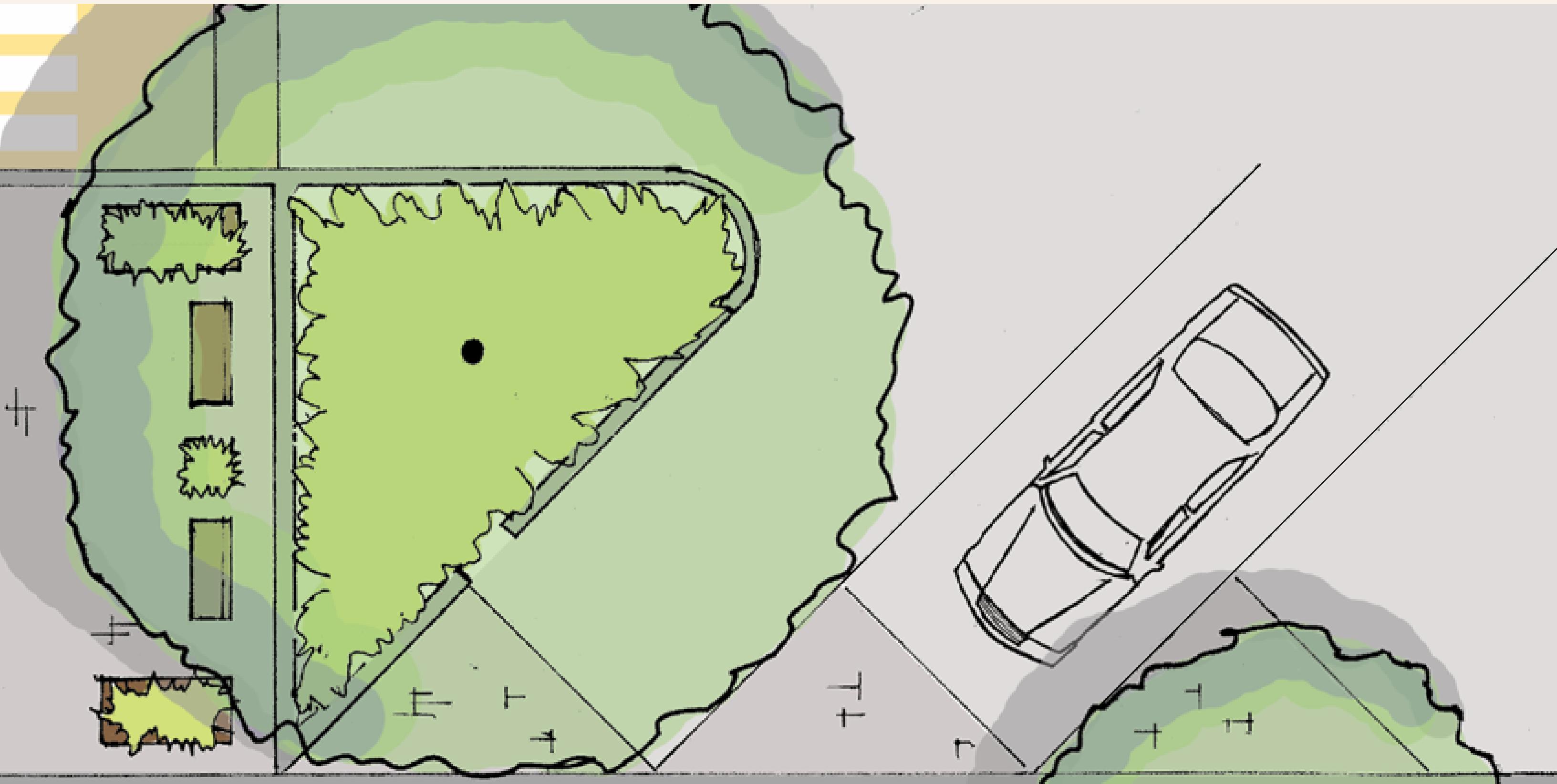
GREEN STREETS GUIDEBOOK

for the City of Holyoke, Massachusetts

The Conway School • Winter 2014



GREEN STREETS GUIDEBOOK

for the City of Holyoke, Massachusetts

The Conway School • Winter 2014
Michele Carlson, Willa Caughey, Nelle Ward

CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION....1

THE NEED FOR GREEN STREETS IN HOLYOKE....4

TOOLBOX ENCYCLOPEDIA....12

TEMPLATES....28

APPLYING GREEN STREETS TO DOWNTOWN HOLYOKE....42

RELATIVE COSTS & BENEFITS....52

NEXT STEPS....58

REFERENCES....62

EXECUTIVE SUMMARY

Once a thriving industrial center built upon the power of hand-dug canals channeling the Connecticut River, Holyoke has a historically diverse ethnic population that has struggled with a fragile economy since the early twentieth century. However, over the past decade, the industrial remains of the city, once perceived as a symbol of economic collapse, have been reconceived as fertile grounds for a thriving, historically rich arts and cultural center. Recent interest in urban revitalization has caused city officials to re-evaluate some of its out-dated infrastructure systems.

Holyoke has a combined system for collection of sewage and stormwater. In a combined sewer system, wastewater is sent to a treatment facility, but during heavy storms, the system overflows into nearby waterways, causing combined sewer overflows (CSOs) and polluted stormwater discharges. CSOs and polluted stormwater discharges are a common problem for old cities, but as environmental degradation worsens, the Environmental Protection Agency (EPA) is taking measures to reduce them and has issued Holyoke an Administrative Order to reduce its CSOs.

Holyoke's city planners are in the process of figuring out how to redevelop with both its redevelopment goals *and* the city's stormwater issues in mind. The Conservation Commission recognizes the potential for green infrastructure to support Holyoke's urban renewal process and stormwater management. Because Holyoke is already in the process of renovating commercial streetscapes and right-of-ways to separate sewersheds, Green Streets have been proposed.

Green Streets are streetscapes designed to infiltrate stormwater close to its source using green infrastructure, while also creating more vibrant, livable communities. This Guidebook is intended to introduce city planners and policy makers to Green Streets, advocate for Green Streets implementation in Holyoke, and serve as a preliminary set of design guidelines to transform Holyoke's streets into more ecologically, socially, and economically positive spaces.

The Guidebook includes a Toolbox with recommended Green Street strategies related to green infrastructure, complete streets, and placemaking; a set of nine design templates representative of a variety of street characteristics found in Holyoke that can be applied and adapted to future projects; a site-specific application of Green Street design principles in downtown Holyoke; an exploration of relative costs and benefits; and recommended next steps for the city to implement Green Streets.

As the climate changes, Holyoke's issues with stormwater and CSOs will only worsen. In order to be resilient in the face of these changes and step confidently into revitalization, Holyoke needs to reconsider its dated approach to stormwater management. Once one of the most culturally and economically vibrant cities in the region, Holyoke once again has the opportunity to establish itself on the list of New England's great cities through thoughtful revitalization efforts. Green Streets can play an important role in this process as the city seeks to redefine itself and build upon its valuable cultural and infrastructure assets.

INTRODUCTION

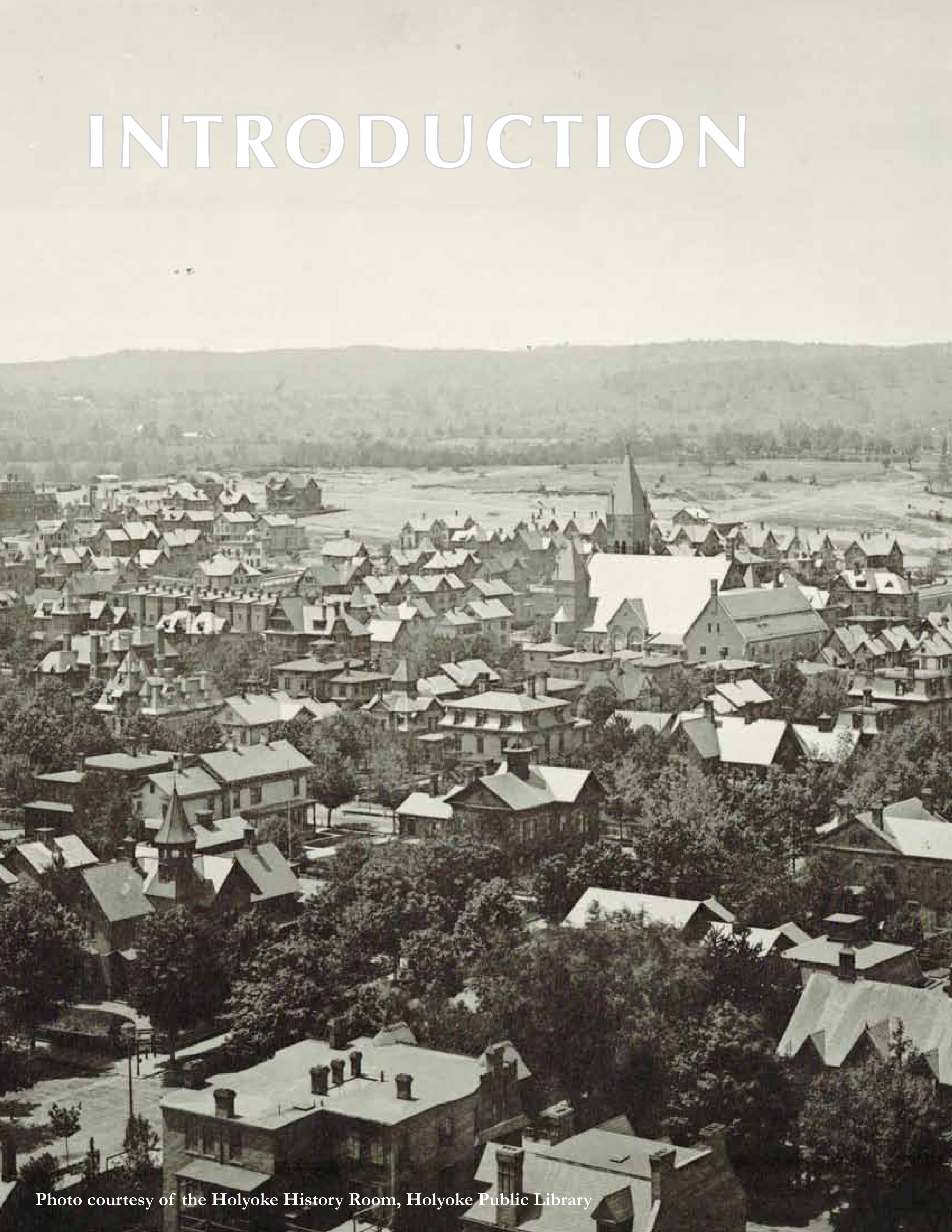


Photo courtesy of the Holyoke History Room, Holyoke Public Library

INTRODUCTION

HISTORY

Holyoke was one of the first planned industrial cities in the country. Its historic hand-dug canals and grand mills tell the story of the hard work and enterprise the city was built upon.

The Connecticut River is the longest river in New England, spanning four states from the Canadian border to the Long Island Sound. In 1847, a sixty-foot drop in the river was surveyed at present-day Holyoke and identified as the site with the greatest mill-power potential in New England. In 1849, a large dam and an elaborate four-and-a-half-mile canal system was constructed. Harnessing the power of the Connecticut River catalyzed rapid economic and population growth, precipitating the city's incorporation in 1850 (Thibodeau). By 1883, the city was known as "the Paper City of the World," producing 177 tons of paper daily, accounting for 75 percent of the world's paper (Thibodeau). By 1894, the city housed the workers and families of twenty-seven paper manufacturers, eleven textile mills, and numerous miscellaneous manufacturers. It reached its peak population of roughly 60,000 residents in 1920 (Thibodeau).

Hailing mostly from Ireland, Holyoke's first citizens also included British, German, Polish, Russian, and Italian immigrants. During the 1960s, following the economic recession in Puerto Rico, Holyoke received a large influx of Puerto Rican citizens. Fifty percent of the current population of 40,000 identify themselves as Hispanic. Holyoke's rich history as a city of immigrants is integral to its cultural identity today.

With the decline of the industrial age, mills and manufacturers closed, the population of Holyoke shrank, and the city was left with many vacant lots and buildings. Although it has an aging infrastructure, the bones of a great city remain, including beautiful old industrial buildings and a gridded street system uncharacteristic of most New England cities.

The streets were created well before the automobile, wide enough to accommodate horse and carriage and a trolley system. The Holyoke Street Railway began horse and carriage service in 1884 (Thibodeau, 136). With the arrival of electricity, the city converted to electric streetcar service in the 1890s, but this was phased out in the late 1930s with the growing popularity of the automobile ("History Walk 1924-1927: Turning Point"). Most of the original tracks were simply paved over; redevelopment projects occasionally unearth them.

Holyoke, like many cities built in the late eighteenth century, has a sewer system in which sewage and stormwater are combined. Paved streets and these combined sewer systems pose two of the most significant ecological issues in older cities: polluted stormwater runoff and combined sewer overflows into waterways during large storm events.

Holyoke is at a crossroads in its redevelopment. How can its historic infrastructure be both celebrated and retrofitted as the city moves into the twenty-first century?

PROBLEM & GOALS

Holyoke was planned in an era when it was considered sanitary to direct stormwater and sewage flows into the adjacent river, where theoretically it would flow "away" and be taken care of naturally. This belief led many cities, including Holyoke, to construct combined sewer and stormwater systems. While today these combined flows are primarily directed to wastewater treatment plants, Holyoke's system was not designed for today's higher flow volumes and heavy precipitation events, so combined sewer overflows (CSOs) into the Connecticut River are a common occurrence. This not only poses significant ecological and human health risks, but CSOs are also subject to EPA regulations.

As a city with a highly impervious downtown directly adjacent to the Connecticut River, Holyoke is especially interested in reducing its CSOs. The city anticipates significant revitalization in the near future and Green Streets may be a way to address the problem of CSOs and stormwater as well as some of the social and economic challenges facing the city. The intention of this Guidebook is to demonstrate the efficacy of Green Streets in addressing these problems and to provide recommendations for Holyoke's streets.

HOW TO USE THIS GUIDEBOOK

The goal of this Guidebook is twofold: to help city planners and policymakers advocate for Green Streets in Holyoke, and to serve as a preliminary set of design guidelines as the City seeks to transform its streets into more ecologically, socially, and economically positive spaces. The Guidebook does not necessarily need to be read sequentially; sections can be referenced as needed.

Section 2: Making the Case for Green Streets

This section demonstrates the need for Green Streets in Holyoke, providing users with vital information and background that can be used to gain support from city departments and citizens for Green Streets.

Section 3: The Toolbox Encyclopedia

This section provides an encyclopedic breakdown of the Green Streets tools, or strategies, recommended in this document, including information on the spatial and functional characteristics of each tool. Tools are referenced as they are used in each template and site-specific design. The section can also serve to guide users to substitute or add tools to templates when applying them to specific sites.

Section 4: Templates

This section includes nine different Green Street Templates based on common right-of-way (ROW) characteristics in the city. If the user has a specific street in mind, the user can find the template that most closely matches the characteristics of the street and use it as the basic redesign concept. Each template provides additional guidance for the user to adjust the design based on differing characteristics of the site, and refers the user to the Toolbox for more information on the strategies recommended in each design.

Section 5: Applying Green Streets to Downtown Holyoke

This section demonstrates how the principles, strategies, and processes from this guidebook can be applied to and transform a network of actual streets in downtown Holyoke. Based on iconic, widely recognizable streets, these designs will help readers envision the true potential of Green Streets to transform their city.

Section 6: Relative Costs & Benefits of Green Infrastructure

This section demonstrates that Green Streets can often be more cost-effective than grey infrastructure over time. Users can point to relevant case studies highlighted in this section to garner political and financial support for Green Streets.

Section 7: Next Steps

This section includes recommendations on how the city can move toward implementing Green Streets, including general recommendations for operations and maintenance, serving to encourage political and financial support for the development of and long-term investment in a comprehensive Green Streets Operations and Maintenance Plan.

BUILDING ON EXISTING PLANS

The *Green Streets Guidebook* follows and builds upon a number of related resources, including plans and studies that relate to the context and redevelopment of the city. These should serve as a reference and provide additional contextual information to users of this document. Some of the most relevant documents include:

- *Holyoke Center City Vision Plan*
- *Holyoke Urban Renewal Plan*
- *Holyoke Open Space and Recreation Plan*
- *Creating the Community Health Coalition*
- *Biking in Holyoke: Needs Assessment*
- *City of Holyoke Energy Reduction Plan*
- *Innovation-Based Economic Development Strategy for Holyoke and the Pioneer Valley*
- *Holyoke Inventory of Holyoke Street Trees*

WHAT ARE GREEN STREETS?

Green Streets are streets that are designed to infiltrate stormwater close to its source, and to create more vibrant, livable communities. For the purpose of this guidebook, three principles for designing Green Streets have been identified. The strategies and benefits associated with each principle contribute to sustainable streets and communities.

1. Green Infrastructure: *Use naturalized systems to treat stormwater close to its source*

Green infrastructure uses naturalized systems to infiltrate, evapotranspire, and/or recycle stormwater runoff close to its source. Green infrastructure often uses vegetation, engineered soils, and permeable surfaces to intercept stormwater before it reaches the wastewater system, reducing the burden on the grey infrastructure system, limiting the amount of polluted stormwater runoff entering waterways, and reducing the number and volume of combined sewer overflows. These naturalized systems seek to complement rather than replace existing grey infrastructure, often linking green infrastructure to existing sewer and stormwater systems. Benefits of green infrastructure can include:

- Reduced and filtered stormwater, minimizing total suspended solids (TSS), peak discharge volumes, and combined sewer overflows (CSOs)
- Reduced flooding
- Reduced wastewater pumping and treatment costs
- Added urban green space and wildlife habitat
- Sequestered CO_2
- Improved air quality
- Shade and reduced urban heat island effects
- Recharged groundwater

2. Complete Streets: *Create bicycle- and pedestrian-friendly streets*

Complete Streets are designed for all users, contrary to the conventional car-dominated streets most prevalent today. They create safe, convenient, and comfortable access for all users, regardless of age, ability, income, or mode of transportation, and prioritize the health, safety, and comfort of a city's residents and visitors. Through the use of designated bike lanes, safe pedestrian crossings, traffic-calming elements, and accessible transit systems, Complete Streets create healthier, more pleasant streetscapes that offer opportunities to walk and bicycle daily and to safely and comfortably navigate the street. Benefits of Complete Streets can include:

- Beautified streetscapes
- Increased bicycle, pedestrian, and vehicular safety
- Decreased car dependence
- Decreased CO_2 emissions
- Increased physical activity and improved health
- Increased social equality
- Improved traffic flow and connected forms of transit

3. Placemaking: *Generate a strong sense of place*

Placemaking, or generating a strong sense of place, is about strengthening the connection between people and the places they share. Placemaking creates spaces that reflect the identities and histories of its residents, taking any number of forms, from pocket parks to participatory art projects to human-scale environments. Good public spaces can range from the temporary, such as streets closed off on weekends using bollards, to a permanent public park. Benefits of placemaking can include:

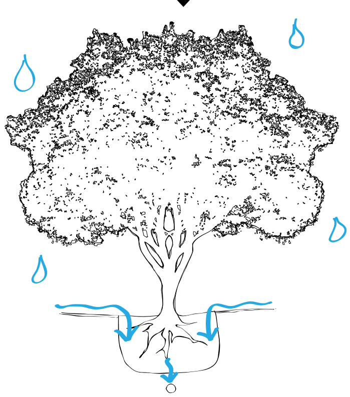
- Increased positive interactions between people
- Increased sense of inclusion, belonging, and pride
- Beautification
- Increased comfort and improved quality of life
- Economic growth

3 PRINCIPLES OF DESIGNING GREEN STREETS

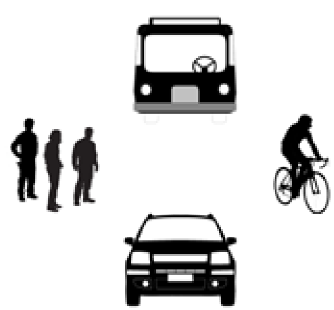
GREEN INFRASTRUCTURE
Use naturalized systems to treat stormwater close to its source

COMPLETE STREETS
Create bicycle- and pedestrian-friendly streets

PLACEMAKING
Generate a strong sense of place

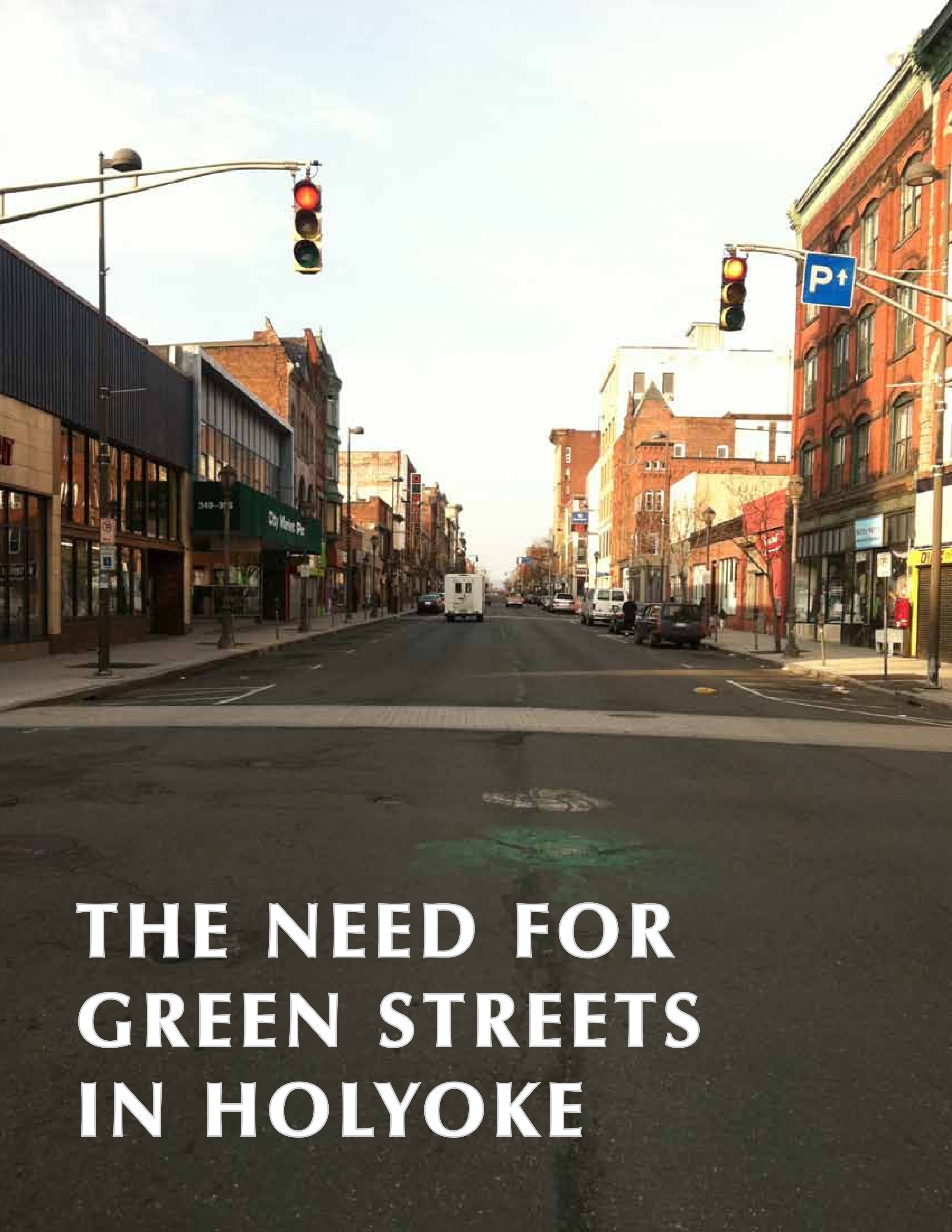


Green infrastructure uses naturalized systems such as trees and bioswales to capture and infiltrate stormwater runoff close to its source, limiting the amount that enters into the combined sewer system.



Complete Streets accommodate all users including pedestrians, cyclists, transit riders, and motorists through more equitable distribution of right-of-way space.

Placemaking uses pedestrian amenities such as parklets to encourage people to linger and generate a strong connection to a place.



THE NEED FOR GREEN STREETS IN HOLYOKE

THE NEED FOR GREEN STREETS

This section explores the social, economic, and ecological conditions of Holyoke and demonstrates how Green Streets might address some of the greatest challenges facing the city today.

DRAINAGE

Holyoke's unique topography is breathtaking; yet at the same time, drainage patterns on the steep slopes west of the downtown lie at the heart of the city's current flooding issues. Referred to as "the Spine of the City," the Mount Tom mountain range runs north to south, spanning the entire length of Holyoke and encompassing 7,000 acres of forest. Mount Tom, rising 1,200 feet over Holyoke's urban center, has sheer cliffs and sloped ridges of greater than 25 percent.

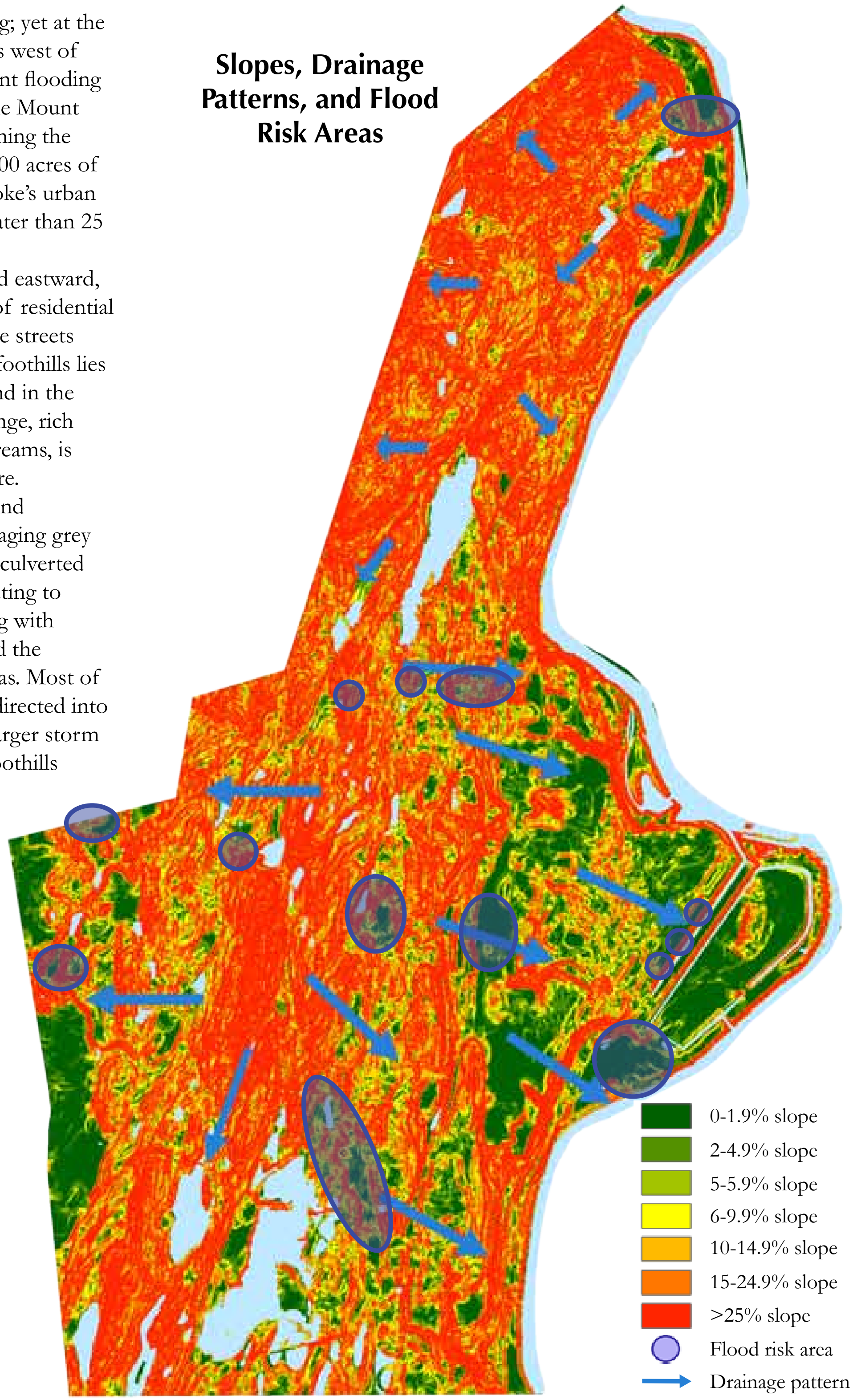
These steep slopes flatten out as they extend eastward, eventually becoming foothills where a number of residential neighborhoods are located; the majority of these streets have 8 to 15 percent slopes. At the base of the foothills lies downtown Holyoke nestled in a twelve-mile bend in the Connecticut River. Holyoke's rural mountain range, rich in wildlife and home to numerous headwater streams, is strikingly juxtaposed against its dense, urban core.

As Holyoke's streams leave the mountains and approach development, they are culverted with aging grey infrastructure. In wet weather conditions, these culverted streams increase in volume, sometimes contributing to flooding in the foothills. Stormwater intersecting with impervious surfaces in these neighborhoods and the downtown has created a few high flood-risk areas. Most of the time, precipitation falling in the foothills is directed into the city's combined sewer system; however, in larger storm events, surficial stormwater readily floods the foothills and the downtown, which is densely covered in impervious surface (see map page 7).

