%2030.pdf

- Living Shorelines for the Chesapeake Bay Watershed: *http://www.cbf.org/Document.Doc?id=60*
- Sea Level Rise Tool for Sandy Recovery: *http://www.globalchange.gov/what-we-do/assessment/coastal-resilience-resources*
- Tools for Coastal Climate Adaptation Planning: A guide for Selecting Tools to Assist with Ecosystem-Based Climate Planning: *http://www.natureserve.org/biodiversity-science/publications/tools-coastal-climate-adaptation-planning-guide-selecting-tools*
- Urban Waterfront Adaptive Strategies: *http://www.nyc.gov/html/dcp/html/sustainable_communities/sustain_com7.shtml*

Stormwater Management

- Design Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas: *http://www.epa.gov/brownfields/tools/swdp0408.pdf*
- Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows: *www.nrdc.org/water/pollution/rooftopsii/files/rooftopstoriversII.pdf*
- The Green Edge: How Commercial Property Investment in Green Infrastructure Creates Value: *http://www.nrdc.org/water/files/commercial-value-green-infrastructure-report.pdf*

Urban forestry

- US Forest Service Urban Field Station, NYC: *http://www.nrs.fs.fed.us/nyc/*
- Eastern US Climate Change Tree Atlas: *http://www.nrs.fs.fed.us/atlas/tree/tree_atlas.html*
- American Forests: Urban forestry and case studies: *http://www.americanforests.org/our-programs/urbanforests/*
- King County Forestry CPR tool and guidebook: *http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Climate-Smart-Communities/NWF-Programs/King-County/Forestry-CPR-Guidebook.aspx*
- Alliance for Community Trees: *http://actrees.org/*
- i-Tree: Tools for Assessing and Managing Community Forests: *http://www.itreetools.org/*
- EPA: Urban heat island information and case studies: *http://www.epa.gov/hiri/*
- Climate Change Response Framework – Urban Forestry: http://www.climateframework.org/node/352
- Climate Considerations for Management of Natural Areas and Green Spaces in the City of Chicago: *http://adapt.nd.edu/resources/1107/download/Climate_Considerations_Chicago_FINAL.pdf*

Wetlands Protection

- Wetlands-At-Risk Protection Tool: *http://www.wetlandprotection.org/*
- NOAA Habitat Conservation: *http://www.habitat.noaa.gov/protection/wetlands/*
- EPA Wetlands: Landowner Assistance and Stewardship: *http://water.epa.gov/type/wetlands/landasst.cfm*

Definitions

Accretion: Accretion is a naturally occurring process that involves the accumulation of sand, sediment, or other organic matter in coastal due to due to the natural action of waves, currents and wind.

Climate Adaptation: The process of embracing forward-looking goals and implementing strategies specifically designed to prepare for and adjust to climate change impacts. Adaptation actions may be anticipatory (actions that prepare for known or potential future impacts) or reactive (actions that respond to impacts already realized) (Stein et al., 2014).

Climate Mitigation: Efforts that address the underlying causes of climate change, through a focus on reductions in greenhouse gas concentrations in the atmosphere.

Coastal Impoundments: Located in all states along the eastern seaboard, impoundments are areas of upland or wetland habitats where low-level dikes have been constructed to restrict, retain, or exclude water over a selected area. Many were constructed in the 1600s and 1700s for agriculture and to protect important thoroughfares. Most were constructed between 1930 and 1975 to alleviate mosquito breeding and to attract waterbirds. Today, many state fish and wildlife agencies have integrated impoundments into their wildlife management programs (Kane, 2011).

Green Infrastructure: Also called GI, green infrastructure is a phrase that is used to describe a variety of practices that rely on natural or nature-based approaches to mange water. GI includes naturally-occurring landscape features, such as trees, floodplains, and wetlands, as well more engineered practices that mimic natural processes, such as green roofs and rain gardens.

Living Shorelines: This term refers to techniques aimed at minimizing shorelines erosion while simultaneously providing wildlife habitat. Most often used in sheltered coastlines where wave energy is less than open beaches, these shorelines often employ a combination of soft structures such as vegetation and hard structures such as rocks or oyster reefs (Kane, 2011).

Low Impact Development (LID): LID is a land development approach that works with nature to manage stormwater as close to its source as possible. This development approach aims to conserve and restore natural landscape features, which reduces imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. By implementing LID principles and practices, water can be managed in a way that lessens the impact of built areas and supports the natural movement of water within an ecosystem or watershed (EPA, 2014).

Nature-Based Approaches to Adaptation: o Nature-based approaches rely on enhancing, protecting, and restoring natural infrastructure, such as coastal wetlands, parks, and tree canopies, as well as features that mimic natural processes, such as rain gardens or green roofs that are used in low-impact development (LID). Nature-based approaches often provide resilience to multiple climate impacts, typically cost less than structural measures, and provide co-benefits including clean water, fish and wildlife habitat, and economic development and recreational opportunities.

Resilience: In ecological terms, resilience refers to the ability of a system to maintain or return to a particular ecological state following a disturbance (Stein et al., 2014). At the community scale, therefore, climate resilience refers to actions taken to increase the ability of cities and towns to return to desired conditions after a disturbance, that is caused (or worsened) by climate change (eg., storm surge). A robust adaptation strategy, therefore, would include actions designed to bolster the resilience of a community.

Vulnerability Assessment: Vulnerability assessments are typically designed to identify which species, systems, or areas are more or less vulnerable to climate impacts. These assessments can contribute to setting priorities for adaptation (Stein et al., 2014).

Xeriscape: Xeriscaping is a landscape method developed for use in arid and semiarid environments that uses water-conservation techniques, namely through the planting of native, drought-resistant plants.

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