Although flooding is most apparent downtown, drainage should be a primary consideration when applying Green Streets anywhere in Holyoke. It is important to treat stormwater as close to its source as possible; infiltrating stormwater upslope is as important as treating the flood-risk areas below. Although the downtown must infiltrate stormwater in order to manage local flooding, neighborhood streets in the foothills should also be prioritized as Green Streets candidates.

STORMWATER

Drainage and flooding issues in Holyoke are compounded by the dense concentration of impervious surfaces downtown that prohibit infiltration, causing polluted stormwater runoff. Stormwater pollution in Holyoke is not new; the City has been struggling to keep up with the EPA's stormwater regulations for decades. However, in this era of urban renewal, addressing drainage and flooding with Green Streets may provide beautiful and ecological solutions to this ongoing struggle.



What is Stormwater?

Stormwater runoff is precipitation that cannot infiltrate into the ground due to impervious surfaces. As runoff flows over impervious surfaces (paved streets, parking lots, and building rooftops), it accumulates pollutants that may adversely affect water quality if the runoff is discharged untreated. In urban environments these pollutants include:

- Oil, grease and toxic chemicals from motor vehicles
- Pesticides and nutrients from lawns and gardens
- Bacteria and viruses from household waste, pet waste and wildlife
- Heavy metals
- Winter road salt and sand

Holyoke's Stormwater History

In 1972, the Clean Water Act (CWA) established the National Pollutant Discharge Elimination System (NPDES) Stormwater Program to help manage the growing concern over stormwater discharges polluting water bodies in the United States. Up until this time, only point-source pollution (or direct, un-treated pollutant-dumping into water bodies) had been regulated, and stormwater runoff had been considered *non*-point source. Recognizing that a concentration of non-point source pollutant-dumping (such as a densely populated municipality's stormwater runoff discharges) behaves like point-source pollution, the NPDES program redefined point-source criteria, expanding regulation to include Municipal Separate Storm Sewer Systems (MS4s). MS4s must obtain an NPDES permit to discharge into water bodies.

In 1999, under NPDES Stormwater Program Phase II, Holyoke was classified as an MS4 and required "to protect water quality, and to satisfy the appropriate water quality requirements of the CWA" (U.S. EPA, *National Pollutant*). In accordance, Holyoke has developed a Stormwater Management Plan (SMP) using Best Management Practices (BMPs), along with measurable goals for the SMP. Holyoke is also required to evaluate the effectiveness of the program and is subject to NPDES Compliance Monitoring.

2010 Draft NPDES Permit Requirements	
Requirement	**Section in MS4 Permit**
Develop a report assessing existing local regulations to determine the feasibility of making green infrastructure practices allowable.	Part 2.4.6.8
Estimate number of acres of impervious area (IA) and directly connected impervious area (DCIA); report tabulated results and estimation methodology if baselines provided by EPA are not used.	Part 2.4.6.9(a)
Complete an inventory and priority ranking of MS4owned property and infrastructure that may be retrofitted with BMPs designed to reduce the frequency, volume, and peak intensity of stormwater discharges to and from its MS4.	Part 2.4.6.9(c)
Report on those MS4 owned properties and infrastructure that have been retrofitted with BMPs designed to reduce the frequency, volume, and peak intensity of stormwater discharges as well as their pollutant loadings.	Part 2.4.6.9(d)

EPA. 2010 Draft North Coastal Small Municipal Separate Sewer Storm (MS4) Permit

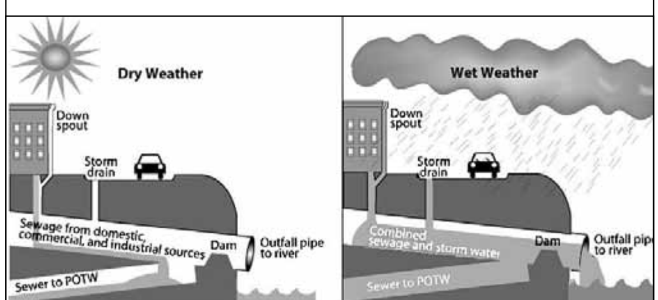
Recognizing the efficacy of green infrastructure to both reduce peak discharge volume and help cleanse polluted stormwater, the EPA's most recent NPDES 2010 draft permit (expected to be finalized in 2014) strongly encourages municipalities to incorporate green infrastructure into their stormwater management practices and to reduce impervious surfaces over time (see table).

Holyoke's Stormwater Runoff Today

Although Holyoke has been classified as an MS4, the incorporation of green infrastructure has not been a priority for the City. Currently, the downtown landscape has a disproportionately high percentage of impervious surfaces in comparison to the rest of the city, with very little existing green infrastructure (or opportunities to infiltrate). In the entire city, impervious surface covers 17 percent of the landscape and open space covers 49 percent. In the downtown, impervious surface covers 63 percent of the landscape and open space covers only 5 percent. According to *Banking on Green*, "water quality becomes degraded when total impervious surface exceeds 10%" (Odefy et al., 31). Much of the impervious surface in Holyoke is devoted to roads and parking. According to a 2012 parking analysis funded by the EPA, "there is a significant excess of parking capacity within downtown Holyoke's public parking supply," with only 40 percent of on-street parking and 53 percent of off-street parking utilized (Planning and Economic Development, 2-25 - 2-26). This presents an important opportunity to reduce impervious surfaces.

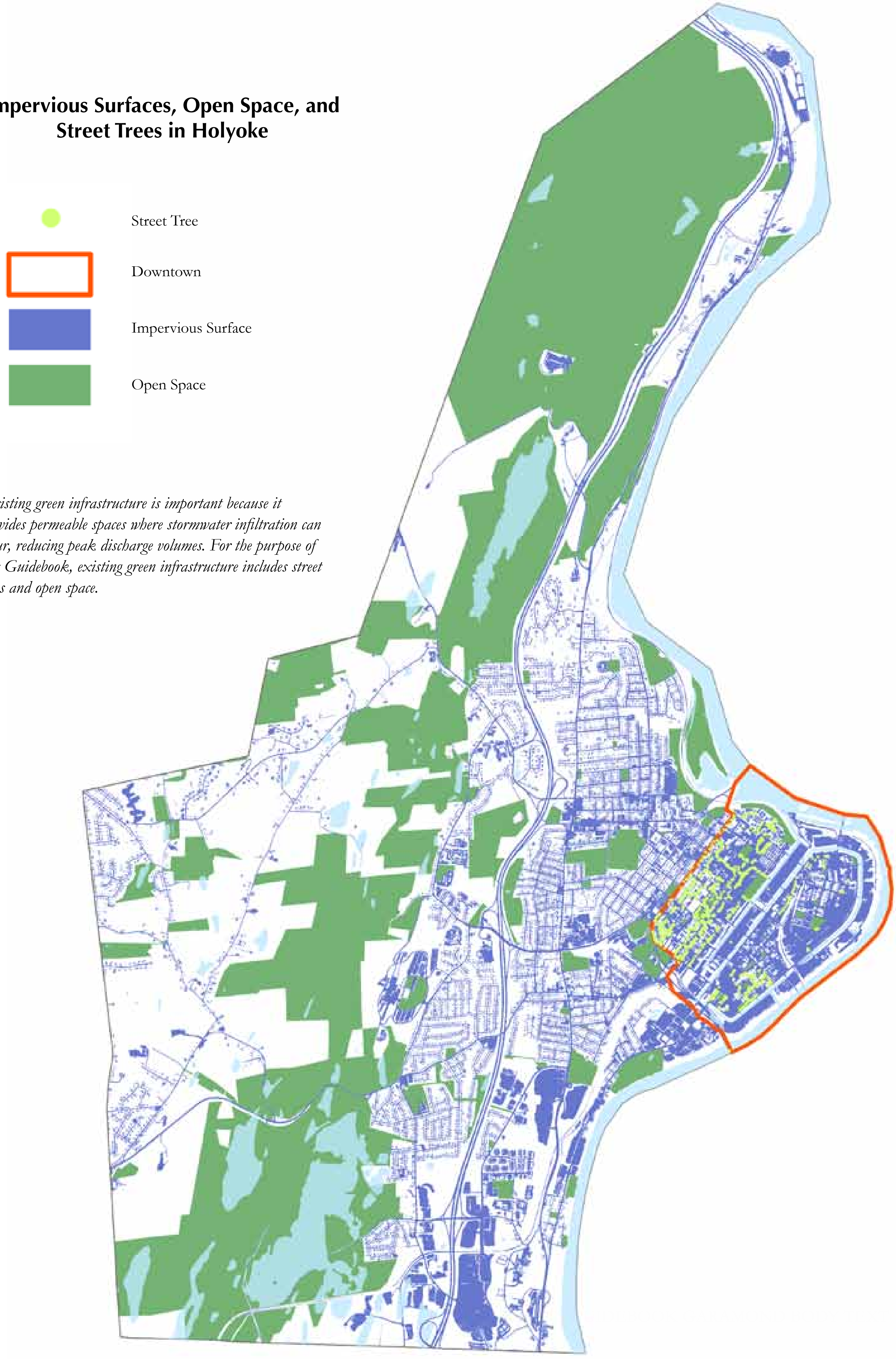
Downtown Holyoke's high percentage of impervious surfaces in conjunction with its complex history of industry and site contamination make polluted stormwater discharges a serious matter. Most of the city's stormwater is directed into a combined sewer system (CSS), but stormwater that falls in some areas is not directed into a sewershed at all and is instead directly discharged into the Connecticut River untreated (area shown in grey on page 8). During wet weather conditions, stormwater directed into the CSS occasionally overwhelms the system and causes combined sewer overflows (CSOs) into the Connecticut River.

COMBINED SEWER OVERFLOWS DIAGRAM



CSO events occur in wet weather conditions when stormwater and raw sewage overwhelm the combined sewer system and are released directly into water bodies, rather than being treated at a wastewater treatment facility (EPA image).

Impervious Surfaces, Open Space, and Street Trees in Holyoke



Existing green infrastructure is important because it provides permeable spaces where stormwater infiltration can occur, reducing peak discharge volumes. For the purpose of this Guidebook, existing green infrastructure includes street trees and open space.

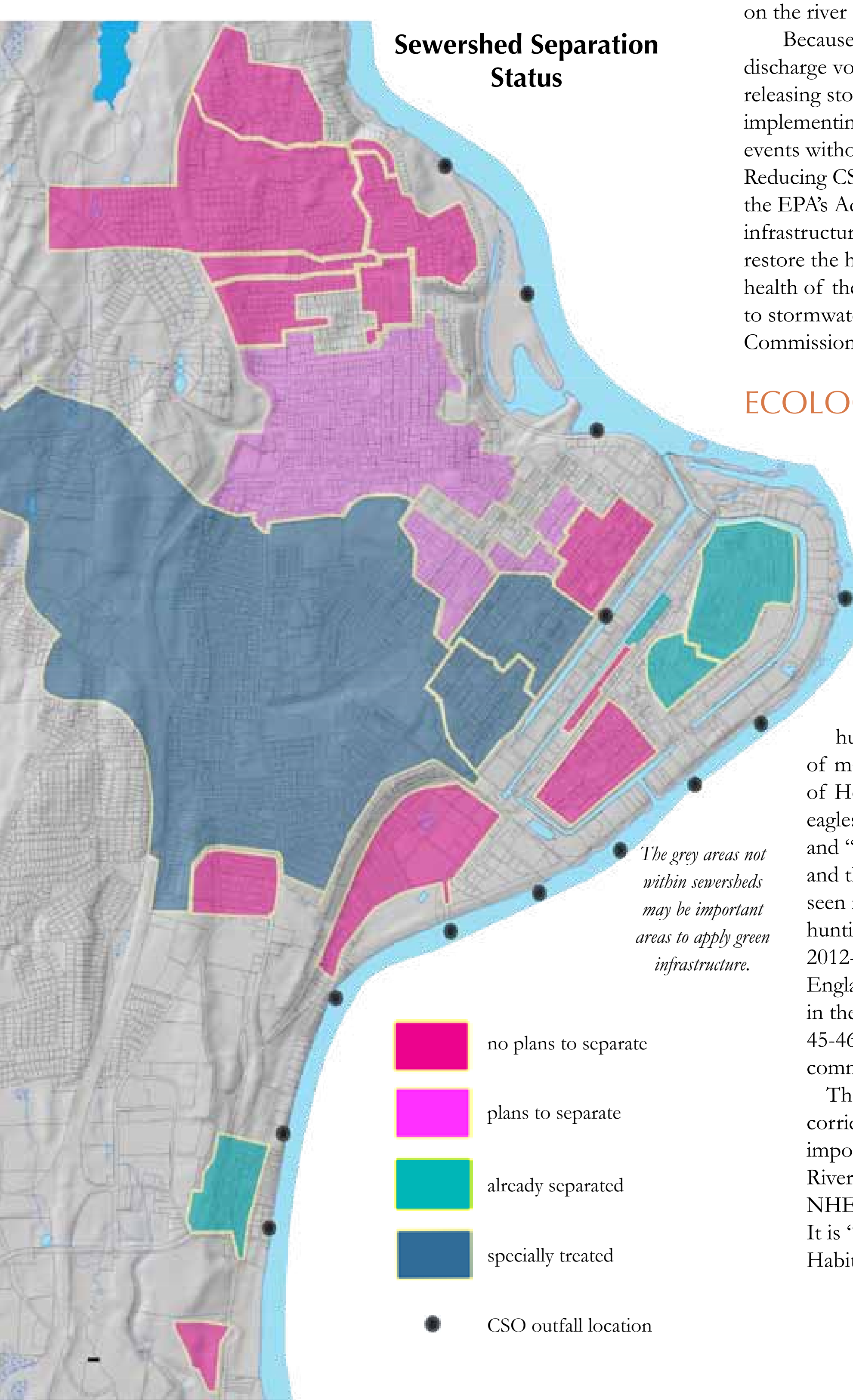
COMBINED SEWER OVERFLOWS

Holyoke has an aging combined sewer system with thirteen outfall locations that release combined sewer overflows into the canals and river. In 2005, Holyoke released 36 to 68 trillion gallons of wastewater into the river (City of Holyoke OSRP 2012-2017, 25).

In order to comply with the EPA's mandate to reduce its CSOs, the City's Department of Public Works developed a Long-Term Control Plan in 2012 to separate stormwater from sanitary sewer pipes by sewershed.

The City has already begun the process of separating its sewersheds (see map below), but total implementation cost estimates range from $44 to 78 million. Since 2001, only three have been successfully separated. Funding for the remaining sewersheds is yet to be identified. In the interim, the City has eliminated two CSO outfall locations on the Connecticut River and constructed a CSO abatement facility in 2007 at the most significant CSO outfall, once the largest on the river (see map below; "specially-treated" area).

Because green infrastructure helps reduce peak discharge volumes by retaining, infiltrating, and slowly releasing stormwater after the peak of a storm event, implementing Green Street strategies may reduce CSO events without necessarily having to separate the sewers. Reducing CSOs would not only help Holyoke comply with the EPA's Administrative Order and potentially reduce grey infrastructure implementation costs, but would also help restore the health of the Connecticut River. The ecological health of the Connecticut River is compromised largely due to stormwater and CSO pollution (Pioneer Valley Planning Commission).



The grey areas not within sewersheds may be important areas to apply green infrastructure.

ECOLOGY

The City of Holyoke and the Connecticut River are unusually rich in biodiversity. In fact, roughly 50 percent of the city is designated NHESP Rare and Endangered Species Habitat.

Approximately 242 species of vertebrates have been identified, including 29 species of fish (smallmouth and largemouth bass, brook and rainbow trout, and yellow perch); at least 160 species of birds (ruby-throated hummingbirds, bald eagles); and about 42 species of mammals (common gray squirrels to moose) (City of Holyoke OSRP 2012-2017, 45-46). "Wintering eagles are also found along the river in Holyoke," and "Peregrine Falcons, which nest in Springfield and the Holyoke City Hall Clock Tower, can also be seen migrating and wintering along Mt. Tom and hunting pigeons downtown" (City of Holyoke OSRP 2012-2017, 47). Yellow lampmussels, one of New England's rarest freshwater mussels, can be found in the canals (City of Holyoke OSRP 2012-2017, 45-46). Holyoke hosts a surprisingly diverse natural community in an urban area.

The Connecticut River forms a major wildlife corridor for aquatic species of critical ecological importance. The whole portion of the Connecticut River along Holyoke's eastern border is designated NHESP Rare and Endangered Species Habitat. It is "the spine of a much more extensive Core Habitat that connects many of the most biologically important sites in the river valley" (Department of Fish and Game, 29). CSOs and stormwater discharges along the length of the canals and river continue to put strain on Holyoke's rare river ecology.

Finally, Holyoke residents recreate and subsistence fish in the river, putting them at risk of illness after CSO discharges. Reducing Connecticut River pollution with Green Street strategies could help improve ecological health, both for wildlife and for residents.

ENVIRONMENTAL JUSTICE

All of downtown Holyoke and much of the surrounding area is considered an environmental justice (EJ) area by the Massachusetts Executive Office of Energy and Environmental Affairs (EEA). Environmental justice areas are defined by populations with less than $30,000 annual household income, greater than 25 percent minority population, and/or greater than 25 percent non-English-speaking households, all of which are found in Holyoke. Environmental justice populations are often burdened with a disproportionate share of environmental problems. The concentration of Holyoke's large EJ population within and near the downtown, with its large amount of impervious surfaces, a legacy of industrial pollution, and limited access to open space suggests downtown would benefit most from the ecological and social benefits associated with Green Streets.

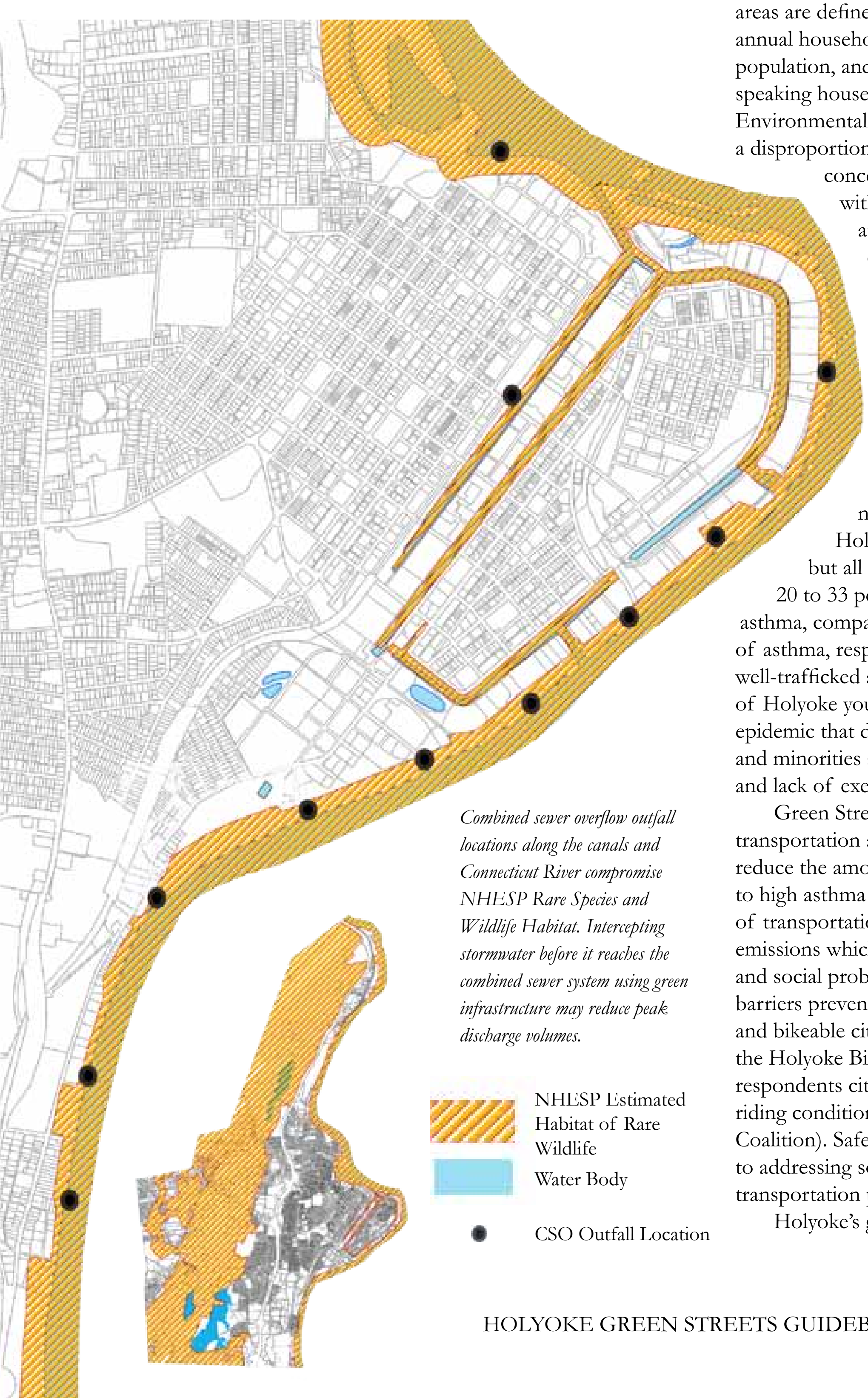
HEALTH & MOBILITY

Poor health and limited access to alternative forms of transportation are notable problems citywide and affect not only Holyoke's Environmental Justice population, but all of the city's residents and visitors. Citywide, 20 to 33 percent of Holyoke's children have pediatric asthma, compared to 10.6 percent nationwide. Incidences of asthma, respiratory ailments, and cancer increase along well-trafficked arterial roads. Additionally, 30 to 40 percent of Holyoke youth are overweight or at risk of obesity, an epidemic that disproportionately affects the nation's poor and minorities and is strongly linked to vehicle dependence and lack of exercise (U.S. EPA, *Creating the Community*).

Green Streets, which promote alternative forms of transportation and utilize vegetation to filter air, could reduce the amount of vehicular air pollution contributing to high asthma rates, make space for alternative modes of transportation that combat obesity, and reduce carbon emissions which may contribute to a number of health and social problems in the future. However, a number of barriers prevent Holyoke from becoming a more walkable and bikeable city. Although 89 percent of respondents to the Holyoke Bike Survey would like to bike more often, respondents cited insufficient bike lanes and dangerous riding conditions as major barriers (Massachusetts Bicycle Coalition). Safe, reliable bicycle infrastructure is integral to addressing some of Holyoke's greatest health and transportation problems.

Holyoke's gridded blocks are short, walkable distances,

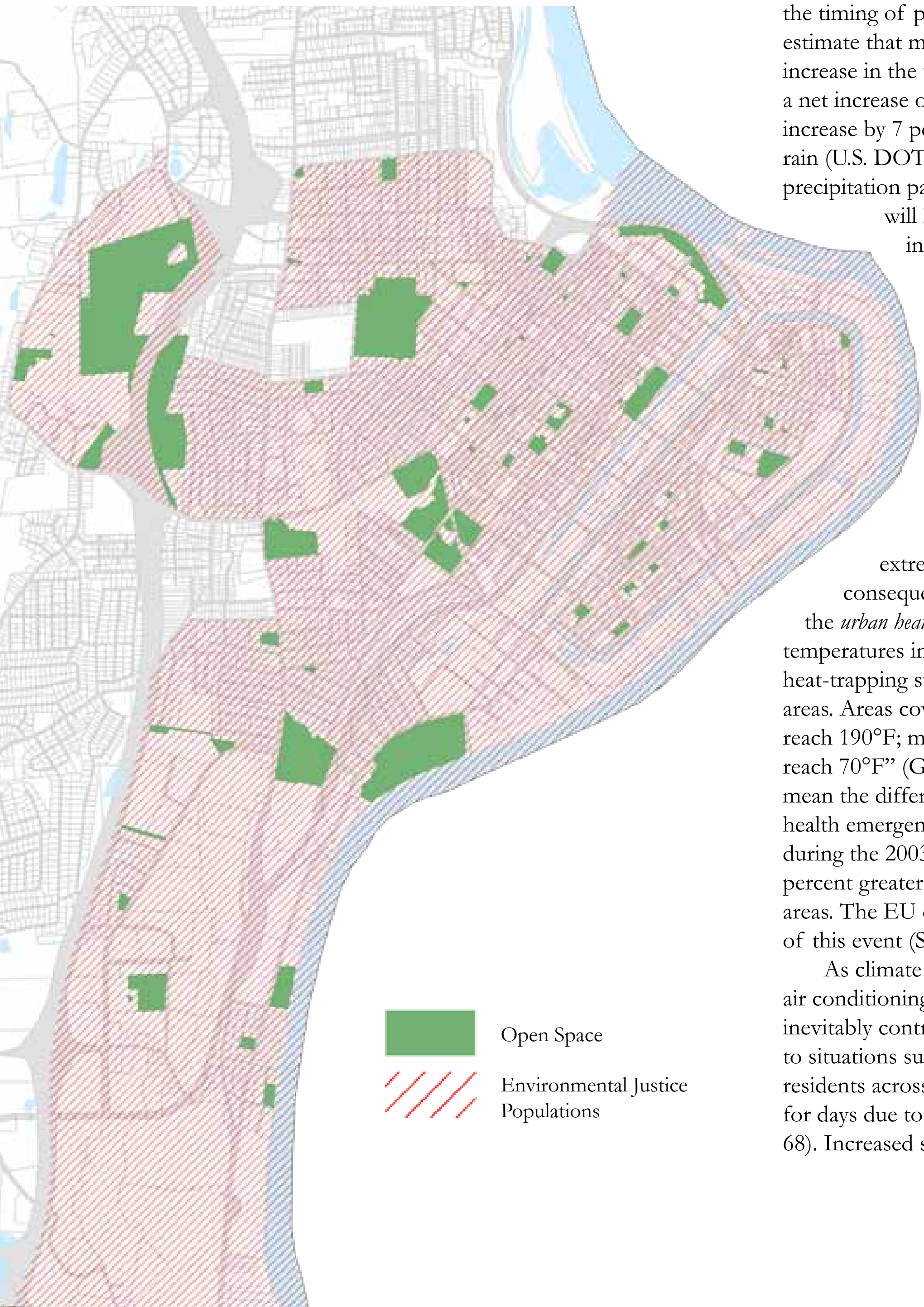
NHESP Habitat and CSO Outfall Locations



Combined sewer overflow outfall locations along the canals and Connecticut River compromise NHESP Rare Species and Wildlife Habitat. Intercepting stormwater before it reaches the combined sewer system using green infrastructure may reduce peak discharge volumes.

but most streets lack the amenities that promote a pleasant and safe walking experience. However, with the anticipated construction of the new train station connecting downtown Holyoke to Springfield, New York, and cities throughout the Northeast, train trips in conjunction with the existing bus system are expected to increase the use of public transportation, and with it, encourage walking and biking between transit options. Walking, cycling, and public transportation are the most equitable forms of transportation, therefore promoting Green Streets would support environmental justice and equality in the area that needs them most.

Environmental Justice Populations and Access to Open Space



CLIMATE CHANGE

Significant Temperature and Precipitation Fluctuations for New England by 2040

Global climate change, largely a result of the release of greenhouse gas emissions including CO_2, is anticipated to destabilize our climate and lead to increased average global temperatures ("Climate Change: Basic Information"). Over the next few decades, New England should expect annual mean temperatures to increase 2.5° Fahrenheit, with hotter, drier summers and longer, wetter winters. The number of extreme days of heat (temperatures above 90°) are expected to double in parts of New England. The region will also see warmer winters, causing an increase in winter precipitation falling as rain, as well as fluctuations in snow melt, affecting the timing of peak river flows (U.S. DOT). Scientists estimate that mean precipitation will decrease in the fall and increase in the winter, yet annual precipitation will still see a net increase of 6 percent. Storm events are expected to increase by 7 percent, arriving in heavier, brief pulses of rain (U.S. DOT). Greater fluctuations in temperatures and precipitation patterns mean New England communities will have to be more resilient in the face of an increasingly unpredictable climate.

Holyoke should plan for an increase of four inches of annual rainfall over the next few decades. Increased precipitation will only further contribute to stormwater pollution and strain Holyoke's combined sewer system, exacerbating the issue of CSOs without appropriate intervention.

The Urban Heat Island Effect

The anticipated doubling of days of extreme heat in New England could have severe consequences for Holyoke. Holyoke experiences the *urban heat island effect*, or the phenomenon of higher temperatures in cities caused by a concentration of darker, heat-trapping surfaces and less vegetative cover than rural areas. Areas covered in "barren, impermeable surfaces can reach 190°F; more natural vegetated surfaces might only reach 70°F" (Gartland, 15). During the hottest days, this can mean the difference between a hot summer day and a public health emergency. For instance, in Strasbourg, France, during the 2003 heatwave, the heat-index value was 30 percent greater downtown compared to surrounding rural areas. The EU estimates that 70,000 people died as a result of this event (Stone, 13).

As climate and cities warm, demand for emergency air conditioning during unusually hot days in cities will inevitably contribute to a strained electrical grid, leading to situations such as the 2003 blackout, when 55 million residents across northeastern North America lost power for days due to high demand for urban cooling (Stone, 68). Increased storm events and days of extreme heat are inevitable, but cities can take precautionary measures to help mitigate their effects before disaster strikes. Straightforward solutions include expanding the urban forest and other vegetative cover, which cool cities through shade and evapotranspiration, and using permeable pavements, which allow water to drain and evapotranspire, cooling surfaces (Gartland, 51).

IN SUMMARY: WHY GREEN STREETS?

Holyoke is in a period of transition and rebirth. At the heart of this evolutionary process is the realization that Holyoke already has the framework with which to create a vibrant and more livable community.

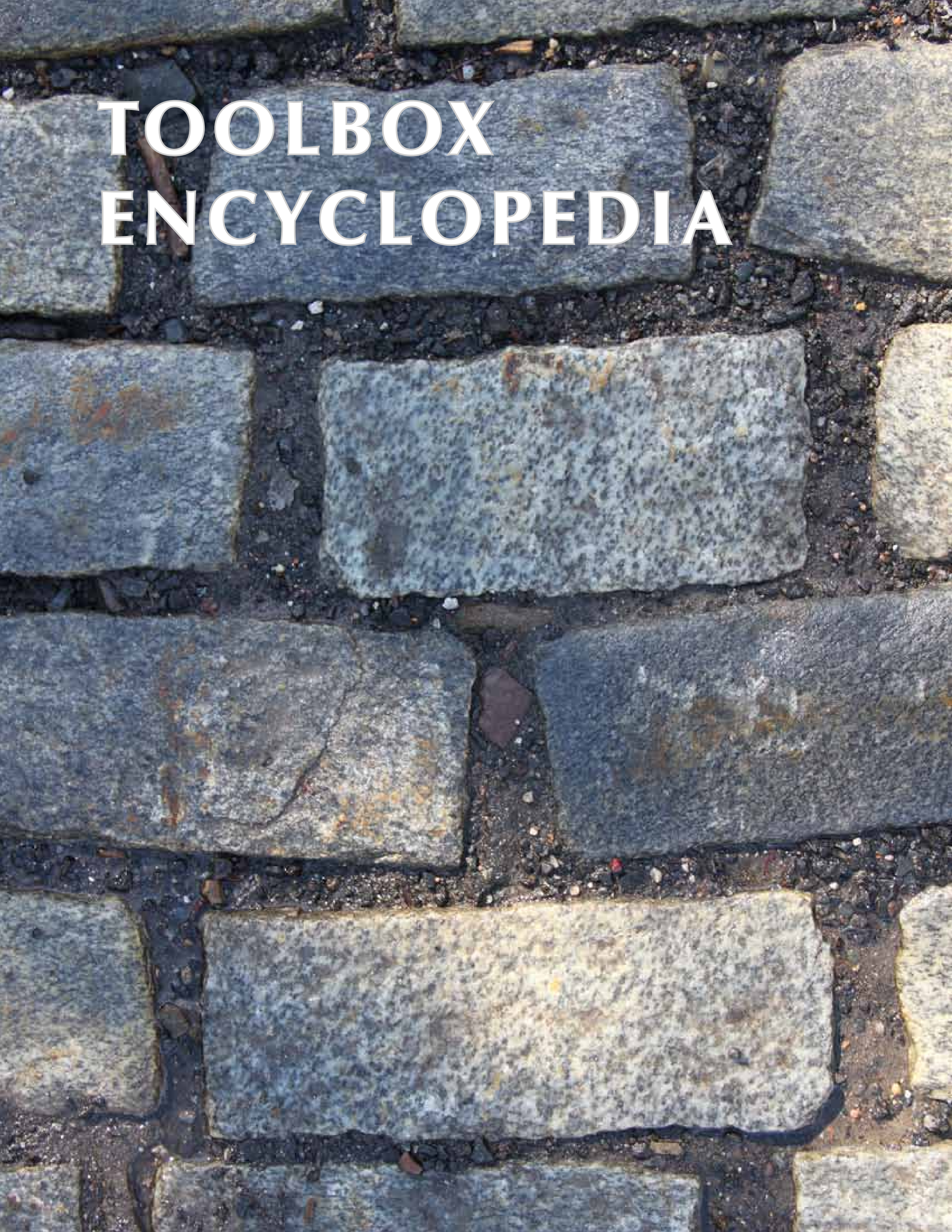
Downtown Holyoke has its fair share of obstacles. Stormwater pollution and CSOs are clearly causing environmental degradation of the Connecticut River and making the river unsafe for recreation. In addition, as a Municipal Separate Storm Sewer System, Holyoke is required by the EPA to treat its polluted stormwater, and it is also under a separate Administrative Order to reduce its CSOs. The City is straining to come up with a solution.

Substantial impervious cover and disproportionately little open space are concentrated downtown, which hosts an environmental justice population. The Executive Office of Energy and Environmental Affairs recommends that the City take measures to provide these residents with access to open space and a greener, healthier environment. Transportation options are extremely limited and currently centered around motor-vehicle use, causing a whole host of associated health problems for Holyoke residents.

Climate change is expected to compound all of these issues: increased precipitation and warming will increase stormwater pollution and CSOs; impervious surfaces will get hotter, exponentially contributing to the urban heat island effect; fossil-fuel independence and alternative transportation will become more important; less affluent people will be the first to be subject to environmental injustices.

Green Streets are designed to treat stormwater at its source and to create more vibrant and livable communities. Green infrastructure could help Holyoke infiltrate and clean its polluted stormwater, subsequently reducing CSOs. Reduced pollution in the Connecticut River could make a healthier and more resilient river ecology and resident population. Designing for complete streets could empower and inspire Holyoke's residents, perhaps most importantly the downtown's environmental justice population, to cycle, walk and enjoy their outdoor living space. Identifying opportunities for placemaking could bring the city a strong sense of identity and bring all of the city's residents into this new era of rebirth. Green Streets in Holyoke have the potential to begin the process of addressing the interconnected complexities of these issues.

TOOLBOX ENCYCLOPEDIA



TOOLBOX ENCYCLOPEDIA

WHAT IS THE TOOLBOX?

The Toolbox is a collection of recommended tools related to the three principles of Green Streets. While many relevant strategies and practices exist, the Toolbox is a compilation of those considered most effective and relevant to Holyoke based on current research. However, as green infrastructure, complete streets, and placemaking are relatively new concepts, research and experimentation is ongoing. The successful implementation of each tool depends not only on its demonstrated efficacy, but also the particular ecological, social, and economic conditions of a site. In Section 2, a number of these conditions were explored, but ongoing analysis is necessary as the Toolbox is applied to the streets of Holyoke in the future.

HOW IS IT USED?

The tools within the Toolbox are divided into three categories: **Green Infrastructure**, **Complete Streets**, and **Placemaking**, corresponding to the three principles of Green Streets. The purpose of the Green Infrastructure Tools is to capture and treat stormwater close to its source through naturalized systems such as bioswales and tree trenches. Complete Streets Tools such as bike lanes emphasize flow of traffic and issues of access, while Placemaking Tools such as parklets enhance the sense of belonging in a space. Although some tools can individually or collectively address more than one Green Streets principle, each is categorized according to the principle it addresses most directly.

The Toolbox provides information on the relevant characteristics of each Tool, allowing users to learn about and compare them. Each Tool includes a schematic drawing, brief description, dimensions, important benefits and considerations, and a table of spatial and functional characteristics. Tools are also referenced as they are applied to designs in Sections 4 and 5. Users seeking to implement these designs or find a suitable substitute for a Tool used in these designs may refer back to the Toolbox for more detailed information. Small white icons of each Tool on the outside of each page correspond with icons used to identify tools in Sections 4 and 5.

Finding the right Tool for the right place can be tricky, and in many cases there may be no one correct answer. However, it is important that, before selecting a Tool for a specific street, the user properly assesses the existing conditions of the site and establishes goals for its redesign. Useful questions include:

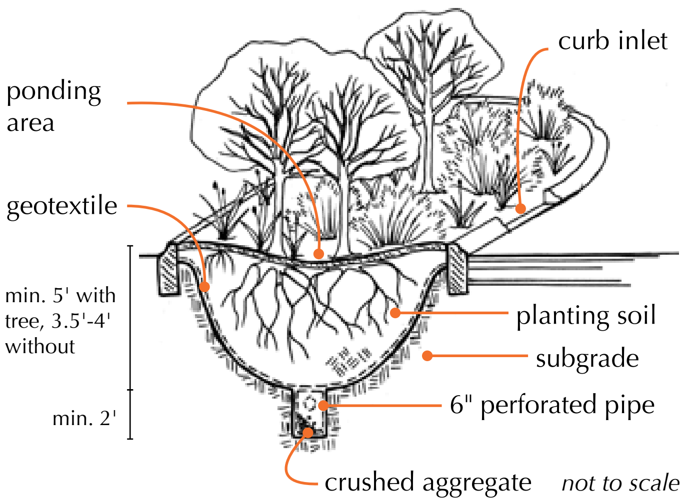
- What is the width of the right-of-way (ROW)?
- How many lanes of traffic, and in what direction(s) do they flow?
- What is the slope of the street?
- What type(s) of land use abut the street? How close are buildings to the ROW?
- What is the street's speed limit and functional road classification? Should vehicular traffic be slowed or kept moving?
- How do pedestrians, cyclists, and public transit vehicles currently move through the street? How might they be better accommodated?
- What placemaking opportunities exist?

Once site assessment and goals have been conducted, the user can refer to the Toolbox to select the tool(s) most suitable for the site at hand. References in the appendix can orient the user to more information on specific tools.

STRUCTURAL SOIL AND THE URBAN FOREST

Two of the most common constraints to growing healthy urban trees are a lack of adequate soil volume for tree roots and compacted soils that inhibit tree root growth and water infiltration. Structural soil, patented by Cornell University as CU-Structural Soil™, is designed to support tree growth and aerate soils in urban environments. The specially engineered soil consists of stones that form a load-bearing lattice structure, with lattice voids filled with porous soil, allowing water to infiltrate. Structural soil can be used as a continuous base course under pavements, and can thus extend a tree's root zone under commonly compacted paved areas. The success of many of the green infrastructure tools in the following pages depend on the use of structural soil *(Bassuk et al. 183-5)*.

BIOSWALE (WITH TREES)



Description:
A bioswale is a linear vegetated swale that channels stormwater, infiltrating and filtering it with vegetation and soils as it travels.

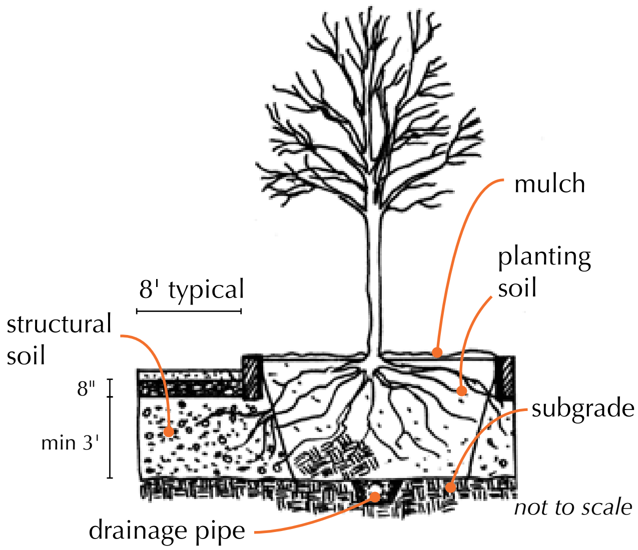
Benefits:
- Allows stormwater to travel and infiltrate
- Does not require energy-intensive structural walls
- Excess stormwater flows can travel to grey infrastructure system through perforated pipe
- Can be planted with a variety of wetland-tolerant vegetation

Considerations:
- Requires excavation
- Limited to slopes 6% or less
- Roadside vegetation must be wetland tolerant, hardy to salt, snow piles, and high sediment flows

Slope	Optimal Use	Dimensions	Spacing
1-6% (if greater than 5%, use check dams and dense vegetation)	Along roads, linear and uninterrupted channels	Min. 2' wide; min. 3.5' deep without tree; 5' with tree	Recommended tree spacing: 20'

Sources: New York Department of Environmental Protection (2013)

BREAK-OUT



Description:
Break-outs are excavated areas filled with structural soil, often under sidewalks or roads. Used in combination with other green infrastructure tools such as tree trenches or stormwater planters, break-outs provide more room for tree roots to grow in tight spaces, increasing the longevity and survival rate of urban trees.

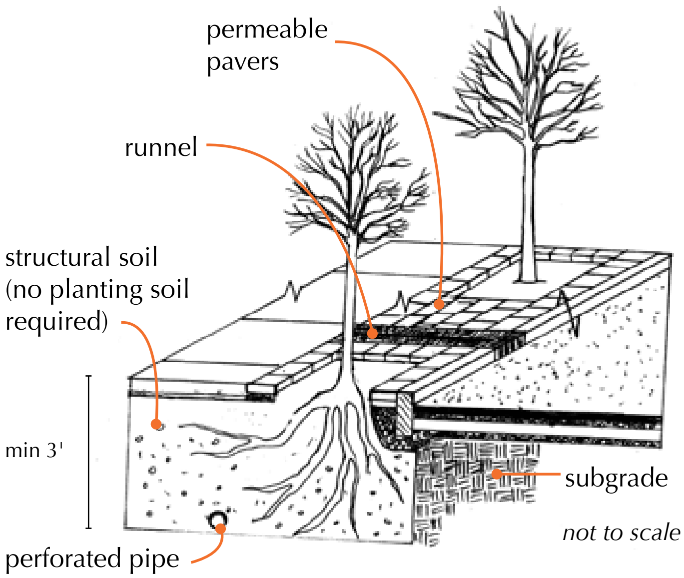
Benefits:
- Provides additional space for tree roots, improving health
- Increases amount of infiltration area by replacing compacted native soil with more porous structural soil
- Requires little maintenance after installation

Considerations:
- Requires pavement to be ripped up and replaced for retrofits, increasing costs

Slope	Optimal Use	Dimensions	Spacing
n/a	In combination with other tools in which trees are planted	min. 3' below paving	n/a

Sources: Bassuk et al., (2005), Bassuk et al., (1998)

COVERED TREE TRENCH



Description:
A covered tree trench is a linear system of trees connected by structural soil underground and covered with permeable pavers. Stormwater flows into the trench via inlets or runnels and through the permeable pavers, infiltrating into the soil. The continuous mass of soil combined with soil break-outs under sidewalks and streets gives roots more room, increasing vitality.

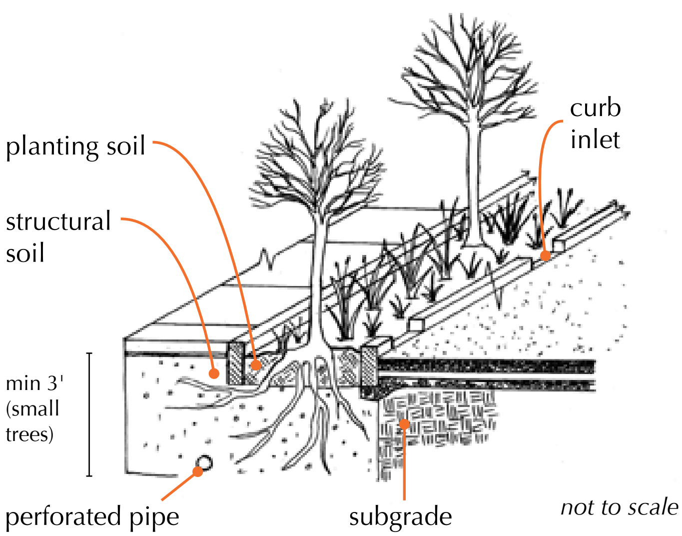
Benefits:
- Maximizes infiltration area
- Increases life-span of trees
- Allows pedestrian access between sidewalk and road

Considerations:
- Requires considerable excavation, especially in combination with break-outs; may be expensive
- Limited to slopes less than 5%
- Sensitive to heavy compaction over root systems

Slope	Optimal Use	Dimensions	Spacing
<5%	Along roads and sidewalks, to promote pedestrian crossings	2.5' minimum width, 3' minimum depth	Recommended tree spacing: 20' (varies by species)

Sources: City of Milwaukee (2013): Boston Transportation Department

OPEN TREE TRENCH



Description:
Like a covered tree trench, an open tree trench is a linear system of trees connected by structural soil underground, but it is filled with vegetation, not covered with permeable pavers. Stormwater flows into the trench via inlets and infiltrates into the soil. The continuous mass of soil in combination with soil break-outs into sidewalks and streets gives roots more room, increasing vitality.

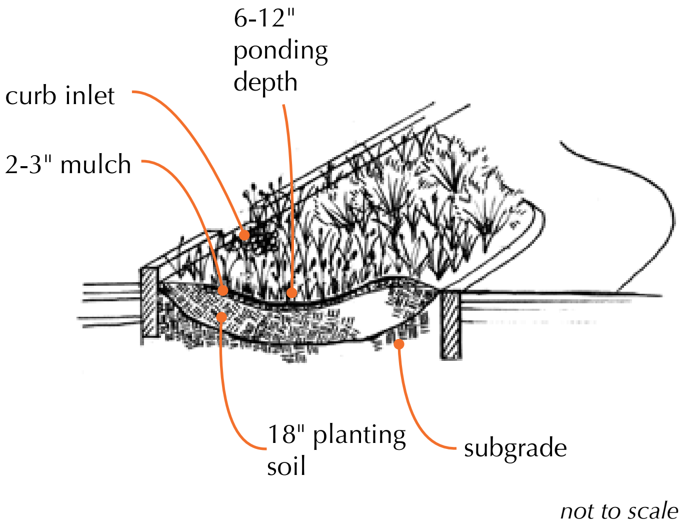
Benefits:
- Maximizes infiltration, especially with break-outs
- Increases life-span of trees
- Allows for variety of wetland plantings

Considerations:
- Requires considerable excavation, especially in combination with break-outs; may be expensive
- Limited to slopes less than 5%
- Limits pedestrian access between sidewalk and road

Slope	Optimal Use	Dimensions	Spacing
<5%	Along roads and sidewalks, to protect pedestrians or cyclists	2.5' minimum width, 3' minimum depth	Recommended tree spacing: 20' (varies by species)

Sources: City of Milwaukee (2013); Boston Transportation Department

RAIN GARDEN



Description:
A rain garden is typically a moderately depressed, vegetated area designed to capture, pond, and gradually infiltrate stormwater within 72 hours. It is different from most other green infrastructure tools because it is often not connected to the grey infrastructure system and requires less excavation.

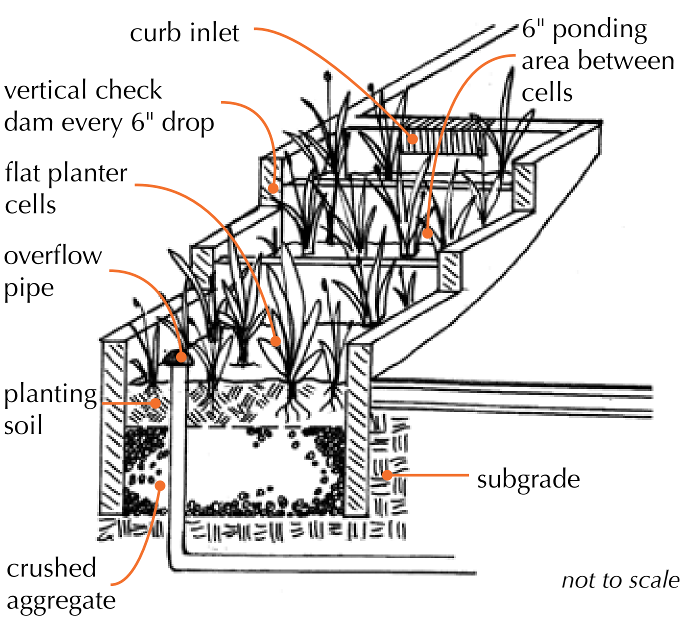
Benefits:
- Easy to incorporate into retrofit projects
- Can vary in size and shape
- Effective at removing pollutants
- Can double as snow storage area

Considerations:
- Because they are disconnected from the grey infrastructure system, rain gardens must either be located where soils can drain within 72 hours, or soil must be amended
- Plants must be wetland tolerant

Slope	Optimal Use	Dimensions	Spacing
>1%	To replace traditional landscaping; residential and school settings	Flexible in shape and size; ideally 18" deep and allow for 6-12" ponding depth	Spacing depends on amount of stormwater being captured and rate of infiltration

Sources: "Simple Infiltration Rain Garden"

STEPPED STORMWATER PLANTER



Description:
Ideal for sloped sites, stepped stormwater planters consist of walled, vegetated cells that allow stormwater to pond and infiltrate over time. For every six inch drop in elevation, a vertical check dam is placed between each level cell, allowing for overflowing water to travel downslope from cell to cell.

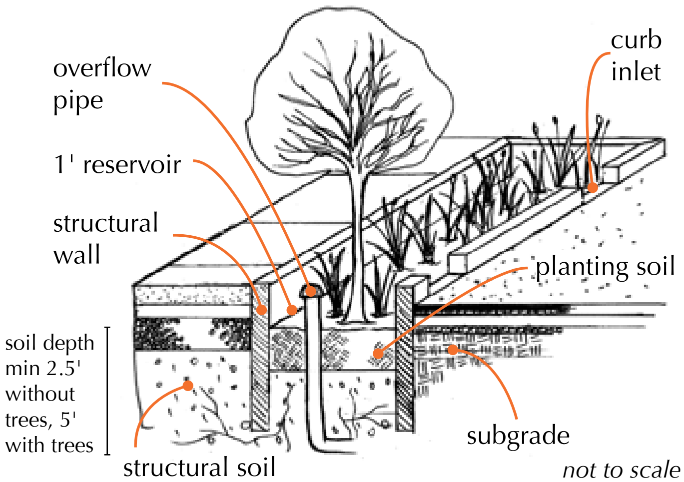
Benefits:
- Adaptable to varying slopes
- 6" ponding depth (1' in bottom cell) provides large capacity during peak flows and allows infiltration over time

Considerations:
- Water must be able to infiltrate into the soil within 48 hours of a storm event
- If planted with trees, proper examination of vertical check dam locations, additional excavation of soil, and break-outs may be necessary; use wetland-tolerant plants

Slope	Optimal Use	Dimensions	Spacing
>5%	Steeper slopes; along roads and sidewalks, to protect pedestrians and cyclists	Length & width vary; soil depth & width min. 2.5' without trees, 5' with trees	Spacing depends on access needs; recommended tree spacing: 20' (varies by species)

Sources: Environmental Protection Agency (2009); Milwaukee Office of Environmental Sustainability (2013)

STORMWATER PLANTER



Description:
A stormwater planter is usually a rectangular, vegetated planter, sometimes planted with trees. Its four concrete sides double as a curb and structure for the planter and allow water to pool up to 1' before overflowing into another planter or the grey infrastructure system, storing and infiltrating water over time.

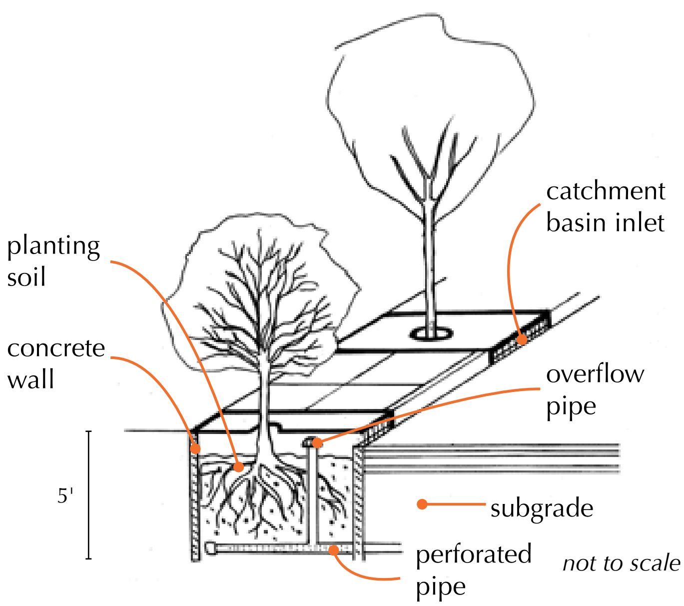
Benefits:
- 1' ponding depth increases capacity during peak stormwater flows and allows for infiltration over time
- Effectively buffers pedestrians and cyclists from vehicles with curb and vegetation strip

Considerations:
- Water must be able to infiltrate into the soil within 48 hours of a storm event
- If planted with trees, additional excavation for soil and break-outs may be necessary; use wetland-tolerant plants

Slope	Optimal Use	Dimensions	Spacing
<5%	Along roads and sidewalks, to protect pedestrians or cyclists	Length & width vary; soil depth & width min. 2.5' without trees, 5' with trees	Spacing depends on access needs; recommended tree spacing: 20' (varies by species)

Sources: "Section of Stormwater Planter"

TREE BOX FILTER



Description:
A tree box filter is a bioretention container filled with soil and planted with a tree or shrub. Stormwater runoff from roads enters the system through a catchment basin inlet, is infiltrated and treated by the soil and tree, and overflows into a perforated pipe below. It is ideal for small urban spaces and retrofits, where little hardscape can be removed. Tree box filters can have open or closed bottoms, depending on soil type and infiltration goals. Closed bottoms are ideal for contaminated sites.

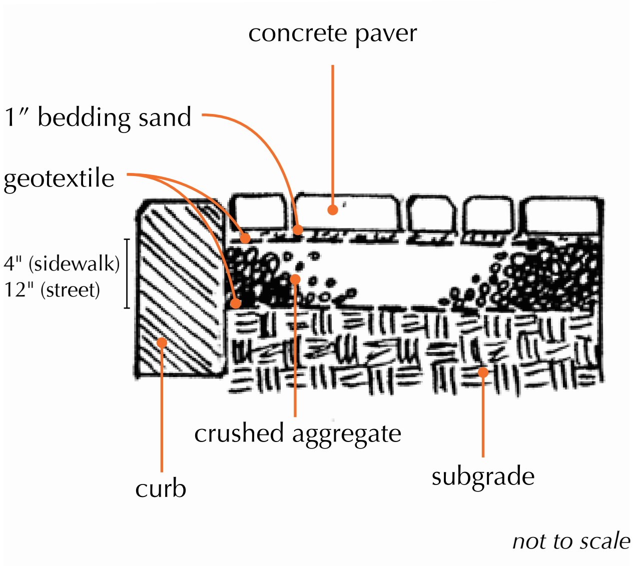
Benefits:
- Highly effective at water quality treatment
- Can be used in place of or adjacent to catchment basins

Considerations:
- Costly ($3,000 per unit, $3,000 for installation) (UNH)
- Only suitable for smaller trees; use wetland-tolerant plants
- A relatively new technology; may require additional research

Slope	Optimal Use	Dimensions	Spacing
<5%	Retrofit projects; tight spaces	Can vary; suggested 5' x 5' x 5' for tight spaces; consider tree or shrub sizes	Recommended tree spacing: 20' (varies by species)

Sources: "Tree Box Filter"

PERMEABLE PAVERS



Description:
Permeable pavers are any type of paver laid on sand and gravel that allows runoff to flow through the pavers into an infiltration area below.

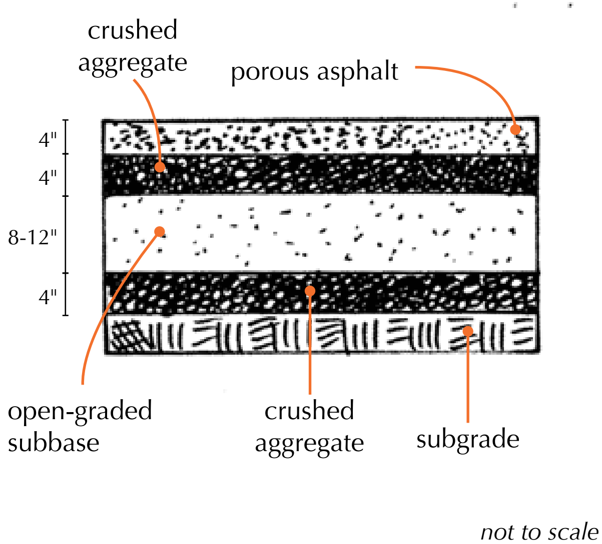
Benefits:
- Allows water to infiltrate through traditionally impervious surfaces, reducing the amount of impervious surface without necessarily reducing hardscape
- Reduces ice accumulation, the need to plow and salt

Considerations:
- Periodic vacuuming of surface is required to prevent loss of permeability; sensitive to snow plowing regime
- If using in bike lanes or sidewalks, ensure material meets ADA accessibility requirements
- Not ideal for high vehicular-traffic areas
- Where infiltration is not desired, use impervious membrane

Slope	Optimal Use	Dimensions	Spacing
<5% optimal	Sidewalks, local streets, parking lanes, parking lots, alleys	3' above water table; 2' above bedrock	n/a

Sources: "Patio/Sidewalk/Plaza On Compacted Aggregate Base"

POROUS ASPHALT



Description:
Porous asphalt allows water to infiltrate through usually impervious hardscape, increasing infiltration and temporary storage of stormwater during peak flows.

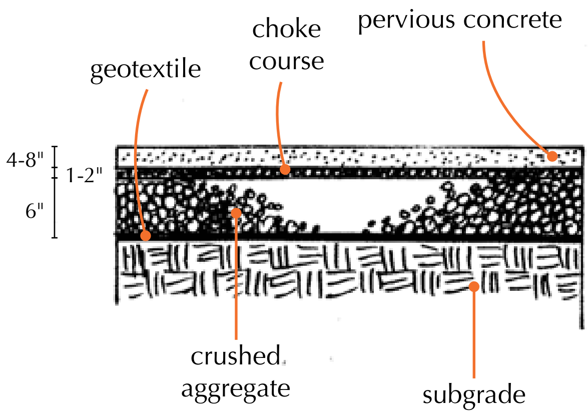
Benefits:
- Allows water to infiltrate while maintaining hardscape
- Reduces ice accumulation, the need to plow and salt
- Blends well with traditional hardscape materials

Considerations:
- Maintenance requires periodic vacuuming of surface or fills with sediment and permeability is lost
- Not ideal for high vehicular-traffic areas
- Where infiltration is not desired, use impervious membrane

Slope	Optimal Use	Dimensions	Spacing
<5% optimal	Sidewalks, local streets, parking lanes, parking lots, alleys	3' above water table; 2' above bedrock	n/a

Sources: "Porous Asphalt Pavement for Stormwater Management"

PERVIOUS CONCRETE



not to scale

Description:
Pervious concrete allows water to infiltrate through usually impervious hardscape, increasing infiltration and temporary storage of stormwater during peak flows.

Benefits:

- Allows water to infiltrate through traditionally impervious surfaces, reducing the amount of impervious surface without necessarily reducing hardscape
- Reduces ice accumulation, the need to plow and salt
- Visually blends with existing materials

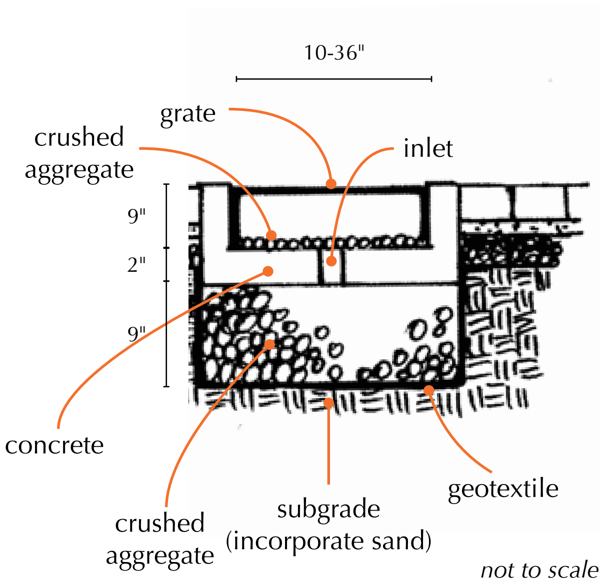
Considerations:

- Maintenance requires periodic vacuuming of surface or fills with sediment and permeability is lost
- Not ideal for high vehicular-traffic areas
- Where infiltration is not desired, use impervious membrane

Slope	Optimal Use	Dimensions	Spacing
<5% optimal	Sidewalks, local streets, parking lanes, parking lots, alleys	3' above water table; 2' above bedrock	n/a

Sources: "Pervious Concrete Pavement"

RUNNEL



not to scale

Description:

- Runnels are depressed channels designed to direct stormwater to other green infrastructure tools or directly to a drain. Though they can vary in shape and materiality, runnels are commonly constructed using concrete or stone and often covered with grates or filled with stone to reduce tripping hazards.

Benefits:

- Quickly and unobtrusively directs water where desired
- Can provide aesthetic and educational interest
- Easily combined with other green infrastructure tools

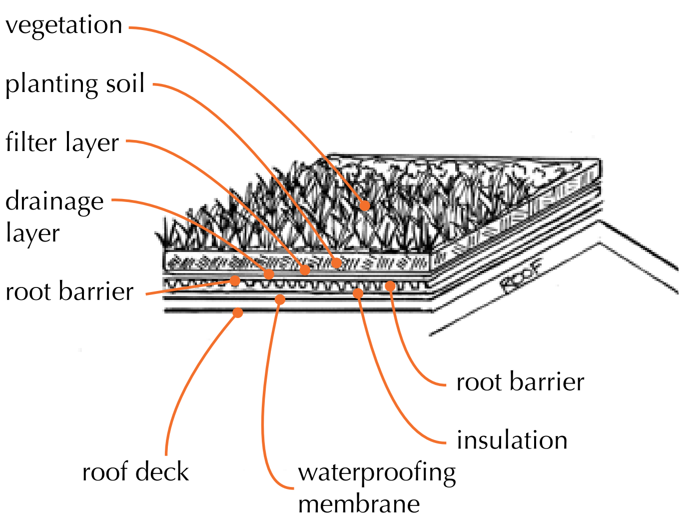
Considerations:

- For ADA compliance, runnels must include an ADA compliant cover like a steel grate (also called trench drain)
- Must be slightly sloped in order to move water effectively

Slope	Optimal Use	Dimensions	Spacing
0.5-3% desired slope toward outlet	To direct stormwater to other green infrastructure tools; sidewalks and plazas	Typically 10-36" wide	n/a

Sources: "Channels and Runnels"

GREEN ROOF



Description:
Though not traditionally considered part of the streetscape, green roofs are an important green infrastructure strategy. Just like paved areas replaced with vegetation, green roofs placed on structurally sound, often flat roofs intercept and retain stormwater before it reaches the street.

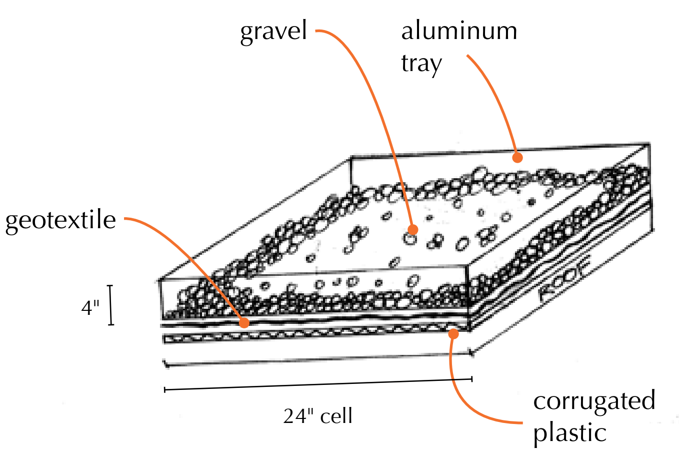
Benefits:
- Intercepts and treats stormwater, improving water quality
- Regulates building temperatures, reducing energy demand for heating and cooling
- Provides wildlife habitat and pollution mitigation
- Increases lifetime of roofing material

Considerations:
- Roof must be able to bear additional weight of green roof
- Initial costs are often greater, though savings can be achieved over time through increased building efficiency

Slope	Optimal Use	Dimensions	Spacing
Roofs 0-30º	Building roofs, bus shelters, pocket park awnings	Extensive system <6" soils; intensive system >6" soils	n/a

Sources: "F.A.Q."

BLUE ROOF



Description
Blue roofs consist of non-vegetated cells that temporarily detain stormwater during peak flows and slowly release it over time into the grey infrastructure system or adjacent green infrastructure.

Benefits:
- Reduces peak stormwater flows
- Less expensive than green roofs
- Coupled with lightly colored materials, can reduce cooling demand

Considerations:
- Does not reduce overall stormwater runoff as effectively as green roof
- Roof must be able to bear additional weight of blue roof

Slope	Optimal Use	Dimensions	Spacing
Usually flat roofs	Building roofs	Typical cell 24" x 24" x 4"	n/a

Sources: "Green Roofs/Blue Roofs"

RECOMMENDED PLANTS FOR GREEN INFRASTRUCTURE TOOLS

Plants are vital to green infrastructure systems, helping slow, infiltrate, and cleanse runoff. Naturalized green infrastructure systems process runoff similar to how a forest, meadow or wetland would. Integrating these systems into an urban environment requires accommodating the needs of plants to ensure their health and longevity.

The following plant list is derived primarily from New York City's Standards for Green Infrastructure and Cornell University Department of Horticulture's Recommended Urban Trees, yet is not an exhaustive list. Plants are identified for their suitability to various site conditions including sun exposure, moisture tolerance, height, bloom time, color, and native status relative to North America. Hardy, salt-tolerant, perennial species native to New England are most recommended here. A horticulturalist or urban forester should be consulted in selecting a plant palette appropriate for specific Tools. The plants should be monitored over time to determine which species are performing optimally under certain site conditions, and planting plans for future systems updated accordingly. Establishment of and care for plants in the first two years such as regular watering and weeding is critical to the longevity and effectiveness of the Green Infrastructure Tools. Avoid soil compaction during construction to promote optimum root growth and water infiltration.

Shrubs are excluded from this list to reduce woody obstacles that would complicate winter snow storage. Species native to North America are encouraged for their resiliency to the local climate and habitat value. Flowering annuals and spring blooming bulbs may also be included for increased color and curb appeal.

Wildflowers, Grasses, and Rushes

Scientific Name	Common Name	Height	Sun Exposure	Bloom Time & Color	**Wetland Indicator Status** (Moisture Tolerance)	Native Status
Acorus americanus	Sweet Flag	2'	full sun	May-July/green flower	OBL (wetter conditions)	non-native
Agastache foeniculum	Anise Hyssop	3'	sun	June-Sept	medium/dry	native
Asclepias incarnata	Swamp Milkweed	5'	sun	June-Aug/pink flowers	OBL (wet-medium wet conditions)	native
Echinacea purpurea	Eastern Purple Coneflower	4'	full or partial sun	July-Sept/red-purple	NI (medium wet to dry)	native
Eupatorium dubium var. *Baby Joe*	Baby Joe Pye weed	2'	full sun or partial shade	July-Sept/Mauve-Lilac	wet-average moister	native
Iris versicolor	Northern Blue Flag	2-3'	full sun to partial shade	May- July/Blue	OBL (medium-wet soils)	native
Juncus effusus	Common Soft Rush	2'	sun	Brown showy seed head	OBL (medium-wet soils)	native
Lobelia cardinalis	Cardinal Flower	5'	full sun to partial shade	July-Sept/Scarlet Red	OBL (moist soils)	native
Monarda fistulosa	Wild Bergamot	2-5'	full sun to partial shade	July-August/Pink to Purple	dryer conditions	native
Nepeta var. *faassenii*	Walkers Low Catmint	2.5'	full sun to part shade	April-Sept/Lavender Blue	dry to medium moister soil	non-native
Panicum virgatum var. *Heavy Metal*	Heavy Metal Switchgrass	4'	full sun to part shade	July-February	FAC (wet to dry soils)	native
Rudbeckia fulgida	Black-eyed-Susan	3'	sun	July-Sept/Orange	OBL (dry to wet soils)	native
Schizachyrium scoparium	Little Bluestem	3'	sun-partial shade	Aug-Oct/Blue, Brown	medium to dry soil moisture	native
Andropogon gerardii var. *Vitman*	Big Bluestem	6'	sun-partial shade	July-Oct/Purple, Brown	FAC (wet to dry soils)	native
Solidago rugosa cv. *Fireworks*	Fireworks Goldenrod	1-3.5'	Sun-moderate shade	Aug-Oct/Yellow	FAC (wet to dry soils)	native
Symphyotrichum novae-angliae	New England Aster	5'	Full sun to light shade	Aug-Oct/Violet,Pink	FACW	native
Vernonia noveboracensis	New York Ironweed	7'	Sun to partial shade	Aug-Oct/Purple	FACW	native

Wetland Indicator Status: *NI = insufficient information to determine status; UPL = obligate upland, almost never occur in wetlands; FACU = usually in non-wetlands; FAC = faculative (equally likely to occur in wetlands or non-wetlands, probability 34-66%); FACW = faculative wetland (usually occurs in wetlands, but occasionally in non-wetlands, probability 67-99%); OBL = obligate wetland (occur in permanently or semi-permanently flooded wetlands, probability >99%). Source: USDA.*

Trees

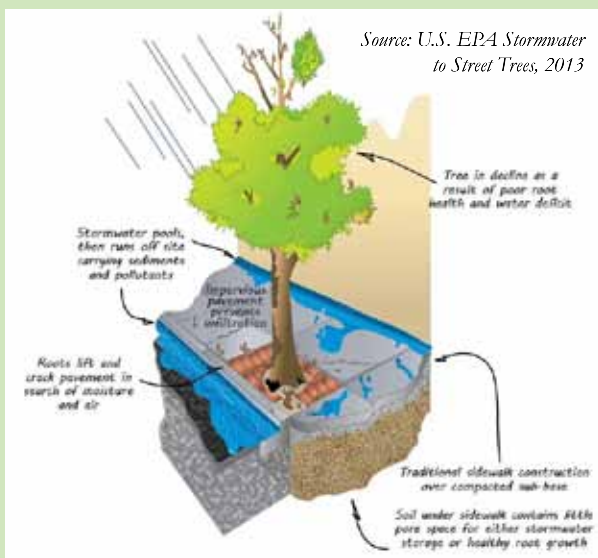
Scientific Name	Common Name	Height	Sun Exposure	Bloom Time & Color	**Wetland Indicator Status** (Moisture Tolerance)	Native Status
Acer campestre	Hedge Maple	25-35'	full sun	April-May/yellow-green	NI	non-native
Cercis canadensis	Eastern Redbud	15-30'	full sun to part shade	April/pink	FACU	native
Cornus mas	Cornelian Cherry Dogwood	20'	sun-part shade	Early spring/yellow	NI	non-native
Crataegus phaenopyrum	Washington Hawthorn	25-30'	full sun	June/white	FAC	native
Ginkgo biloba	Ginkgo	50-80'	full sun	April/green	NI	non-native
Koelreuteria paniculata	Goldenrain Tree	30'	full sun	Mid-summer/yellow	NI	non-native
Platanus x *acerifolia*	London Planetree	70-100'	full sun	April/yellow or red	NI	non-native
Acer pseudoplatanus	Sycamore Maple	40-60'	full sun-part shade	Spring/yellow-green	NI	non-native
Ulmus parvifolia	Lace Bark Elm	40-75'	full sun	inconspicuous	UPL	non-native
Quercus robur	English Oak	40-60'	full sun	Spring/yellow-green	UPL	non-native
Celtis occidentalis	Hackberry	50-60'	full sun-part shade	inconspicuous	FACU	native
Gleditsia triacanthos var. *inermis*	Honey Locust	40-80'	full sun	inconspicuous	FAC	non-native
Pyrus ussuriensis	Ussurian Pear	20-25'	full sun	Spring/white	UPL	non-native
Robinia pseudoacacia	Black Locust	25'	full sun-shade	Late spring/white	FACU	native
Sorbus x thuringiaca	Oak-Leafed Mountain Ash	25-35'	full sun-part shade	Spring/white	UPL	non-native

Trees on the above list are suitable for structural soil.

TREES IN THE CITY

Trees provide massive benefits to urban environments and their inhabitants, and become more effective as they mature. Designing for healthy, long-lived trees by providing proper space for roots and canopies to grow should be a priority for all green infrastructure projects. According to *American Forests*, urban trees provide many vital services:

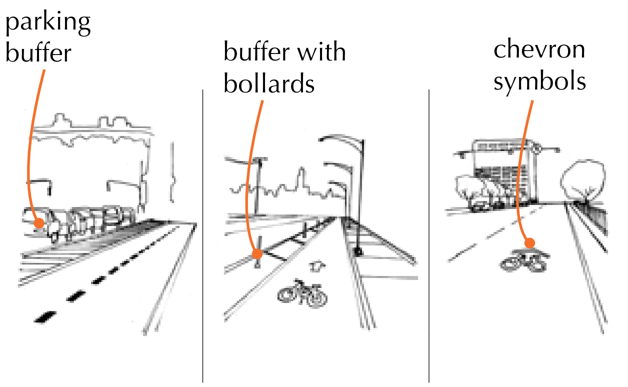
- **Trees help manage stormwater and prevent CSOs**
  - *One tree can intercept 760 gallons of rainwater in its crown*
- **Trees can reduce energy demand and urban heat islands**
  - *Three well-placed trees can reduce air-conditioning costs by 30% in the summer*
- **Trees improve the urban experience for residents**
  - *A dense area of trees can reduce urban noise by 50% or more*
- **Trees can help mitigate climate change**
  - *Urban trees in the lower 48 U.S. states store 770 million tons of carbon, worth $14.3 billion*
- **Trees can help cities adapt to climate change**
  - *Through shade and evapotranspiration, trees reduce urban heat islands, which are expected to worsen with climate change*



Urban street trees are often short-lived due to initial design failures. Proper soil volume is vital to a tree's success. For a mature tree with an approximately 30' spread, 1,000 cubic feet of soil is optimal.

Source: "Tree Facts." *American Forests*

BIKE LANES



protected two-way bike lane | one-way bike lane (protected or unprotected) | shared lane (for cyclists and cars)

not to scale

Description:
Bike lanes are roadside areas designated only for cyclists to increase safety and comfort of cycling. They can come in a variety of forms, including **protected two-way bike lanes**, which allow for two-way bicycle travel protected from vehicular traffic either by parking, a 2-3' buffer, or bollards; **one-way bike lanes**, which often travel in the same direction as vehicular traffic on roadsides; and **shared lanes**, which are travel zones shared by both cyclists and motorists, designated by chevron symbols in the lane.

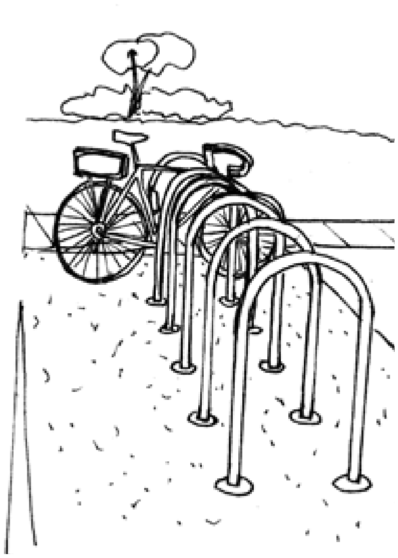
Benefits:
- Increased bicycle safety and use, especially with lanes protected by bollards, buffers, or vegetation
- Increased bicycle visibility and awareness

Considerations:
- Adding bike lanes to existing roads means lanes, parking, or sidewalks may have to be narrowed or removed
- Painted lanes increases visibility and awareness of cyclists, but increases costs

Dimensions	Optimal Use
Lanes 4-6' wide	Along roadsides

Sources: New York City Department of Transportation (2013), NACTO (2013)

BIKE PARKING



not to scale

Description:
An important complement to bike lanes, bike parking provides safe, designated areas for cyclists to lock up their bikes. They can come in a variety of forms and can double as aesthetic streetscape elements.

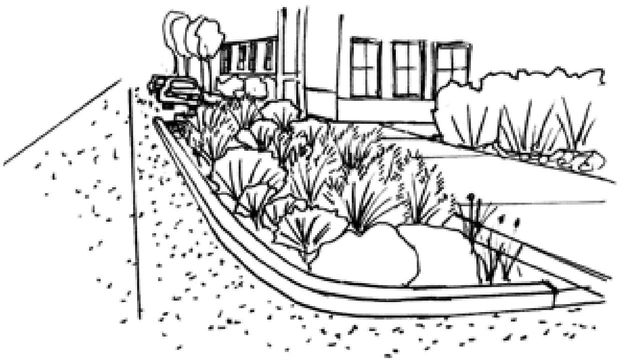
Benefits:
- Promotes cycling as form of transportation, potentially decreasing dependence on motorized transportation and reducing carbon emissions and pollution
- Provides an opportunity to engage local artists in the design of bike racks and parking areas

Considerations:
- May require the displacement of vehicular parking or sidewalk space

Dimensions	Optimal Use
Typically accommodates a 6' long bike	Along roadsides, parklets, in place of vehicular parking

Sources: New York City Department of Transportation (2013), NACTO (2013)

BUMP-OUT



not to scale

Description:
Bump-outs extend the sidewalk toward the center of the street, visually and physically narrowing the roadway and providing space for pedestrians, plantings, and other street amenities. Bump-outs may be applied at intersections to increase pedestrian visibility and decrease crossing distances, mid-block to calm traffic, or at bus stops as "bus bulbs" to increase efficiency of bus travel and the safety of waiting riders.

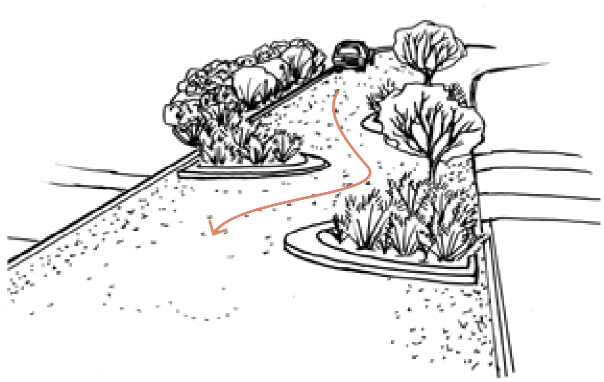
Benefits:
- Slows traffic; increases pedestrian visibility
- May be planted and paired with green infrastructure strategy or paved

Considerations:
- Bus bulbs should be at least the length of one bus and 6-10' wide
- When combined with plantings, maintain sight lines

Slope	Optimal Use	Dimensions	Spacing
Any slope	Mid-block; intersections; bus stops (bus bulb)	Varies by use; often size of on-street parking space or 2' narrower; bus bulbs larger	Varies

Sources: National Association of City Transportation Officials; New York City Department of Transportation (2013); NACTO (2013)

CHICANES



not to scale

Description:
A chicane is a traffic-calming tool that uses often vegetated bump-outs to create an "S" curve that drivers must maneuver through, slowing speeds as they approach and travel through. Chicanes also provide an opportunity to increase the amount of green infrastructure and sidewalk space available on a street.

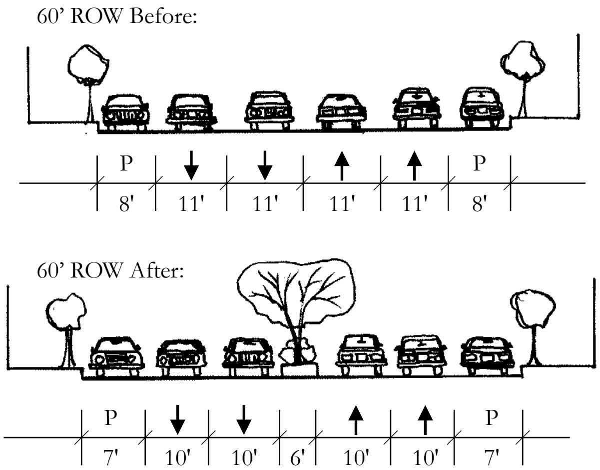
Benefits:
- Slows traffic
- Increases opportunity for stormwater infiltration
- Increases aesthetic appeal of street

Considerations:
- Low vegetation is recommended to preserve sight lines
- Other traffic-calming tools such as speed tables or speed bumps may be a desirable alternative
- Consider cyclists and snow removal systems

Slope	Optimal Use	Dimensions	Spacing
Adaptable; consider limitations of green infrastructure tool used	To calm traffic; 1 or 2 way streets	Varies based on desired vehicular speed	Varies based on desired vehicular speed

Sources: New York City Department of Transportation (2013), NACTO (2013)

LANE DIET



not to scale

Description:
A lane diet is the process of reducing lane widths while retaining the existing number of lanes. Vehicular lanes are often wider than necessary, which promotes higher speeds and allocates more right-of-way space to vehicles.

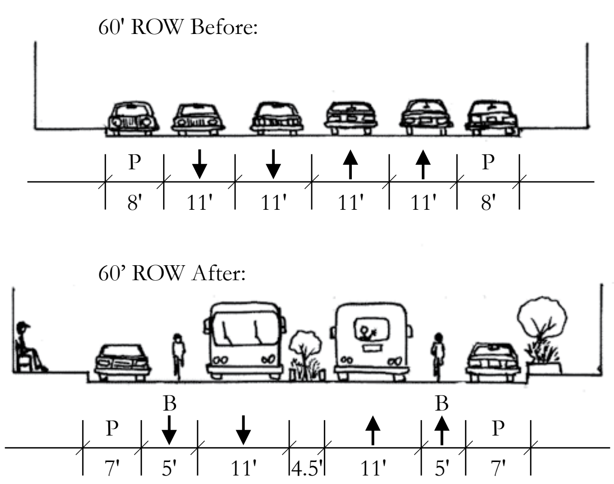
Benefits:
- Calms traffic
- Reduces street crossing widths for pedestrians and cyclists, promoting safety
- Provides space for other road uses
- Can be applied to road reconstruction, resurfacing, or restriping projects

Considerations:
- If the road has a truck or bus route, lanes must be a minimum of 11' wide

Optimal Use	Dimensions
Streets with lanes wider than 10'	11-12' driving lanes for truck and bus routes, 10' for local roads

Sources: New York City Department of Transportation (2013), NACTO (2013)

ROAD DIET



not to scale

Description:
A road diet is the process of removing vehicular lanes from a right-of-way to make room for other uses such as bicycle lanes, green infrastructure, widened sidewalks, or parking.

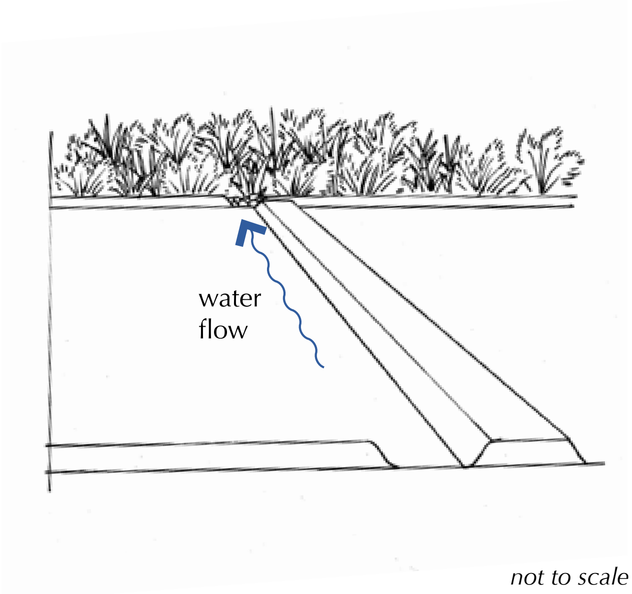
Benefits:
- Provides space for other road uses
- Can be applied to road reconstruction, resurfacing, or restriping projects
- Can increase road safety for all users

Considerations:
- A capacity analysis should be conducted to determine if a street is a candidate for a road diet
- Only applies to streets with more than one lane traveling in a given direction
- Can be combined with lane diet (see above)

Optimal Use	Dimensions
Multi-lane roads not at capacity	11-12' driving lanes for truck and bus routes, 10' for local roads

Sources: New York City Department of Transportation (2013), NACTO (2013)

SPEED BUMP / WATER BAR



Description:
A speed bump / water bar is a bump in the road that serves both to slow vehicular traffic as well as direct stormwater to adjoining green or grey infrastructure systems. It is recommended for lower-traffic roads where water needs to be channeled.

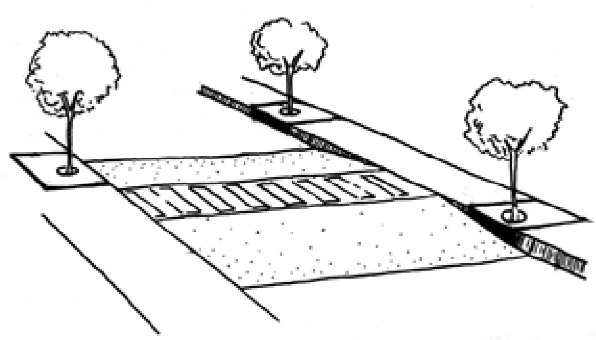
Benefits:
- Calms traffic
- Directs stormwater to adjacent green or grey infrastructure
- Good for moderately steep slopes where stormwater interception is necessary

Considerations:
- For higher-traffic or commercial areas, consider using the speed table (below) as an alternative

Optimal Use	Dimensions
Sloped low-traffic roads where green infrastructure tools will be implemented	3-6"

Sources: New York City Department of Transportation (2013), NACTO (2013)

SPEED TABLE



Description:
A speed table is an elongated speed bump, often doubling as a crosswalk, that calms traffic and increases visibility of pedestrian crossings. It provides a more comfortable crossing for vehicles than a speed bump while also effectively reducing travel speeds.

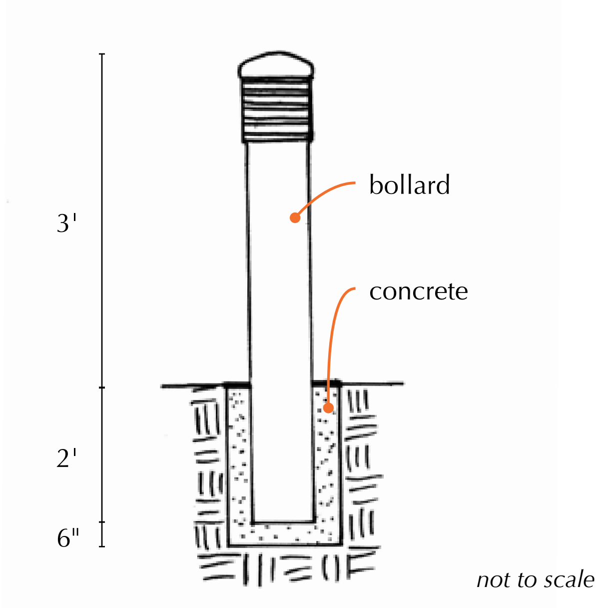
Benefits:
- Reduces travel speeds
- Provides safer crossing opportunities

Considerations:
- Consider snow removal operations
- Avoid placing at the bottom of a steep hill, where cyclists traveling at fast speeds may be endangered
- Speed tables are most effective when applied with other traffic-calming tools such as increased vegetation, chicanes, or lane diets.

Slope	Optimal Use	Dimensions	Spacing
Adaptable; avoid at bottom of steep slopes	To calm traffic; for speeds of 25-30 mph; best utilized in series	Typically 22' long, 3-6" higher than roadway	Varies

Sources: New York City Department of Transportation (2013), NACTO (2013)

BOLLARD



Description:
A bollard can be a permanent or removable fixture in the street that provides a boundary between different modes of travel or different zones of use within a right-of-way. They can protect cyclists, pedestrians, and specific areas from vehicle use. As removable features, they can redefine the use of a space for weekends or events, or can be removed in the winter for snow removal or emergency vehicle access.

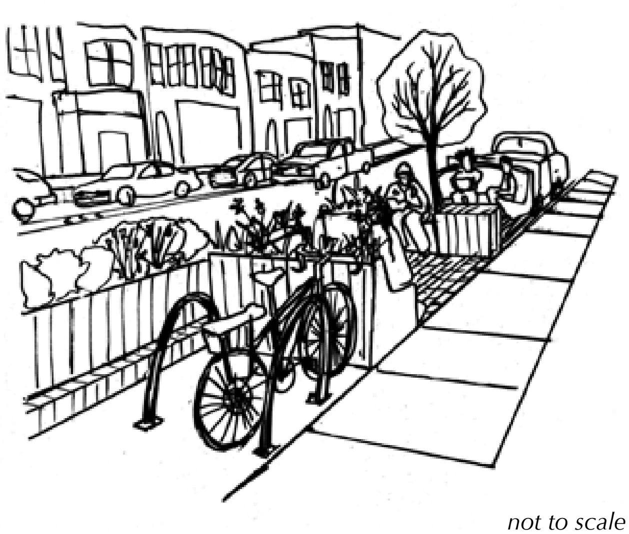
Benefits:
- Increased legibility and safety of different zones of use
- Temporary bollards can diversify the uses of a street space

Considerations:
- Can be expensive
- Requires maintenance to uninstall and reinstall removable bollards and to fix damaged bollards

Slope	Optimal Use	Dimensions	Spacing
Any	Between bike and road lanes, to block off streets, around pedestrian-only zones	Typically 3' tall, 4" diameter, with 2' encased below ground	Enough to prevent vehicular access

Sources: New York City Department of Transportation (2013), NACTO (2013)

PARKLET



Description:
Often installed on busier commercial streets, a parklet converts one or more on-street parking spaces to a small park open to the public. They serve to extend the pedestrian zone and encourage people to linger and interact.

Benefits:
- Temporary parklets can test the success of the feature in an area and make way for more permanent installations
- Often engages adjacent businesses, residents, and artists in maintenance and design

Considerations:
- Not suitable for all areas; consider parking restrictions, waste pick-up, emergency access, bus stops, and adjacent land use (commercial is preferred)
- May require maintenance agreements with local businesses and residents

Slope	Optimal Use	Dimensions	Spacing
Minimal preferred for seating comfort, though designs can adjust to slopes	Commercial streets with high pedestrian activity; to extend businesses onto street	Width of parking lane, length dependent on amount of parking removed	Varies

Sources: New York City Department of Transportation (2013), NACTO (2013)

TEMPLATES

TEMPLATES

WHAT ARE THE TEMPLATES?

The Green Streets Templates are conceptual designs that exemplify how the principles and tools discussed in this guidebook can be applied to the variety of streets that exist throughout the city. Based on a hypothetical but representative set of physical characteristics, the Templates serve as basic design formats and a simple reference for users to implement Green Streets. Each Template represents a 100' long segment of the middle of a ROW.

HOW ARE THEY USED?

The Templates provide a model for Green Street design based on varying street characteristics. Users with a specific street in mind should first define the most significant physical characteristics of that right-of-way, including the ROW typology, slope, land use, speed limit, and functional road classification. Comparing these characteristics to those of the templates (page 31), the user can jump to the most similar Template or Templates, which serve as the basis for a Green Street design. Though the Templates are unable to adequately represent all the different types of streets found in the city, each Template page contains additional recommendations for how the design can be adapted to meet a number of different site conditions. Additionally, design elements from different Templates can be combined. Toolbox icons allow Tools used to be easily identified and compared between Templates, and refer to more detailed drawings and descriptions in the Toolbox section.

Without a specific street in mind, Templates can educate and inspire users about future projects. Together, they illustrate the potential for green streets to be widely applied throughout Holyoke.

DESIGN PROCESS

A four-step design process (below) was developed to create the nine Templates in this chapter and the site-specific designs in the following. The process acknowledges that, out of necessity, Templates are simplifications of actual right-of-way conditions in Holyoke, and the process provides a framework for generating designs which apply the Green Streets principles in response to existing physical conditions. The nine Templates in this chapter demonstrate the range of strategies and Tools that can be applied to streets, but all are adaptable. By revisiting this design process, guidebook users can select and modify templates to apply to specific streets.

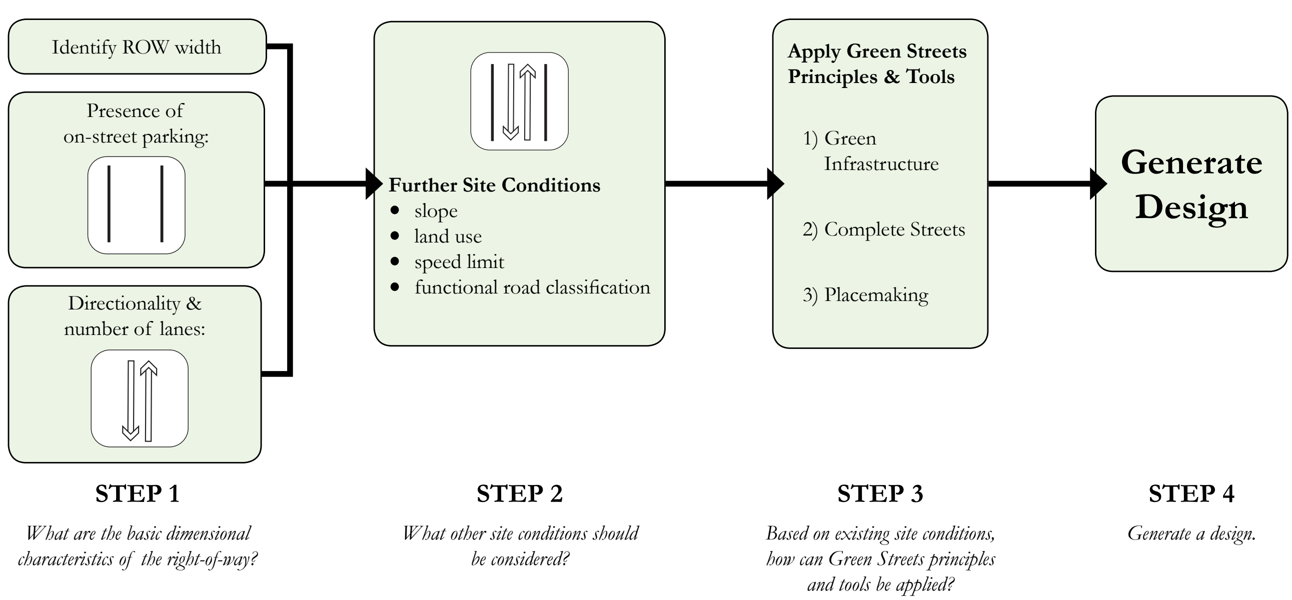
For each Template, hypothetical goals were envisioned, based on each Template's combined criteria. Then, strategies from each principle of Green Streets (green infrastructure, complete streets, and placemaking) were selected based on their ability to achieve each Template's identified goals.

In order to create appropriate, hypothetical goals for each Template, assumptions were made about the imagined circumstances in which they would be used:

1. All templates were designed to maximize stormwater infiltration, except for templates where placemaking was prioritized.
2. Residential neighborhoods were prioritized for traffic calming strategies and more on-street parking.
3. Commercial areas were prioritized for more pedestrian amenities.
4. The Templates assume the City of Holyoke will buy a vacuum for permeable surface maintenance; porous asphalt is recommended for all streets and pervious concrete is recommended for all sidewalks.
5. Existing grey infrastructure, sewershed and CSO

DESIGN PROCESS

For Templates and Site-Specific Designs



status, underground utilities, hydrology, and seasonal maintenance were considered beyond the scope of the Templates.

METHODOLOGY

In order to create Templates representative of typical streets in Holyoke, ROW typologies (including width, number of lanes and directionality, and presence of on-street parking) and a list of the most influential existing characteristics (slope, land use, speed limit, and functional road classification) were developed based on a citywide assessment of conditions.

First, **ROW widths** were divided into 6 ranges: 20-20', 30-39', 40-49', 50-59', 60-69', and 80+', mapped, and the percent distribution of each was calculated (table below). ROWs 20-29' wide, representing only 0.9 percent of streets, were considered statistically insignificant and eliminated from the list of template typologies. ROWs 30-39' wide, 60-69' wide, and 80+' wide each constituted about 10 percent of the ROWs citywide and thus were only represented in approximately 10 percent of the Templates (one each), while the more abundant ROWs 40-49' and 50-59' wide were represented in three templates each.

The number and directionality of lanes and presence of on-street parking, which constitute the **ROW typologies**, were determined using Google Maps. Because of the large time investment this required, the study area for these two conditions was confined mostly to downtown (map below). Using ROW width, distribution, lane number and directionality, and presence of on-street parking, a set of nine ROW Typologies were developed, which served as the basis for developing the Templates.

Slopes were mapped by percent, with percent breaks defining limitations of green infrastructure tools (see Slopes, Drainage Patterns, and Flood Risk Areas page 9).

Land Use was mapped according to the most recent MassGIS data. Because the city anticipates changes in land use as a result of redevelopment, current industrial parcels were considered to be mixed-use industrial for the purposes of this project.

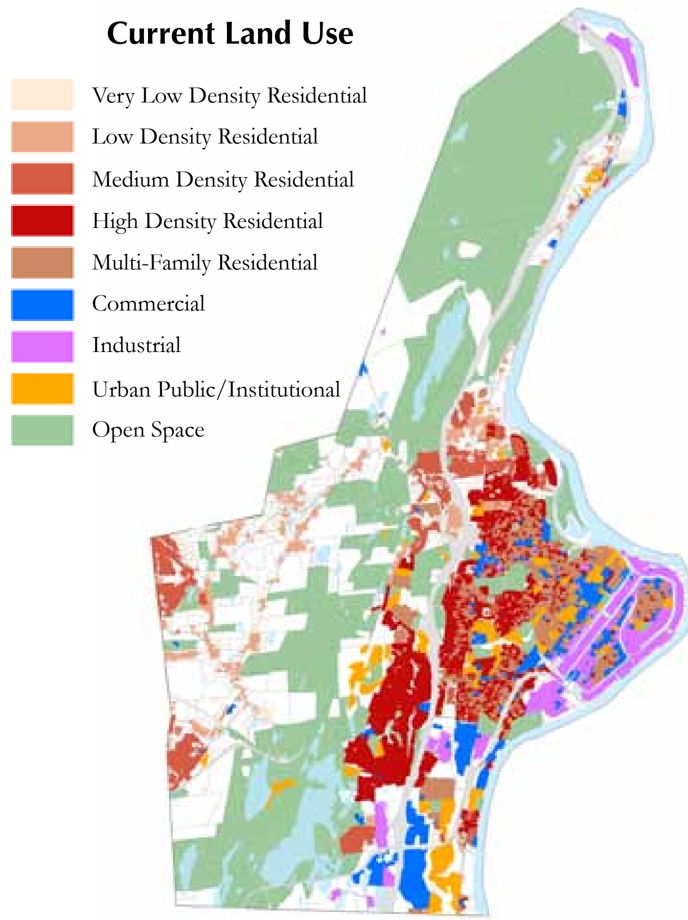
Lacking GIS data for **speed limits**, hypothetical speed limits were based on a mixture of sources: functional road classification, land use, on-the-ground experience, and Google Maps. Low speed limits (primarily 25mph) were prioritized due to their apparent abundance throughout the city, particularly downtown where the most ROW redevelopment is anticipated.

Functional Road Classification was mapped using MassGIS data and applied to templates based on width, speed limit, and examining specific streets.

ROW Widths, Lanes, and Parking

*Street widths are based on MassGIS data and are not necessarily accurate.

Current Land Use

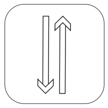
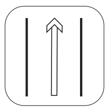
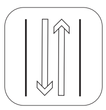
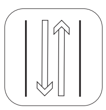
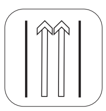
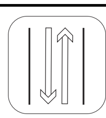
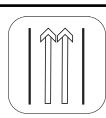
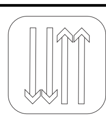


Distribution of ROW Widths

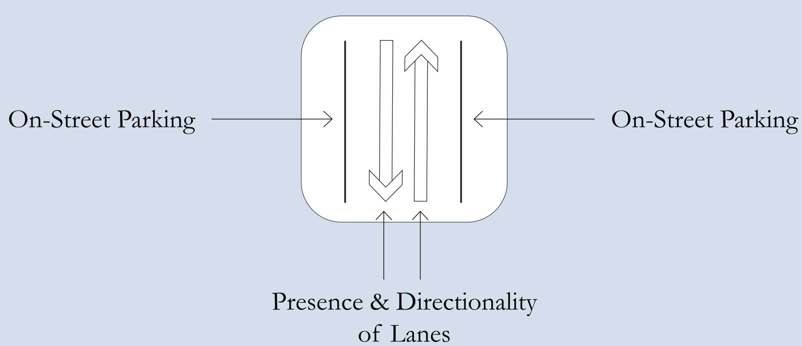
ROW Width*	Percent Distribution	Miles
20-29'	0.9%	2
30-39'	8.9%	20
40-49'	25.5%	57
50-59'	26.9%	61
60-69'	10.5%	24
80+'	10.9%	28

*Above width classes account for 84% of the total roads – the rest have no data and are not considered for the purpose of this analysis.

Templates: Street Characteristics

Template	Typology	Right-of-Way Width	Typical Slope	Typical Land Use	Typical Speed Limit	Functional Road Classification
T1		30' wide	6-15%	High-density residential	25 mph	Major Collector
T2		40' wide	2-5%	Low-density residential	25 mph	Major Collector
T3		44' wide	5-6%	Multi-family residential	25 mph	Major Collector
T4		48' wide	2-5%	Mixed-use industrial	25 mph	Major Collector
T5		50' wide	6-15%	Multi-family residential	25 mph	Other Principal Arterial
T6		54' wide	2-5%	Commercial & public/ institutional	25 mph	Major Collector
T7		58' wide	0-2%	Mixed-use industrial	35 mph	Minor Arterial
T8		68' wide	2-5%	Multi-family residential	25 mph	Other Principal Arterial
T9		108' wide	0-2%	Mixed-use & commercial	30 mph	Other Principal Arterial

Typology Break-Down



TEMPLATE 1

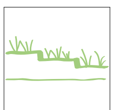
Street Characteristics					
⇅	30' wide	6-15% slope	High-density residential	25 mph	Major Collector

Even the narrowest streets can infiltrate stormwater close to its source with stormwater planters, porous hardscaping, and engaged neighbors who implement green infrastructure on their own properties. Interested residents can engage with the city to select plants that complement neighborhood identity.

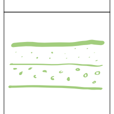
GOALS

- Maximize stormwater infiltration on narrow ROWs in the uplands
- Promote residential awareness of green infrastructure
- Minimize street widths to accommodate local traffic only and calm traffic

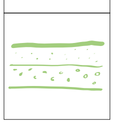
TOOLS



Stepped stormwater planter (page 16)



Pervious concrete (page 19)

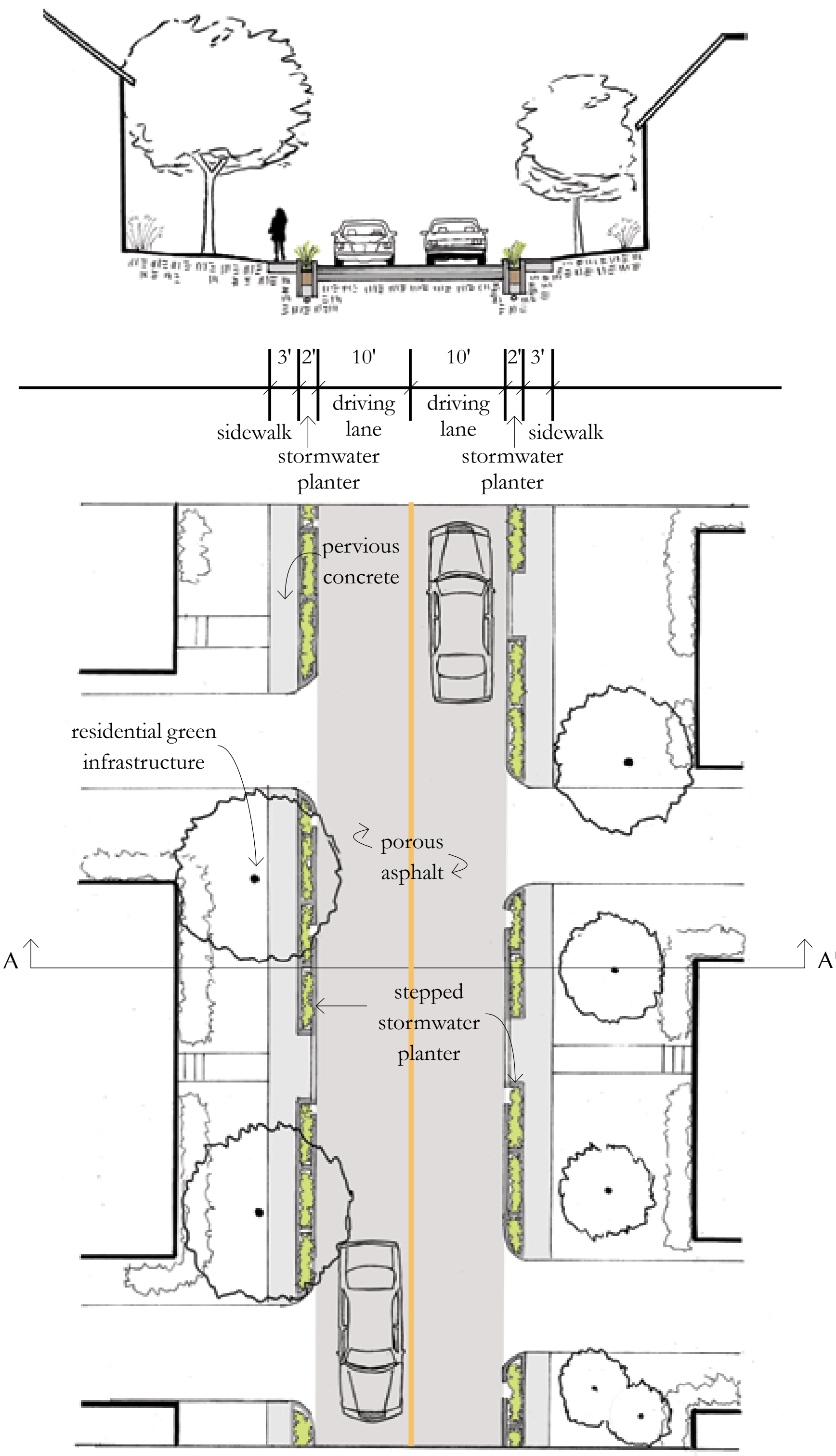


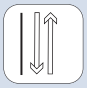
Porous asphalt (page 18)

ADDITIONAL CONSIDERATIONS

- ADA regulations require a minimum of 3' passable sidewalk, with 5' turnaround areas located at intersections and shown here between planters. Consider this when siting stormwater planters.
- Consider replacing stormwater planters with wider travel lanes according to transportation needs. Roads with truck and bus routes must have 11' driving lanes.
- With such narrow streets, engaging neighbors in intercepting and infiltrating stormwater may be the most effective green infrastructure approach. Encourage tree-planting and rain gardens on private properties where ROW widths are minimal.
- Consider engaging residents in plant selection process.

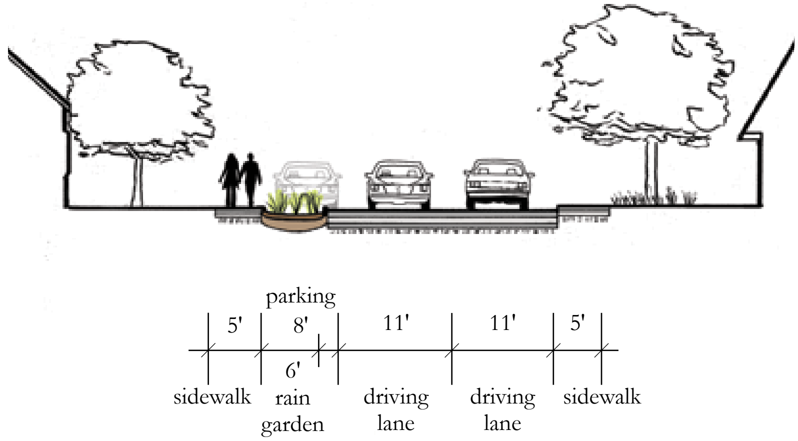
SECTION A – A'

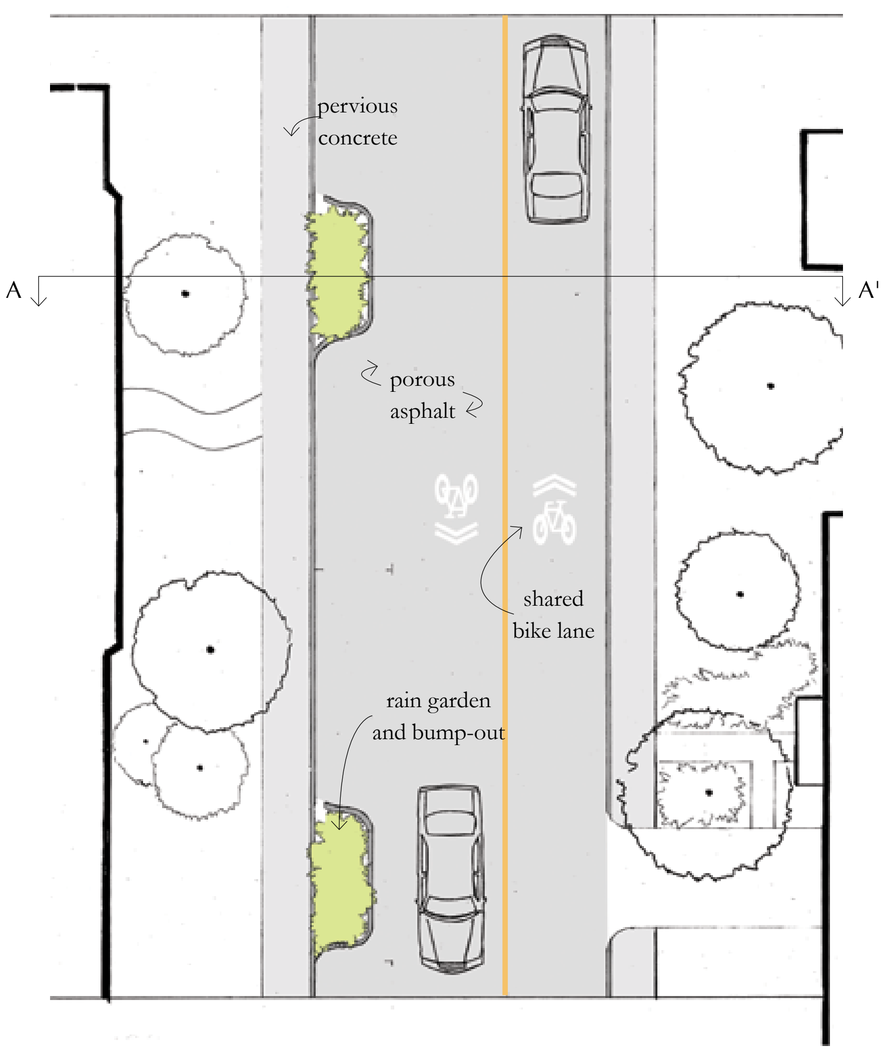


Street Characteristics						TEMPLATE 2
	40' wide	2-5% slope	Low-density residential	25 mph	Major Collector	

Rain gardens with strategically placed inlets can provide stormwater infiltration without connecting to the existing grey infrastructure system while maintaining most on-street parking and calming traffic.

SECTION A – A'

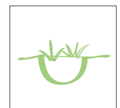
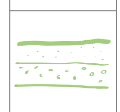
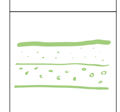
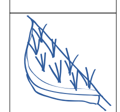
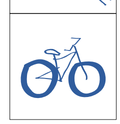




GOALS

- Retain most on-street parking
- Infiltrate stormwater without connecting to grey infrastructure system; minimal excavation
- Calm traffic
- Accommodate cyclists
- Provide community-building opportunities

TOOLS

	Rain garden (page 16)
	Pervious concrete (page 19)
	Porous asphalt (page 18)
	Bump-out (page 24)
	Bike lane (page 23)

ADDITIONAL CONSIDERATIONS

- Rain gardens can be implemented in areas where least excavation is desired.
- When siting rain garden, consider provisions for stormwater overflow.
- For slopes above 5%, consider stepped stormwater planter.
- If road is wider, rain garden bump-outs may be placed on both sides of the road. Also consider including designated bike lanes.
- Encourage neighboring residents to volunteer to help maintain bioswales and to install additional green infrastructure on their own properties.

TEMPLATE 3

Street Characteristics					
⇈	44' wide	5-6% slope	Multi-family residential	25 mph	Major Collector

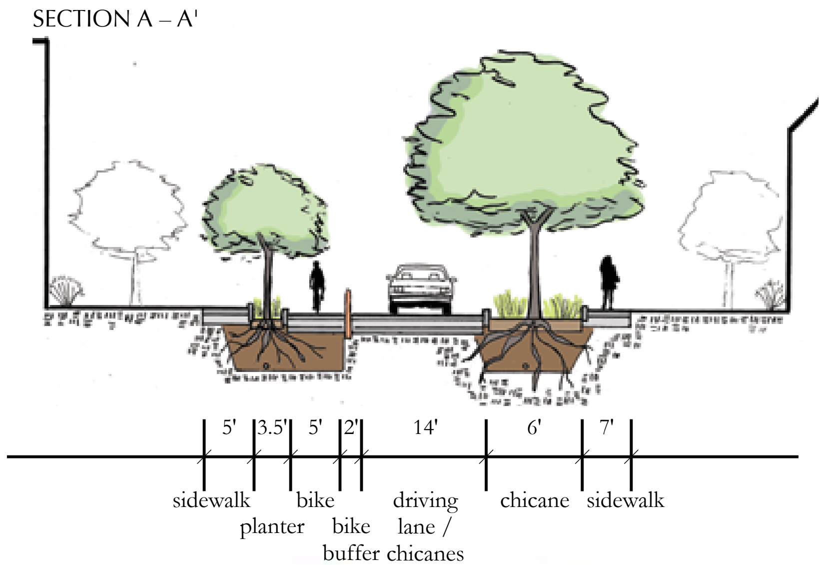
In busy residential neighborhoods, chicanes slow traffic while intercepting large amounts of stormwater, which is additionally captured and treated by stormwater planters and neighboring tree trenches.

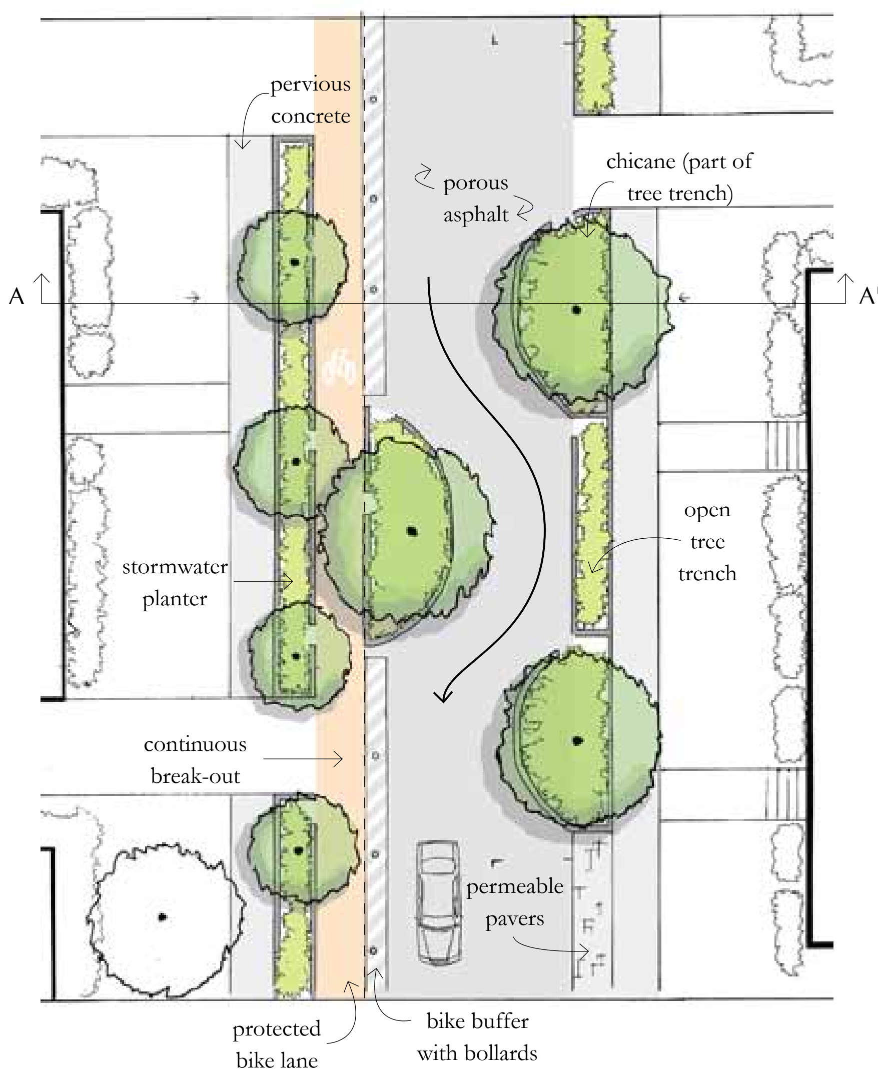
GOALS

- Calm traffic
- Intercept and infiltrate stormwater on steep slopes in the uplands
- Protect cyclists from vehicular traffic
- Provide shade

TOOLS

- Open tree trench (page 15)
- Pervious concrete (page 19)
- Porous asphalt (page 18)
- Chicanes (page 24)
- Bike lane (page 23)
- Bollards (page 27)
- Break-out (page 14)





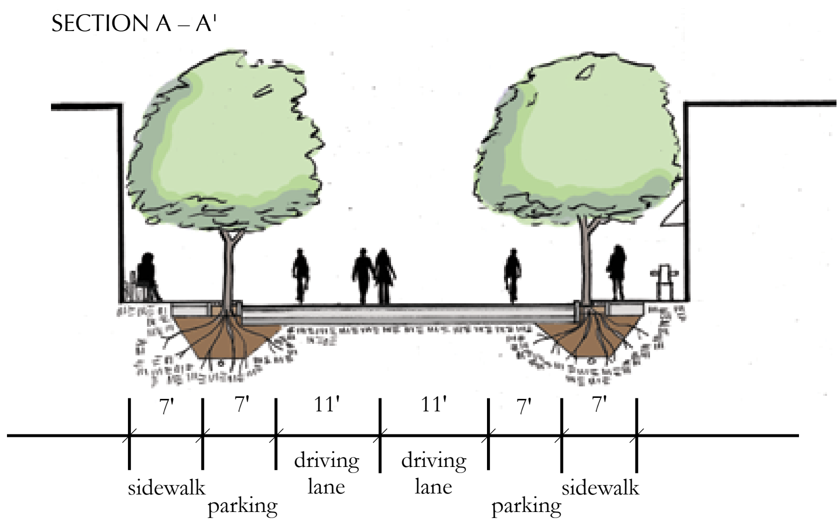
ADDITIONAL CONSIDERATIONS

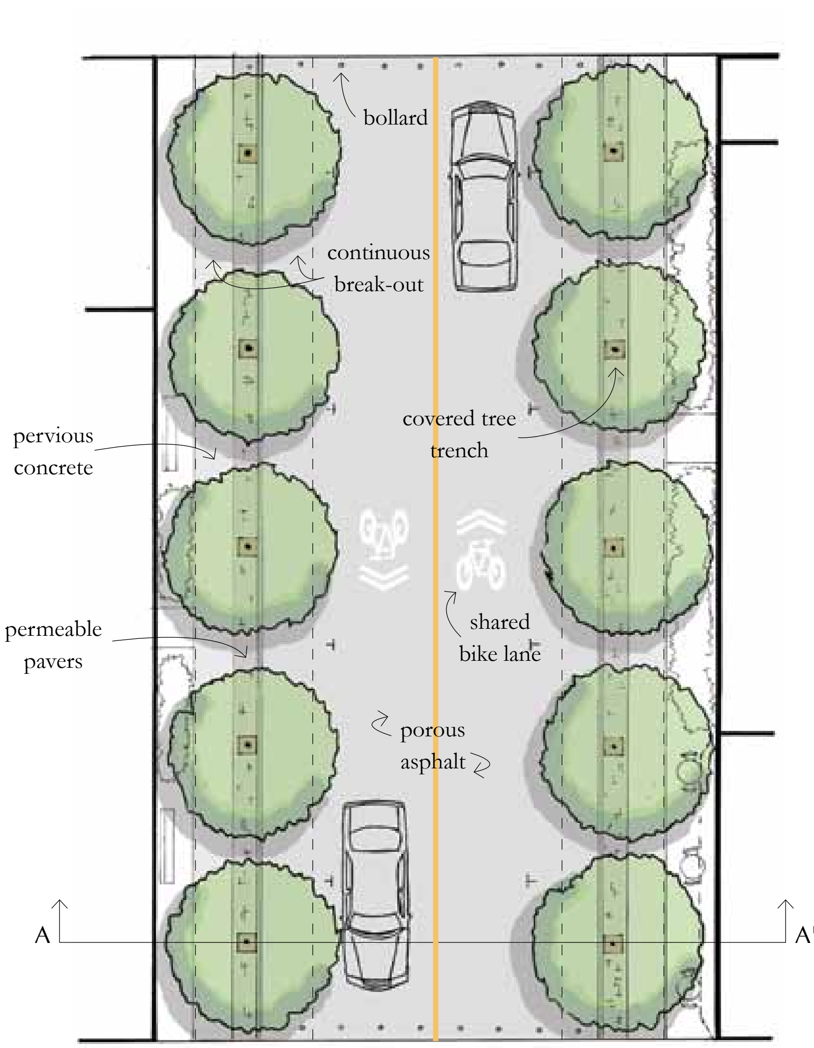
- Tree trench along sidewalk could be replaced with stormwater planter with trees.
- Bike buffer could just be striped without using bollards to avoid removal for snow plowing.
- Chicane could consist of two bump-outs instead of three, allowing parking to alternate from one side of the street to another.

Street Characteristics					
	48' wide	2-5% slope	Mixed-Use Industrial	25 mph	Major Collector

TEMPLATE 4

Using removable bollards, streets can be temporarily closed off to vehicular traffic, restricting use to pedestrians and cyclists for weekends and special events such as farmers markets or Art Walks. Covered tree trenches maximize stormwater infiltration while increasing pedestrian crossing points.





GOALS

- Provide pedestrian-only on-street weekend and event flex-space
- Infiltrate stormwater
- Provide shade for pedestrians

TOOLS

- Covered tree trench (page 15)
- Permeable pavers (page 18)
- Pervious concrete (page 19)
- Porous asphalt (page 18)
- Break-out (page 14)
- Bike lane (page 23)
- Bollard (page 27)

ADDITIONAL CONSIDERATIONS

- This pedestrian-friendly alternative should be prioritized in arts and commercial areas in order to engage the community in creating adaptable, vibrant flex-spaces.
- Ensure trees have enough room to grow unimpeded when buildings directly abut the sidewalk.
- On streets with slopes greater than 5%, stepped stormwater planters may be appropriate.
- For wider streets, consider widening the sidewalk or including designated bike lanes.

Template 5

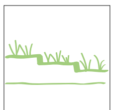
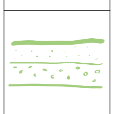
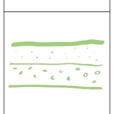
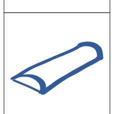
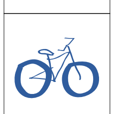
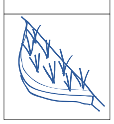
Street Characteristics					
	50' wide	6-15% slope	Multi-family residential	25 mph	Other Principal Arterial

Bump-out stormwater planters placed at the midpoint of a street along with a speed bump that intercepts and directs stormwater on steep slopes calm traffic while maximizing stormwater infiltration.

GOALS

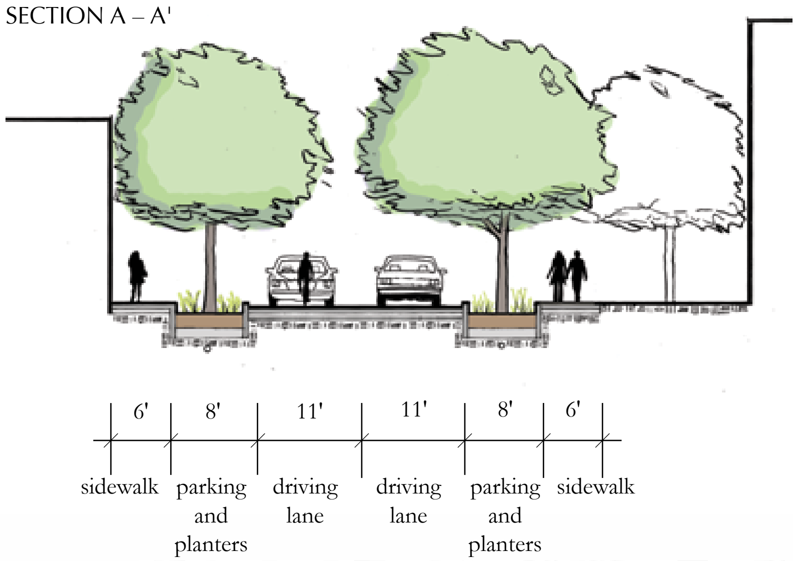
- Infiltrate and direct stormwater on steep slope
- Calm traffic
- Maintain most of the on-street parking for residents

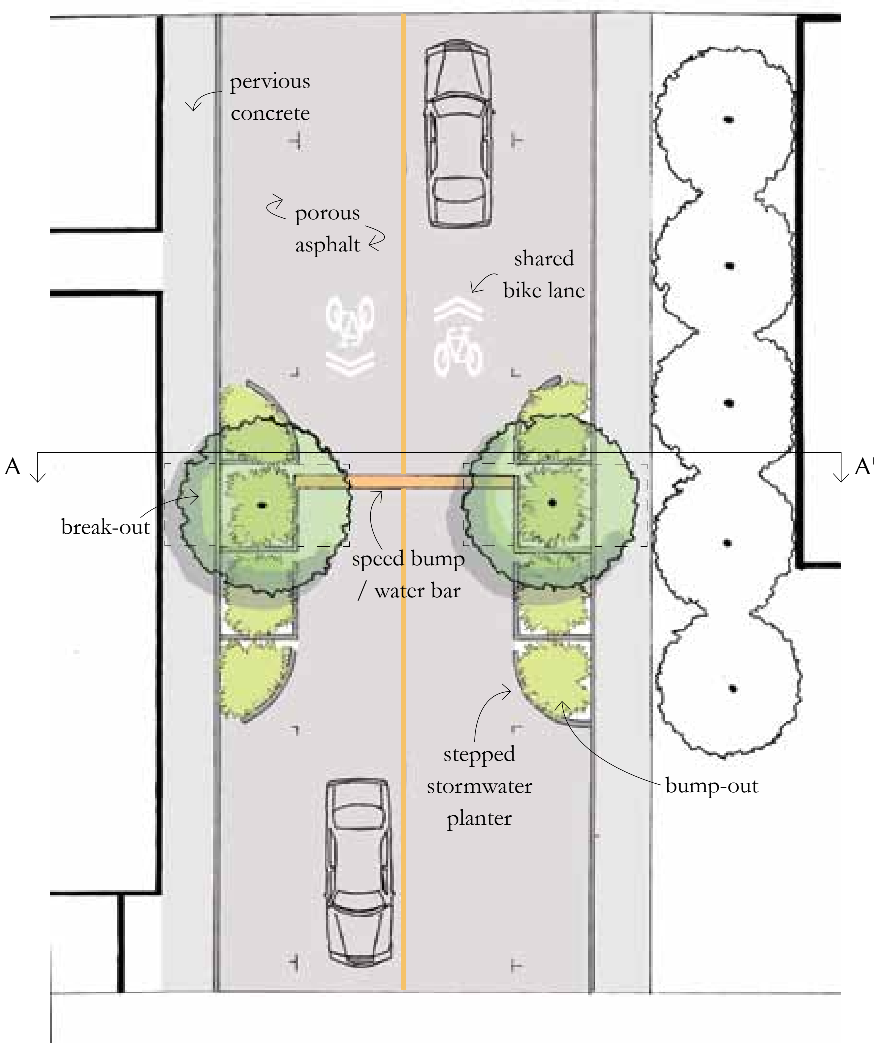
TOOLS

	Stepped stormwater planter (page 16)
	Porous asphalt (page 18)
	Pervious concrete (page 19)
	Speed bump / water bar (page 26)
	Bike lane (page 23)
	Bump-out (page 24)

ADDITIONAL CONSIDERATIONS

- If slope is 5% or less, consider replacing the stepped stormwater planter with another green infrastructure tool such as a stormwater planter.
- If ROW is wider, consider adding designated bike lanes or widening the sidewalk.
- When trees are planted in stepped stormwater planters, increase depth of soil in stormwater planters and add break-outs.

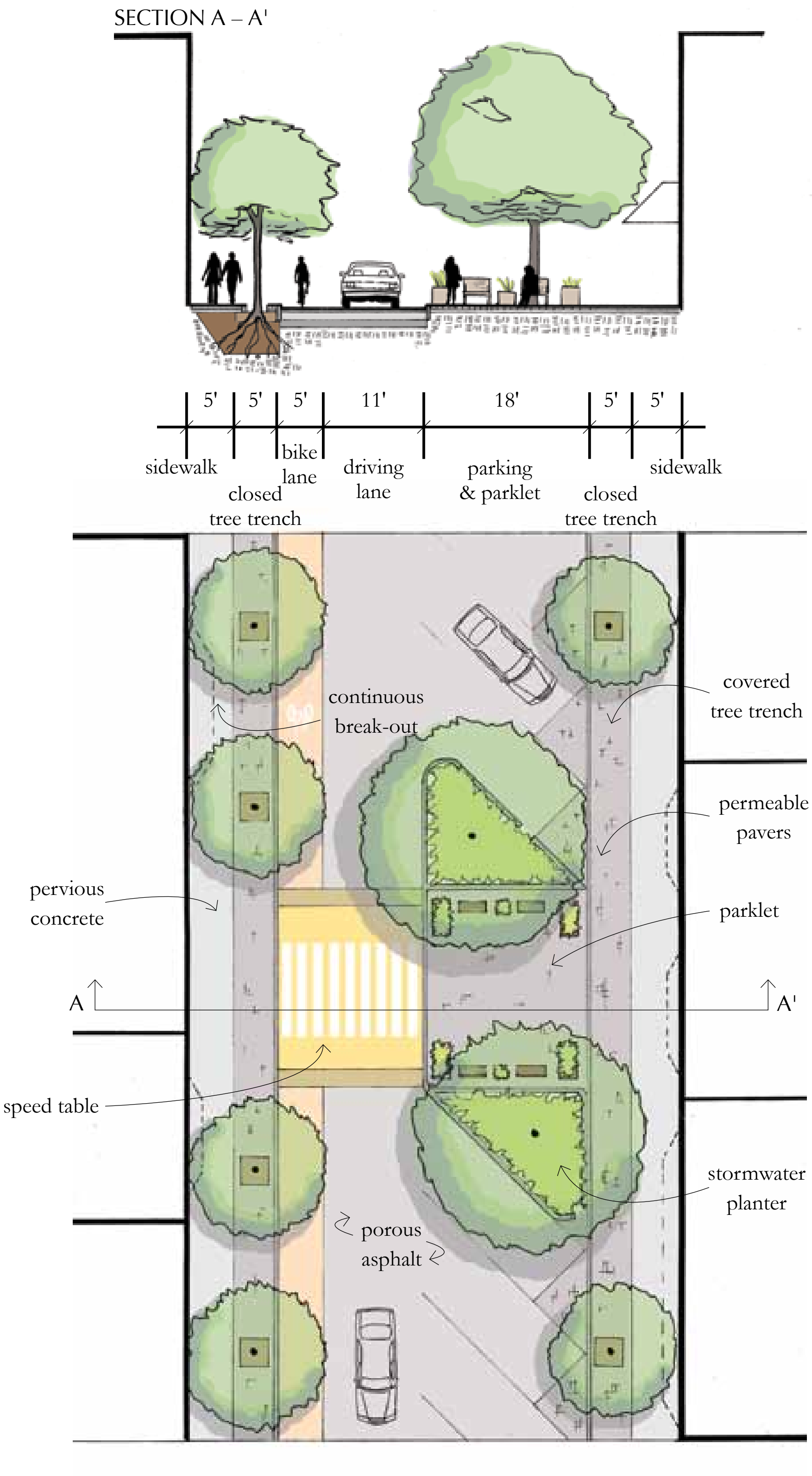




Street Characteristics					
	54' wide	2-5% slope	Commercial & public/ institutional	25 mph	Major Collector

TEMPLATE 6

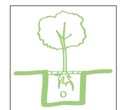
In thriving commercial or public/institutional areas, shaded pedestrian seating areas and calmed vehicular traffic invite residents and visitors to linger. Covered tree trenches manage stormwater while allowing pedestrian access between the sidewalk and the road, improving circulation.

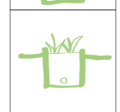


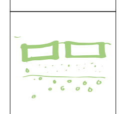
GOALS

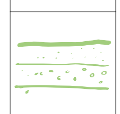
- Provide pedestrian amenities that encourage people to linger
- Emphasize aesthetics of street
- Maximize stormwater infiltration
- Calm traffic
- Demonstrate angled parking

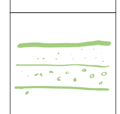
TOOLS

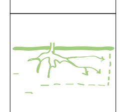

Covered tree trench (page 15)

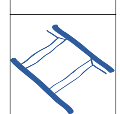

Stormwater planter (page 17)

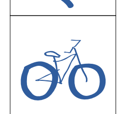

Permeable pavers (page 18)

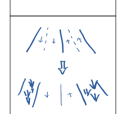

Pervious concrete (page 19)

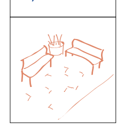

Porous asphalt (page 18)


Break-out (page 14)


Speed table (page 26)


Bike lane (page 23)


Road diet (page 25)


Parklet (page 27)

ADDITIONAL CONSIDERATIONS

- To maintain parking on both sides, consider parallel parking.
- For one-sided parallel parking, consider widening sidewalks.
- Engage neighboring businesses and institutions in maintenance.

TEMPLATE 7

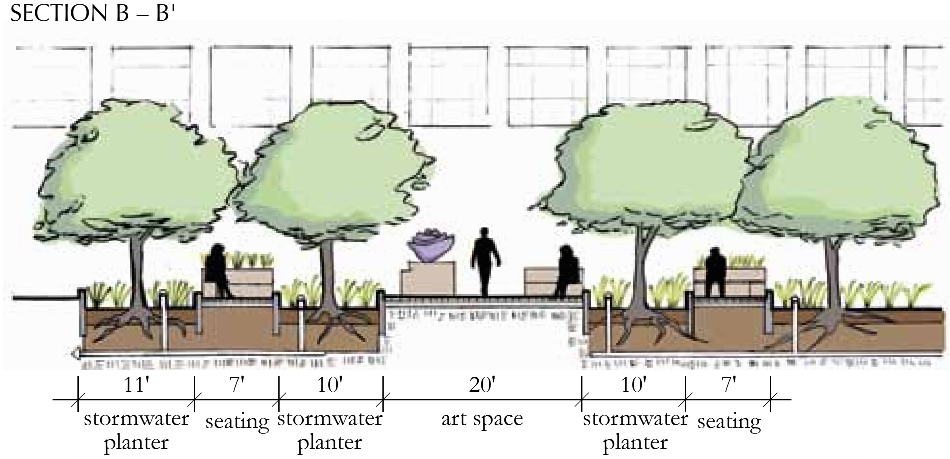
Street Characteristics					
⇅	58' wide	0-2% slope	Mixed-use industrial	35 mph	Minor Arterial

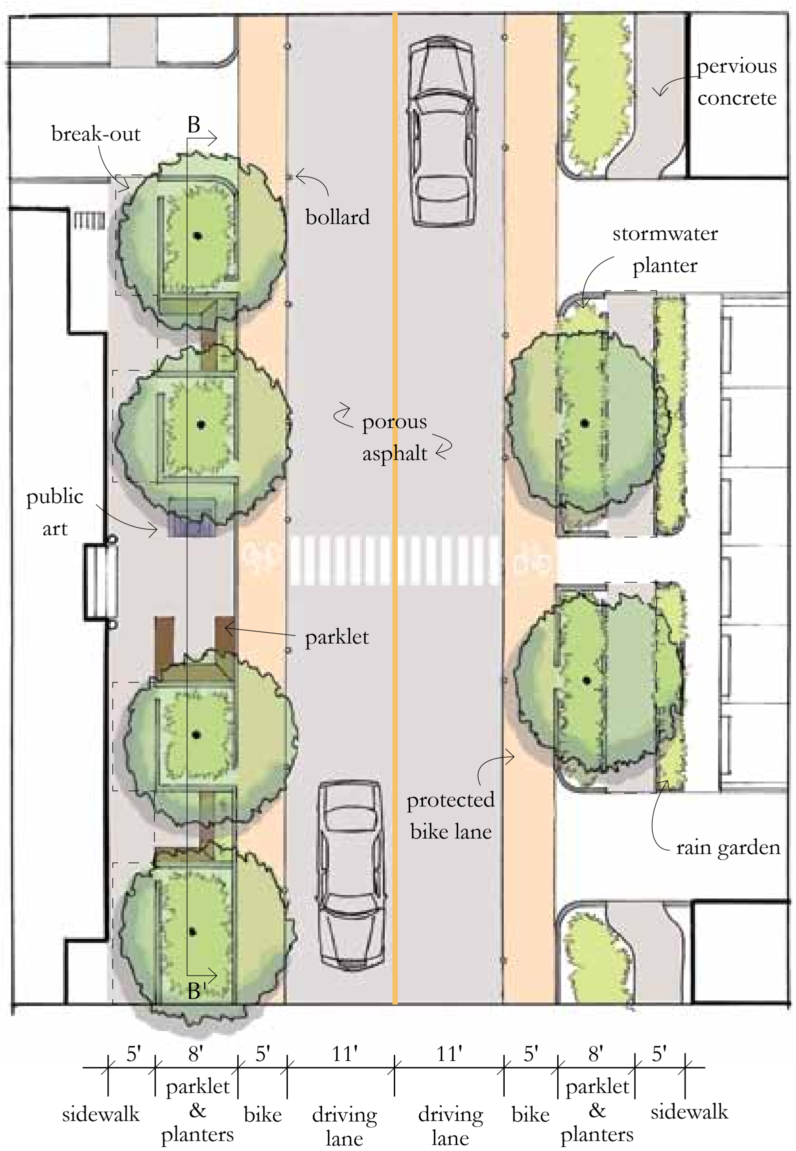
Shaded pedestrian parklets with ample seating and local street art can contribute to more culturally vibrant streets.

GOALS

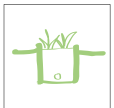
- Celebrate arts and create human-scale gathering spaces
- Maximize stormwater infiltration in highly impervious area
- Protect cyclists
- Remove on-street parking and prioritize other street users

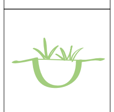
SECTION B – B'

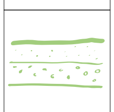


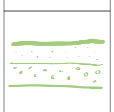


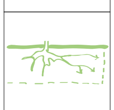
TOOLS

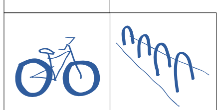

Stormwater planter (page 17)

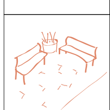

Rain garden (page 16)

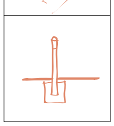

Pervious concrete (page 19)


Porous asphalt (page 18)


Break-outs (page 14)


Bike lane and parking (page 23)


Parklet (page 27)


Bollards (page 27)

ADDITIONAL CONSIDERATIONS

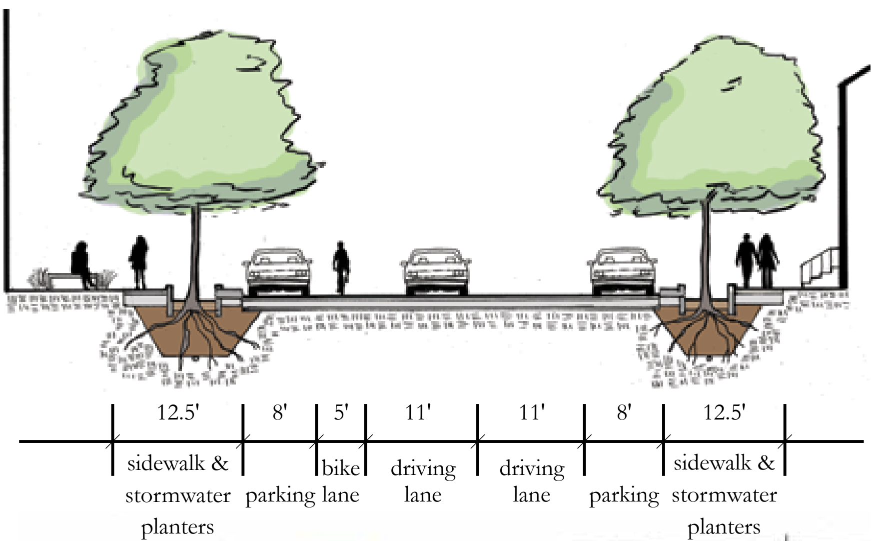
- On flat surfaces, ensure rain gardens have stormwater overflow connection to grey infrastructure.
- Consider this for arts districts; engage local artists and residents.
- If not located in arts district, consider gathering space needs for the local context.

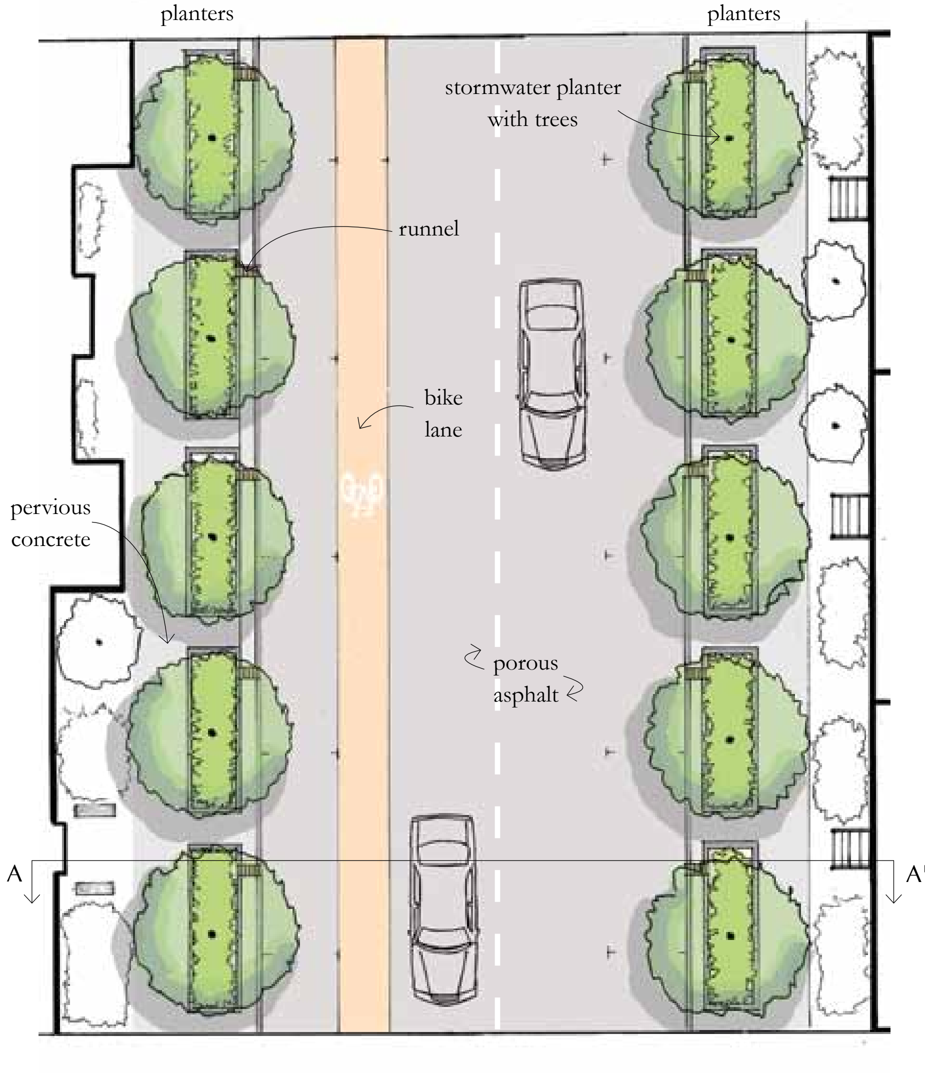
Street Characteristics					
	68' wide	2-5% slope	Multi-family residential	25 mph	Other Principal Arterial

Template 8

Stormwater planters with trees add greenery and shade to dense residential streets while creating a sense of safety and separation from the busy street. On-street parking is easily accessed from the street and adjacent homes.

SECTION A – A'



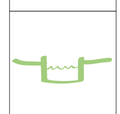


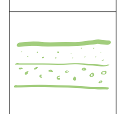
GOALS

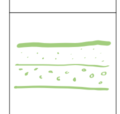
- Maximize stormwater infiltration while maintaining pedestrian access points to and from parked cars
- Provide shade for pedestrians and buildings
- Optimize parking and provide raised curb exit

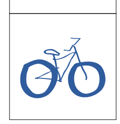
TOOLS

 Stormwater planter (page 17)

 Runnel (page 19)

 Pervious concrete (page 19)

 Porous asphalt (page 18)

 Bike lane (page 23)

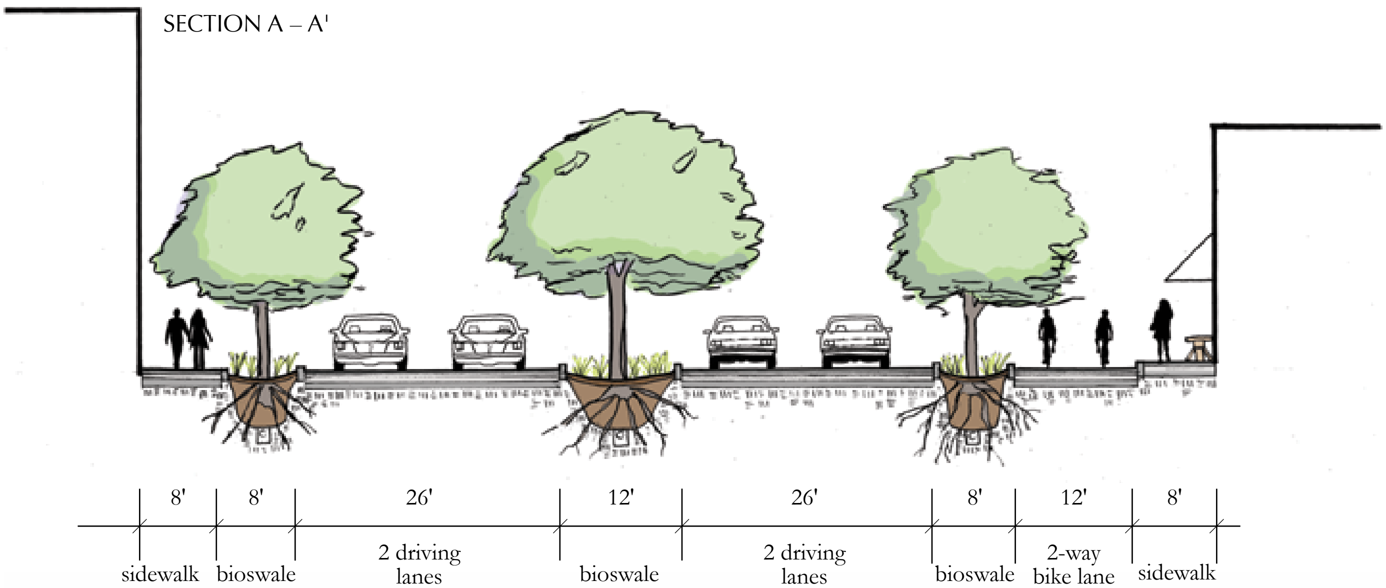
ADDITIONAL CONSIDERATIONS

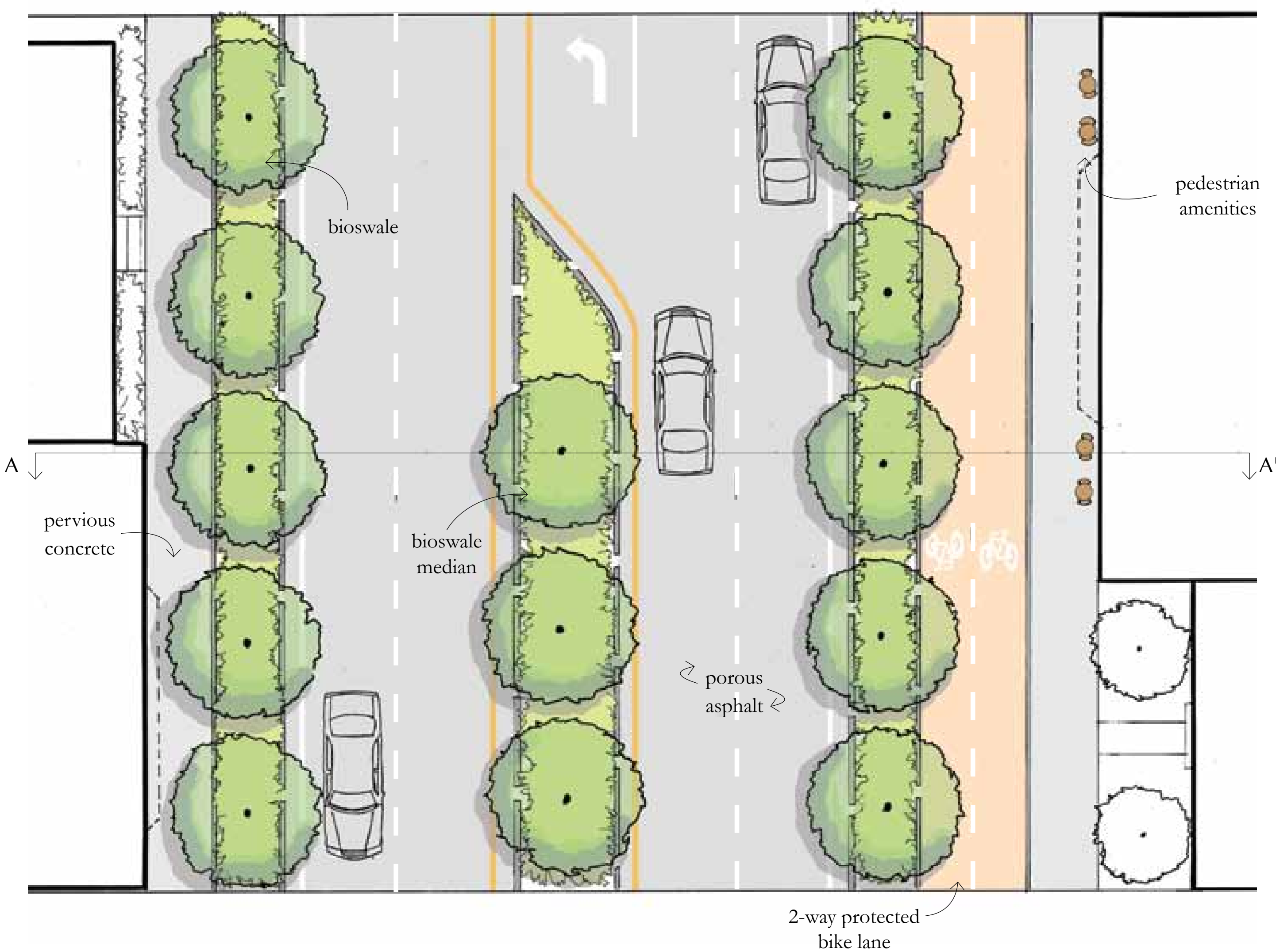
- Consider switching the location of bike and parking lanes to protect cyclists from vehicular traffic.
- Consider engaging neighbors in the planting and maintenance of vegetation.
- For greater pedestrian access between cars and sidewalk, consider replacing stormwater planters with closed tree trenches.

Template 9

Street Characteristics					
[one-way/two-way icon]	108' wide	0-2% slope	Mixed-use & commercial	30 mph	Other Principal Arterial

Even the widest streets where vehicular movement is a priority can be made safer and more pleasant for all users, while serving as a welcoming gateway into the city, by buffering cyclists and pedestrians from traffic with bioswales.

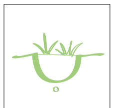


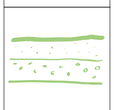


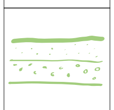
GOALS

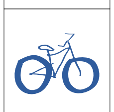
- Maximize stormwater infiltration
- Calm traffic and improve vehicular flow
- Provide protected two-way bike route
- Protect pedestrians from traffic
- Create welcoming canopied boulevard, potentially for entrances into the city
- Prevent oncoming vehicular accidents

TOOLS


Bioswale
(page 14)


Pervious concrete
(page 19)


Porous asphalt
(page 18)


Bike lane
(page 23)

ADDITIONAL CONSIDERATIONS

- Suitable for gateways into the city.
- Bike lanes could be one-way on both sides.
- Visible mid-block crosswalks can be incorporated where needed.
- Parking could replace buffer where needed.
- Lanes could be removed or bottlenecked to calm traffic and provide space for parking.
- Median could be reduced and/or planted with herbaceous plants for increased visibility.
- When selecting trees, consider those that allow for clear sight lines.

CONCLUSION

The preceding Templates were designed to represent a variety of Green Streets strategies exemplified in a set of diverse street characteristics typical of Holyoke. Though the Templates are unable to adequately represent all the different types of streets found in the city, each Template page contains additional recommendations for how the design can be adapted to meet a number of different site conditions.

NEXT STEPS

Before any Template is selected to serve as a design model, it is advisable to contact a site engineer to further investigate the feasibility of a Green Streets design for a specific site. The Template drawings are not for construction and should be modified in response to actual site conditions. The following conditions should be further evaluated professionally:

- Grey infrastructure system, including status of sewershed and CSO separation
- Underground utilities
- Hydrology
- Soil composition and contamination history
- Seasonal maintenance regime
- Opportunities to establish connections to significant sites and corridors
- Any additional considerations deemed appropriate by the site engineer

The Green Streets Templates are conceptual designs that exemplify how the principles and tools discussed in this Guidebook can be applied to the variety of streets that exist throughout the city. These Templates are intended to serve as both an inspirational guide and educational tool, illustrating the potential for Green Streets in Holyoke.

APPLYING GREEN STREETS TO DOWNTOWN HOLYOKE

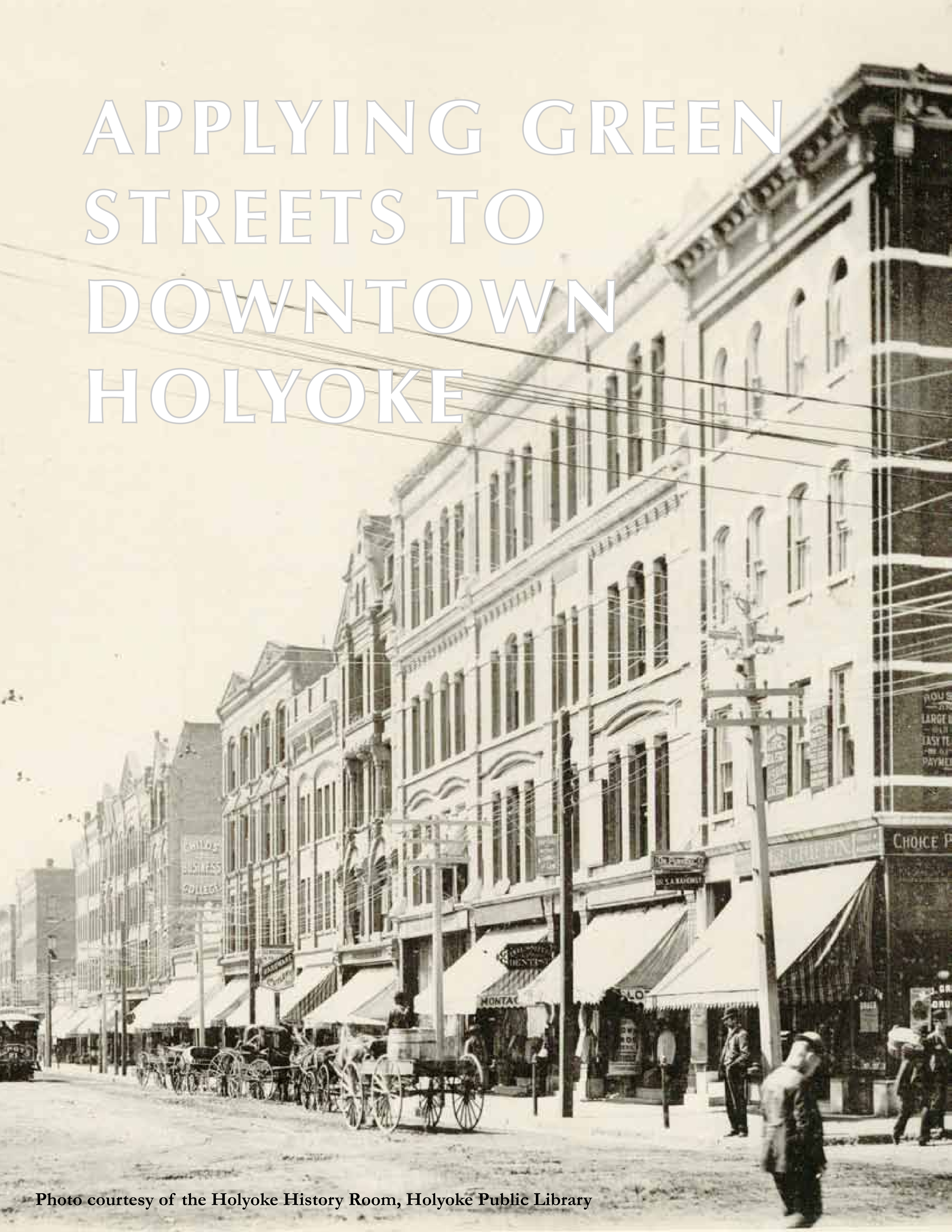


Photo courtesy of the Holyoke History Room, Holyoke Public Library

APPLYING GREEN STREETS

ABOUT THIS SECTION

This section demonstrates how Template designs and knowledge of Tools can be adapted and uniquely applied to specific streets in Holyoke. These designs differ from the Templates in that they respond more acutely to actual site conditions such as land use by parcel, salvageable existing materials, transportation routes, traffic patterns, and slopes. They also represent a larger area ROW length: whereas the templates were 100' long segments, the following designs are 350' long, with the exception of Division Street, which is 80' long. While cursory surveying was conducted for these designs, additional above- and below-ground surveying is required if these designs are to be considered for implementation. These designs serve more as a vision for a greener, healthier, visibly connected downtown rather than detailed recommendations.

SELECTING THE SITE

The four streets selected in this section to exemplify the application of Green Streets in Holyoke were identified based on a number of factors. First, downtown has been identified as a priority for redevelopment by Holyoke's *Urban Renewal Plan* and *Center City Vision Plan* (see plan below), among other documents. Redevelopment plans have already been proposed for portions of Division Street, Heritage Street, and Front Street (part of the Transit-Oriented Development project). See pages 48-49 for maps of current conditions and future plans for these streets.

Overall vision from the Center City Vision Plan.

As the commercial heart of downtown, a likely candidate for redevelopment, and adjacent to proposed development plans, High Street was selected. Suffolk, Division, and Appleton were also selected because they connect to city-approved streetscape plans for Heritage Street and their potential to enhance pedestrian connectivity to Heritage Park, and for the diversity of conditions and possibilities they represent.

DESIGN PROCESS

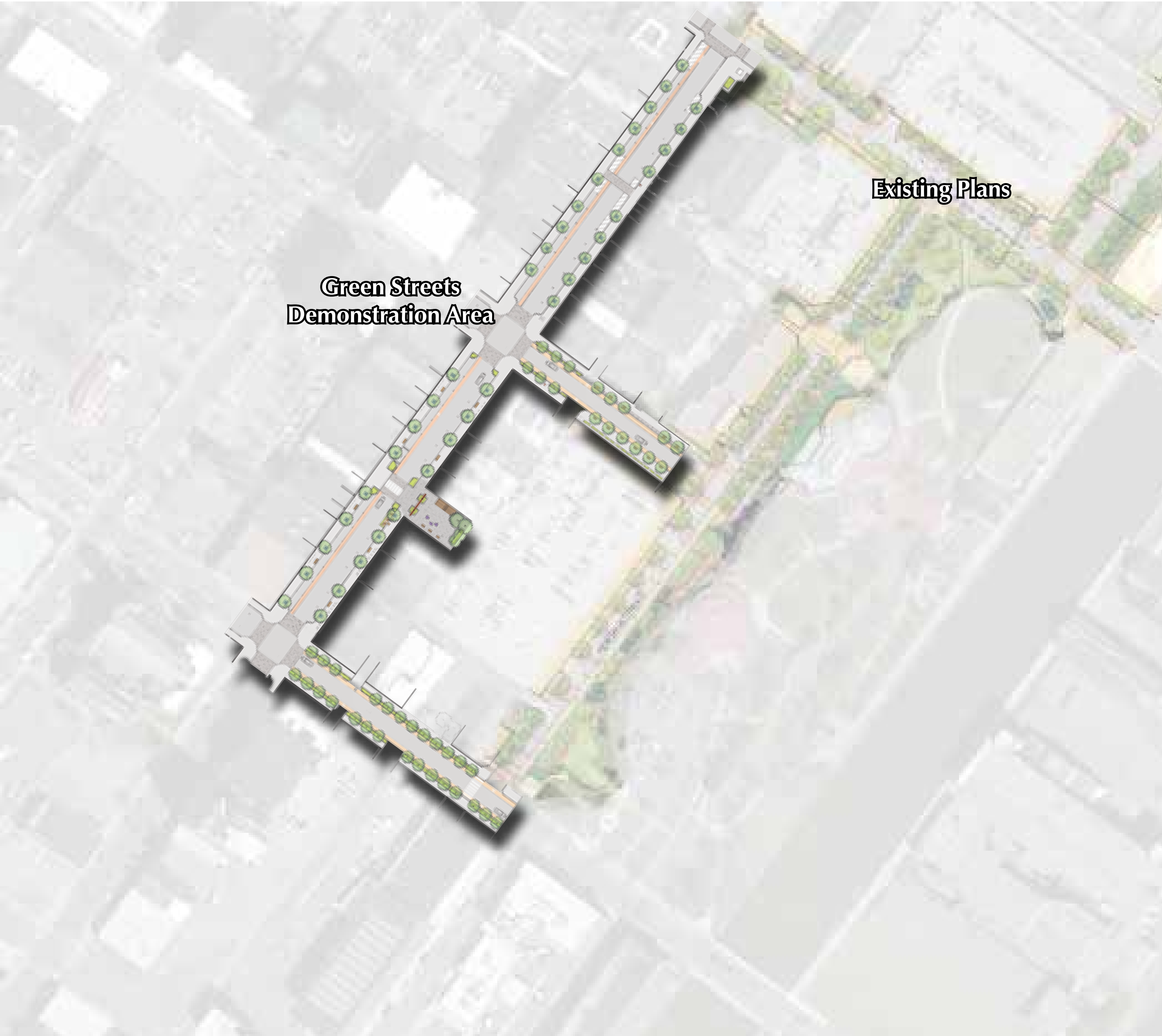
The same design process was used in developing designs for these streets as was used in developing the Templates (see page 33), with a more expanded set of existing conditions and criteria to work with.

GREEN STREETS VISION

proposed green street design areas

streets with proposed redevelopment plans

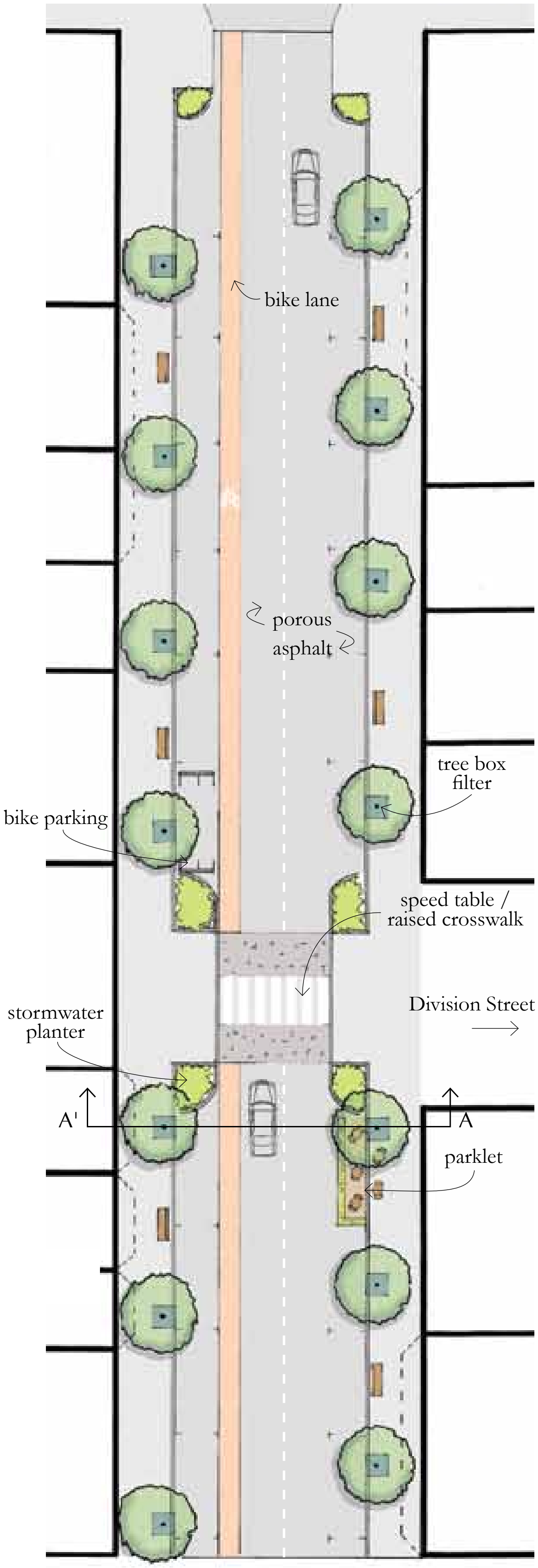
COMPLETING THE VISION: *Making Connections to Existing Plans*

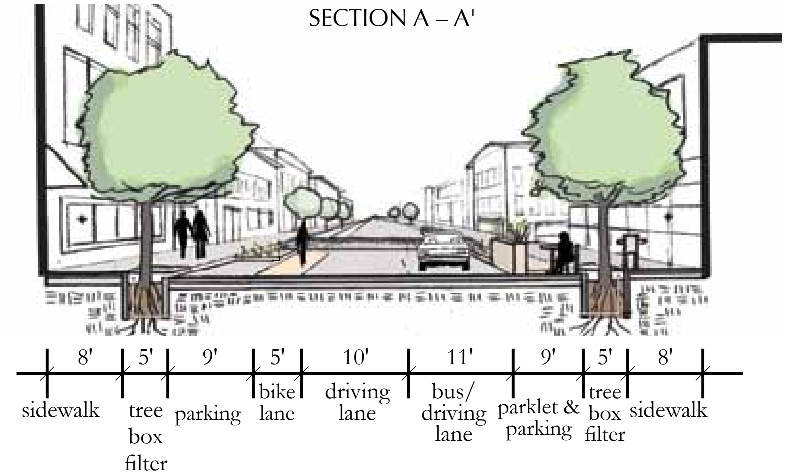


The above green street vision facilitates valuable connections with other streetscape improvement plans. The integration of these plans would create a greener, more inviting, and accessible downtown.

1 HIGH

Existing Street Characteristics					
	70' wide	1% slope	Commercial & public	25 mph	Major Collector



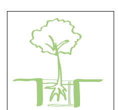


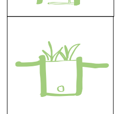
High Street, the primary commercial street downtown, hosts a variety of street-level shops and is an important cultural center for the city. The design adds small interventions to improve the pedestrian experience, accommodate cyclists, and infiltrate stormwater.

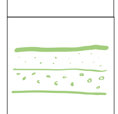
GOALS

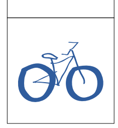
- Keep existing trees, tree grates, sidewalks, and paved crosswalks
- Retrofit empty tree grates with tree box filters, minimizing sidewalk disturbance and maximizing stormwater infiltration
- Create a vibrant commercial center that prioritizes pedestrians
- Calm traffic and improve circulation and flow across the street
- Maintain bus route access

TOOLS

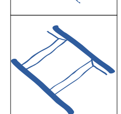

Tree box filter (page 17)

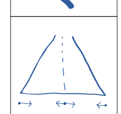

Stormwater planter (page 17)

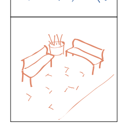

Porous asphalt (page 18)


Bike lane (page 23)


Bike parking (page 23)


Speed table (page 26)


Lane diet (page 25)

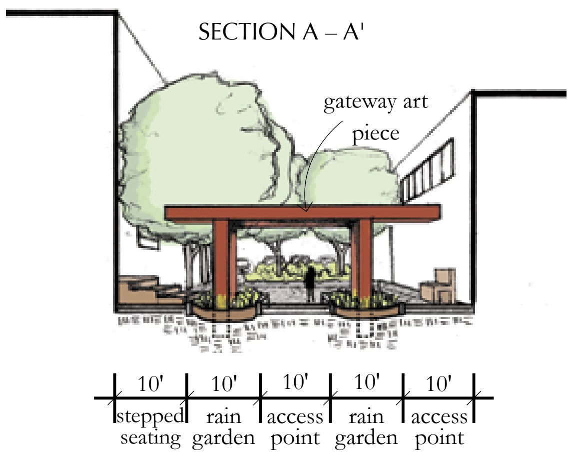

Parklet (page 27)

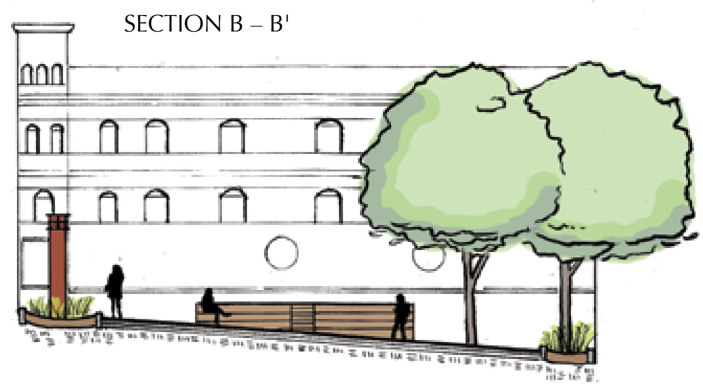
ADDITIONAL CONSIDERATIONS

- Consider adding bus-only pull-over lane and reducing traffic to one lane (road diet).
- Consider seasonal removal of on-street parking entirely; direct parking to Suffolk Parking Garage; add seasonal parklets.
- If central speed table were removed, bike lane could abut sidewalk; parking could buffer bike lane from driving lane.
- If sidewalk is to be renovated, consider a closed tree trench instead of tree box filters.

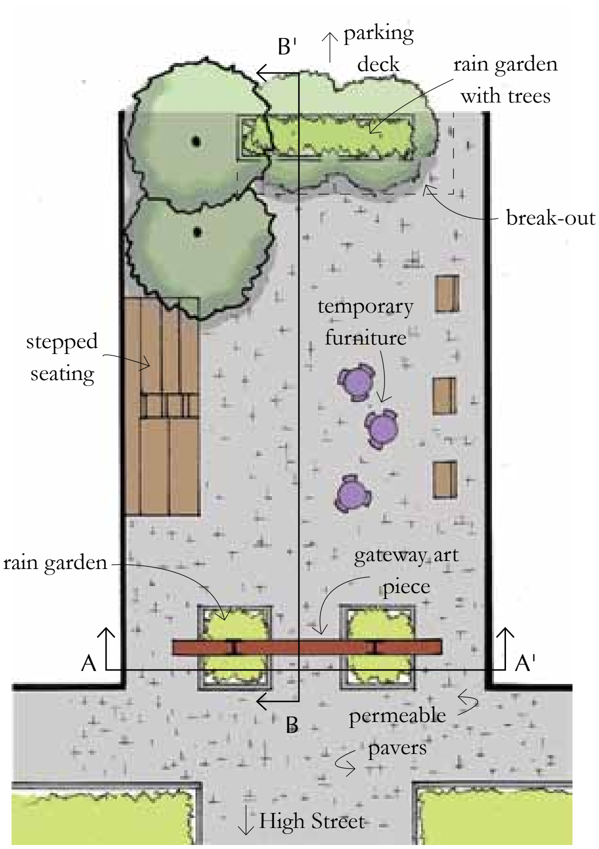
2 DIVISION

Existing Street Characteristics					
	50' wide	4%	Commercial	25 mph	Major Collector





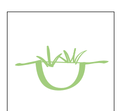
Division is currently an infrequently used side street off of High that leads to the Suffolk Street parking deck. With other vehicular entrances available off of Suffolk Street, this design re-envisions Division as a pedestrian-only space using temporary and permanent furniture, local art, and vegetation.

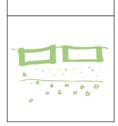


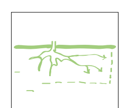
GOALS

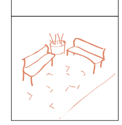
- Create a multi-use flex space and gathering space in commercial center
- Create artistic and historic symbol for residents and visitors near City Hall
- Provide a seating and eating place for commercial district, consumers, and downtown workers
- Keep existing healthy trees

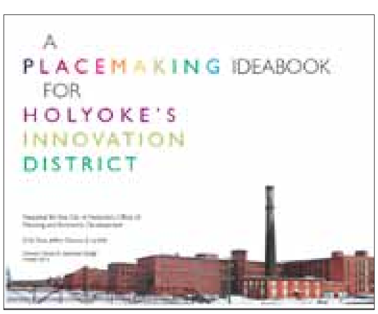
TOOLS


Rain garden
(page 16)


Permeable pavers
(page 18)


Break-out
(page 14)


Parklet
(page 27)



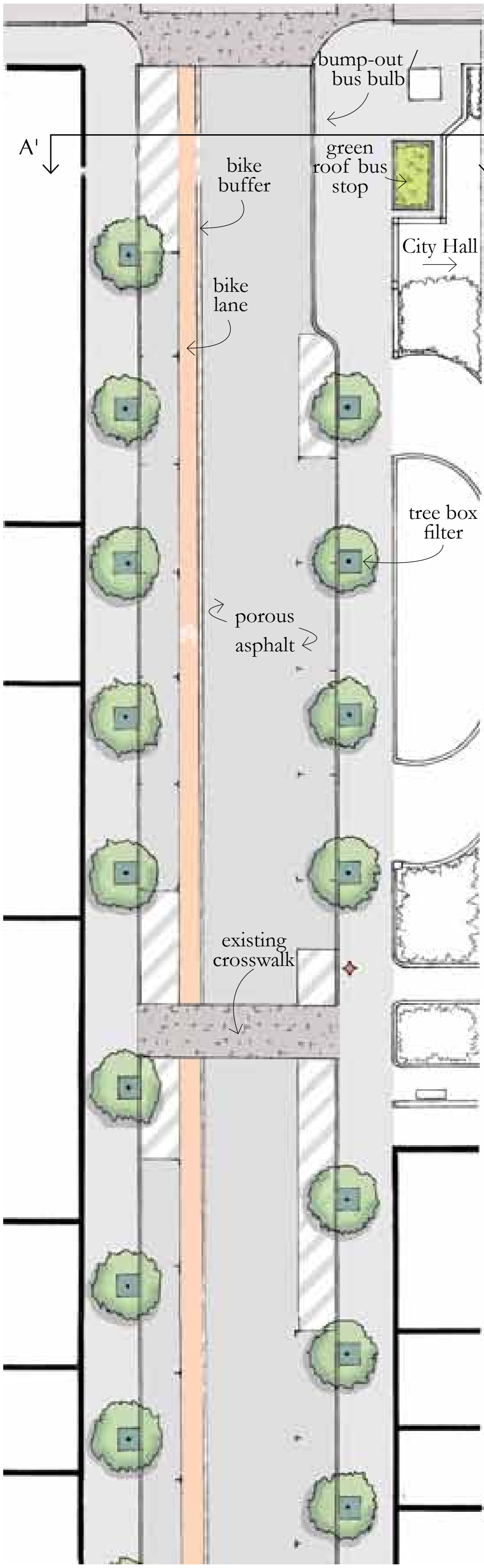
Consult A Placemaking Ideabook for Holyoke's Innovation District (2014) for more placemaking suggestions.

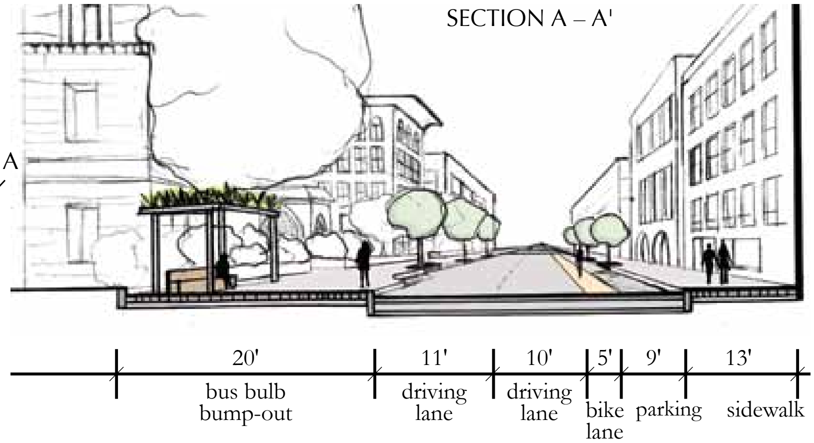
ADDITIONAL CONSIDERATIONS

- To maintain vehicular access to parking deck, consider moving rain garden with trees to one side and using runnels to direct runoff.
- Engage local artists to create a gateway art piece to the Division Street Parklet reflective of the city's culture and identity (I-beam gateway shown in design).
- If vehicular access does not need to be maintained, consider incorporating steps to create a level pedestrian surface.
- The space may be used for a number of community events, including movie screenings projected onto neighboring building wall, arts fairs, and food truck gatherings.
- Business owners and neighboring residents can be engaged to maintain the parklet. Encourage the creation of a volunteer-led "Friends of Division Street" group.

3 HIGH

Existing Street Characteristics					
	70' wide	1% slope	Commercial & public	25 mph	Major Collector



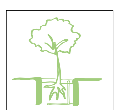


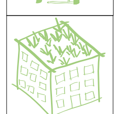
This portion of High Street mixes commercial and public/institutional land uses. The design draws attention to alternative forms of transportation directly in front of City Hall. On-street parking is maintained and empty tree grates are replaced with tree box filters.

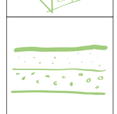
GOALS

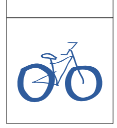
- Keep existing trees, tree grates, sidewalks, and paved crosswalks
- Retrofit empty grates with tree box filters, minimizing sidewalk disturbance and maximizing stormwater infiltration
- Prioritize bus users and cyclists
- Draw attention to opportunities to implement urban green infrastructure in front of City Hall

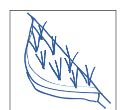
TOOLS

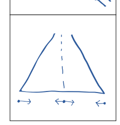

Tree box filter (page 17)


Green roof (page 20)


Porous asphalt (page 18)


Bike lane (page 23)


Bump-out (page 24)

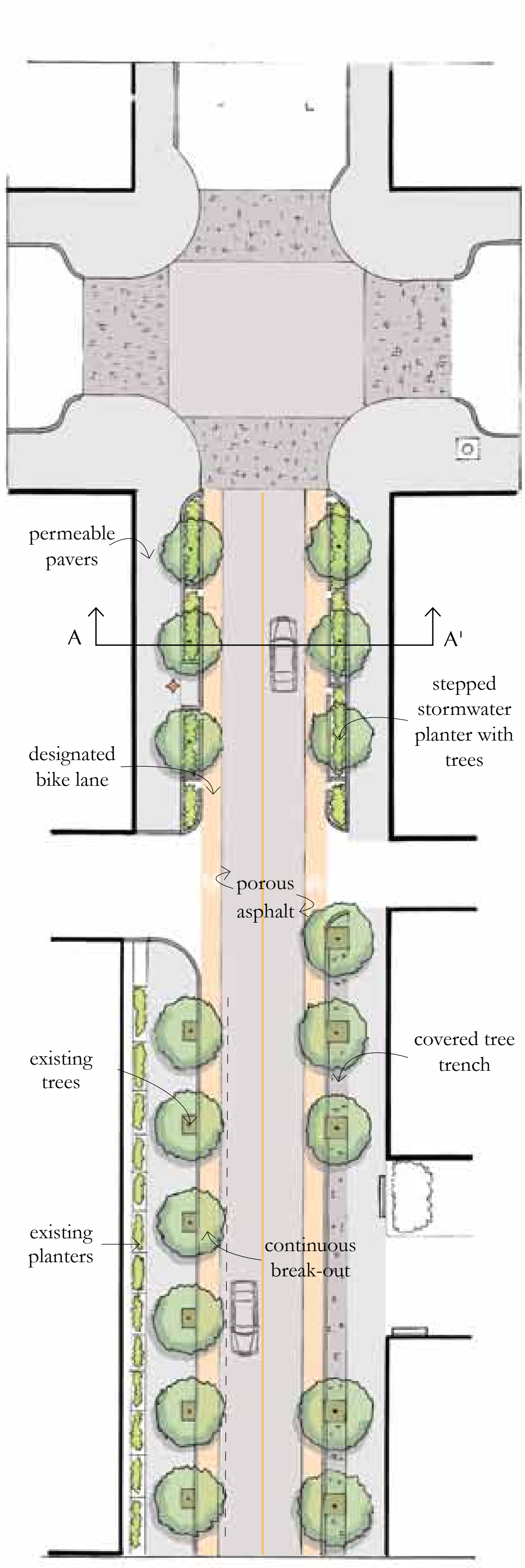

Lane diet (page 25)

ADDITIONAL CONSIDERATIONS

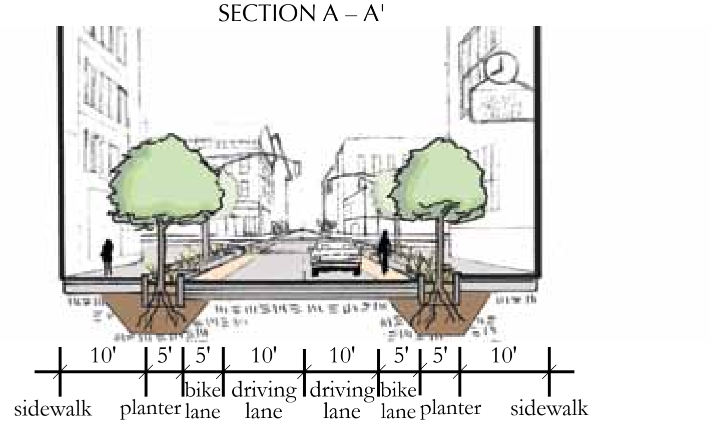
- Two lanes could be reduced to one if bus bulb were removed, allowing a separate pullover lane for bus stop.
- One lane would slow traffic and allow more space for pedestrian amenities, parklets and green infrastructure.
- If sidewalk needs to be replaced, closed tree trenches could be substituted for tree box filters.
- Bike lane could abut sidewalk and be buffered by parking.

4 Suffolk

Existing Street Characteristics					
	60' wide	4% slope	Commercial, public, industrial	25 mph	Other Principal Arterial



SECTION A – A'

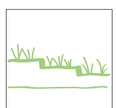


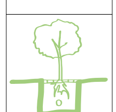
Suffolk Street has the potential to provide a beautiful connection between High Street and Heritage Park. The design redirects parking to an adjacent parking lot and links important areas with a protected, green corridor.

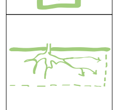
GOALS

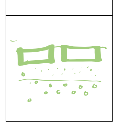
- Keep healthy street trees, but add break-outs under bike lane to ensure survival of existing trees
- Keep existing attractive sidewalk pavers
- Remove on-street parking to accommodate bikes
- Maximize stormwater infiltration on slope
- Create allée that frames connection to commercial area, Heritage Park, and City Hall

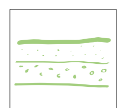
TOOLS

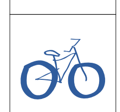

Stepped stormwater planter (page 16)

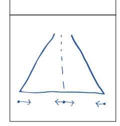

Covered tree trench (page 15)


Break-out (page 14)


Permeable pavers (page 18)


Porous asphalt (page 18)


Bike lane (page 23)

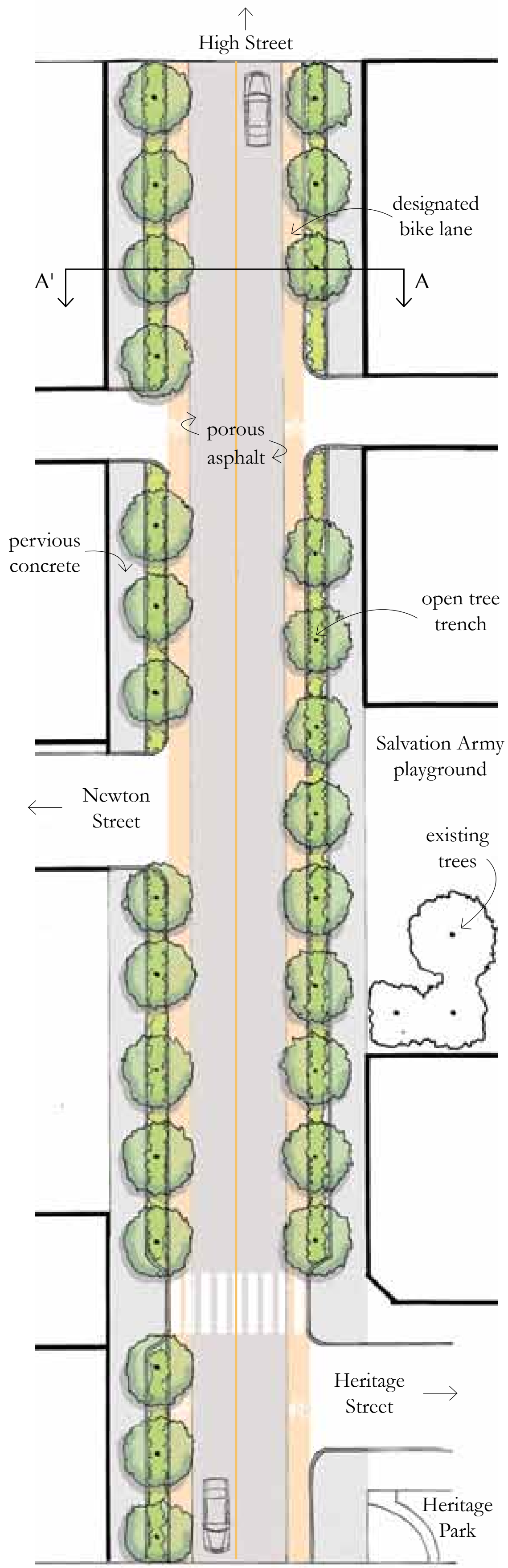

Lane diet (page 25)

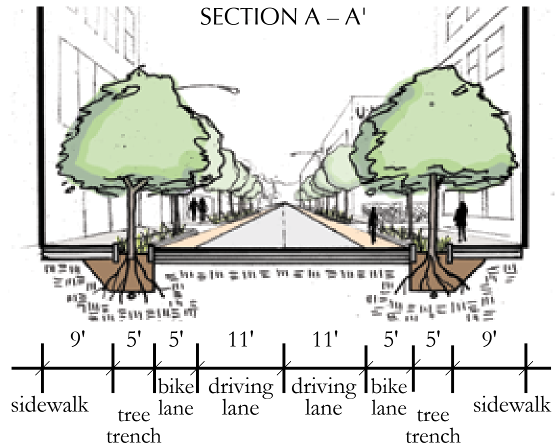
ADDITIONAL CONSIDERATIONS

- Localized slopes may be greater or less than 4%; adjust green infrastructure tools accordingly.
- To maintain on-street parking, use a shared lane instead of designated bike lanes.
- Stormwater planters do not need to be stepped and could be planted without trees.

5 Appleton

Existing Street Characteristics					
	60' wide	4% slope	Commercial, public, industrial	25 mph	Other Principal Arterial



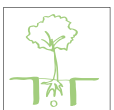


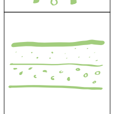
Appleton Street is a major thoroughfare dominated by vehicles, and is one of six streets that cross the first and second canals. This design adds space for bike lanes and creates a framed vista with a protected pedestrian corridor, which also maximizes stormwater infiltration.

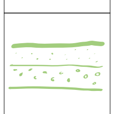
GOALS

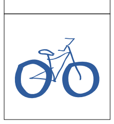
- Maintain vehicular flow
- Introduce bike lanes on arterial road
- Introduce green infrastructure
- Provide shade
- Establish connection to Heritage Park with greenery

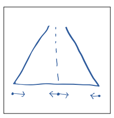
TOOLS


Open tree trench
(page 15)


Porous asphalt
(page 18)


Pervious concrete
(page 19)


Bike lane
(page 23)


Lane diet
(page 25)

ADDITIONAL CONSIDERATIONS

- Maintain vehicular and pedestrian sight-lines, particularly at corners and intersections.
- Consider involving Salvation Army or other community groups in mural or planting projects.
- Keep existing healthy street trees along Heritage Park; consider enhancing them with break-outs.
- Consider adding bollards as a bike lane barrier to increase safety along major travel route.
- Consider interrupting open tree trench with pavers to create more convenient street crossing opportunities.

CONCLUSION

This section conveys the potential for Green Streets to be applied to culturally and commercially important ROWs located within Holyoke's current redevelopment area. Each ROW's unique criteria (ROW characteristics, slope, land use, miles per hour, and functional road classification) in conjunction with a set of hypothetical goals determined which Green Streets strategies were selected for each street-specific ROW design.

For each ROW design, hypothetical goals were envisioned, based on each site's combined criteria. Then, strategies from each principle of Green Streets (utilize green infrastructure, design for complete streets, and generate a sense of place) were selected based on their appropriateness to achieve each of the ROW's identified goals.

In order to create appropriate, hypothetical goals for each ROW, assumptions were made about the design's desired outcomes:

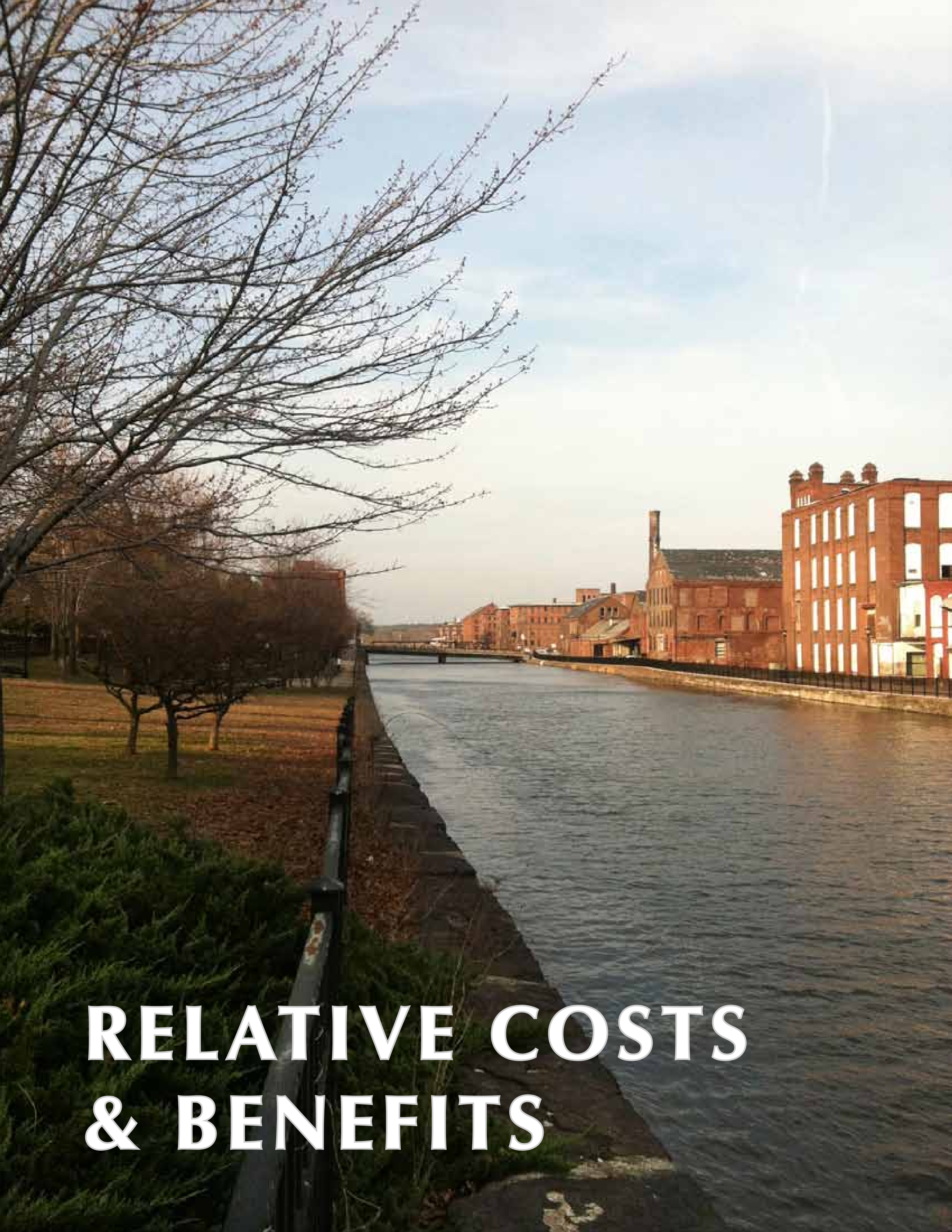
1. All templates were designed to maximize stormwater infiltration, except for templates where placemaking was prioritized.
2. Commercial streets prioritized traffic-calming strategies and more on-street parking.
3. Commercial areas prioritized seating areas
4. Healthy trees were left in place.
5. Permeable pavers and other recyclable materials were reused or left in place.
6. Existing, recently renovated paved sidewalks were left alone.
7. Some existing city ordinances were ignored to allow for optimal designs.

NEXT STEPS

Before any street-specific ROW design is considered for implementation, it is advisable to contact a site engineer to further investigate the feasibility of the green infrastructure strategies selected for the site's conditions. The street-specific ROW design drawings are not for construction. The following conditions should be evaluated professionally:

- Grey infrastructure system, including status of sewershed and CSO separation
- Underground utilities
- Hydrology
- Soil composition and contamination history
- Seasonal maintenance regime
- Any additional considerations deemed appropriate by the site engineer

The street-specific ROW designs are conceptual and are intended to exemplify how the principles and tools discussed in this guidebook can be applied to culturally and commercially important ROWs located within Holyoke's current redevelopment area. These designs are intended to serve as both an inspirational guide and educational tool, illustrating the potential for Green Streets to take root in Holyoke's current era of urban renewal.



RELATIVE COSTS & BENEFITS

To comply with the EPA's stormwater management and CSO pollution regulations and recommendations, cities are beginning to rethink complete dependence on conventional grey infrastructure sewer systems for stormwater management and are instead beginning to combine grey and green infrastructure strategies. Currently, the EPA estimates that approximately $56 billion are spent on CSOs throughout the U.S. annually (Roseen, 2-24 - 2-25). In Holyoke alone, United Waters estimates that updating the city's combined sewer system will cost the city $51 million dollars.

Over the past few decades, thousands of stormwater management programs incorporating green infrastructure have appeared in the U.S. Although some have failed, the EPA reports that in most cases, implementing carefully selected green infrastructure strategies saves money for cities, property owners, developers, and communities, simultaneously protecting and restoring the urban ecology, especially water quality (Roseen, 3-17). Green infrastructure can yield substantial grey infrastructure cost savings, generate socio-economic improvements, and improve environmental health.

GREY INFRASTRUCTURE COST SAVINGS

Multiple cities have successfully implemented green infrastructure stormwater management programs (GISMPs) and have reported significant overall grey infrastructure cost savings, generated in a variety of ways.

Though capital costs for green infrastructure features can be more expensive than their conventional alternative, there are often overall cost savings when total site construction is accounted for. Some cost savings occur when green infrastructure strategies allow costly conventional procedures to be skipped, saving on development costs and the amount of land disturbed. For example, in a residential project conducted by the University of New Hampshire (UNH) which substituted porous asphalt for conventional paving, researchers reported having to disturb 11 percent less land and a 6 percent cost savings (Roseen, 2-26). UNH found that, "although porous asphalt was more costly, cost savings are realized through the reduction in drainage piping, erosion control measures, catch basins, and the elimination of curbing, outlet-control structures and stormwater detention ponds" (Roseen, 2-26). Another 56-acre porous asphalt UNH project saw a 26 percent cost savings for stormwater management through the reduction of similar conventional methods (Roseen, 2-26).

Integrating green infrastructure (GI) has proven to substantially reduce the burden on grey infrastructure and subsequent related costs. For example, in 2000, the City of Portland, Oregon, was faced with the need to upgrade its sewer system in order to stop sewer backups occurring in basements, to control street flooding, to manage CSOs, and to improve the sewer's reliability. At the time, a new sewer system using conventional grey infrastructure was proposed with an estimated total cost of $144 million. However, after further consideration, another plan which incorporated both grey and green infrastructure ($11 million allocated for GI) was proposed, with an estimated total cost of $81 million. The combined approach was chosen, ultimately saving the city $63 million. Portland's stormwater management plan later became a nationally recognized Green Streets success story. Substantial cost savings can also be generated by avoiding stormwater pumping costs. Milwaukee predicts savings of $46,000 annually on pumping costs with their current GISMP, with the added bonus of subsequent reduced carbon dioxide emissions (MMSD, 63).

Finally, as opposed to conventional grey infrastructure, green infrastructure can be regenerative, increasing in efficacy over time, rather than wearing down and requiring replacement after a certain number of years (Odefy et al., 15). For example, Philadelphia expects to save significantly on operations and maintenance costs on both grey infrastructure upkeep and wastewater treatment facilities. Further still, a cost-benefit analysis done by Seattle, Washington, estimated that natural drainage designs may reduce stormwater treatment facility and grey infrastructure operations and maintenance costs by about 24 to 45 percent, compared to conventional street designs (MMSD, 63).

Some cost savings will become more apparent over time, and some green infrastructure strategies take longer than others to reach their maximum cost savings potential.

SOCIO-ECONOMIC IMPROVEMENTS

Integrating green infrastructure into the urban landscape has proven to spur socio-economic improvements. GISMPs can create jobs, make a neighborhood more beautiful and feel safer, and save money on energy expenses for business owners and residents.

Green infrastructure programs create jobs. A major benefit of green infrastructure is that the stormwater management regime changes from massive government spending in short spurts on grey infrastructure revamps, to long-term incremental spending on an unskilled labor force. Maintenance requirements (further discussed in Operations and Maintenance, see page 59) create "a permanent need for unskilled laborers since the majority of work involves landscaping and other activities that require minimal training" (MMSD, 61). Since unemployed persons in poverty are frequently unskilled laborers, a permanent GI workforce could provide a means to help bring some of these people out of poverty. For Holyoke, a GISMP could not only improve the urban ecology, but also create jobs for the residents who need them most.

In addition, increased job availability is correlated with reduced crime, which further reduces spending on the police force, prisons, etc. (MMSD, 61). For example, the

City of Philadelphia produced a report which documented the number of jobs created and social cost reductions attributable to their green infrastructure plan. The study found $100 million on operations and maintenance over the course of twenty years would annually save roughly $2.5 million in social costs, while also providing 250 permanent jobs for unskilled workers (MMSD, 61).

GI also improves the overall psychological experience of a space. Vegetation and amenities not only encourage pedestrian activity by making the ROW more physically accessible, but they create a more pleasing experience. Milwaukee found that "amenity and comfort ratings are approximately 80 percent higher for a tree-lined sidewalk compared to a non-shaded street" (MMSD, 68). Residents tend to make more trips on foot when natural features are visible than when they are not. Studies show that people generally judge distances to be shorter in vegetated neighborhoods than the same distance in less green neighborhoods (MMSD, 69). For Holyoke, encouraging residents to walk may also reduce public health expenses.

These psychological benefits can indirectly influence other socio-economic issues. For example, a study conducted in Portland showed that residential areas with tall trees had less crime because trees made the area look more attractive and livable (Donovan, Prestemon, 24). Safer neighborhoods may also encourage downtown Holyoke residents to walk and bike more.

Green infrastructure has been shown to help residents and property owners save on energy costs. One study in California found that widespread adoption of GI strategies could save 1.2 million megawatt hours annually in electricity (Odefy et al., 16). Another study showed that green vegetation and less paving reduced the need for home cooling by 33 to 50 percent (Roseen, 2-25). These savings would allow Holyoke's residents to save money and spend it in other ways.

Finally, the integration of green infrastructure can help Holyoke's business owners and entrepreneurs by encouraging commercial activity and raising property values. For example, one study showed that "74 percent of the public preferred to patronize commercial establishments whose structures and parking lots have trees and landscaping" (MMSD, 68). Neighborhoods with green infrastructure show an increase of 12 to 16 percent in property values (Roseen, 3-2). In neighborhoods with large tree canopies, studies have shown that tenants will pay 8 to 12 percent more and that landscaping in general adds roughly 7 percent to average rental rates for offices (Clements et al., 6).

Incorporating green infrastructure into Holyoke's SMP may create jobs, create a safer, more desirable place to live, and spur economic activity; however, these socio-economic improvements have the potential to gentrify the downtown, which could strain the local environmental justice population. If a GISMP is undertaken, the City will need to take precautionary measures to ensure real-estate affordability for the environmental justice population, so as not to price them out of their neighborhoods.

IMPROVED ENVIRONMENTAL HEALTH

Reduced Urban Heat Island

The integration of green infrastructure practices and green space can indirectly help mitigate the economic and public health consequences that result from the urban heat island effect. GI keeps stormwater runoff on-site, simultaneously reducing CSO pollution, helping cool the air through evapotranspiration, and providing benefits to public health by reducing heat-related illness and fatalities. Even a small change like substituting some permeable pavement for conventional pavement has shown to have an impact on heating and cooling demand (Odefy et al., 31). For downtown Holyoke, with only 5 percent open space and 63 percent impervious coverage, green infrastructure could significantly mitigate some effects of the urban heat island by creating a cooler summer climate for walking, helping to reduce obesity rates.

Benefits of Improved Air Quality

In urban areas, vegetation plays the critical role of cleaning the air of harmful pollutants, including sulfur dioxide, nitrogen dioxide, ozone, and some types of particulate matter. A study of green roofs in Portland showed that one 40,000 square foot rain garden could remove 1,600 pounds of particulate matter and simultaneously avoid $3,024 in healthcare costs (Odefy et. al., 32). In addition, an Urban Ecosystem Analysis of Washington, DC showed that "tree cover in the city not only saved $4.7 billion in avoided stormwater storage costs, but also created $49.8 million in annual air quality savings by removing 20 million pounds of pollutants from the air every year" (Odefy et al., 32). The City of Philadelphia attributes "1 to 2.4 premature fatalities avoided every year and over 700 cases of respiratory illness days avoided per year" to its GISMP. In fact, over the course of forty years, Philadelphia predicts it will avoid $130 million in related health care expenses (Odefy et. al., 32).

In Holyoke, where 20 to 33 percent of the city's children have pediatric asthma, cleaner air may make a healthier population and substantially reduce some public health expenses (U.S. EPA, *Creating the Community*, 9).

Green infrastructure not only improves air quality and public health, it can also save cities millions of dollars on pollutant-related costs. For example, Philadelphia estimated that reduced carbon dioxide emissions from pumping resulted in approximately $34 million in energy savings and over "$21 million in social benefits for reduced carbon dioxide emissions" (MMSD, 65). Green infrastructure's affect on air quality can benefit residents and at the same time save municipalities money.

CASE STUDY (ATLANTA, 1996):

A CORRELATION BETWEEN VEHICULAR USE AND ASTHMA

During Atlanta's 1996 Summer Olympic Games, researchers took advantage of a decrease in traffic to measure the impact of vehicular use on air quality and public health. The researchers found that when peak early morning traffic decreased 23 percent, peak ozone levels reduced by 28 percent, correlating with a 42 percent reduction in pediatric emergency visits. There was no change in frequency of any other type of emergency room visits, suggesting that the efforts to reduce traffic during the Games had a direct impact on public health ("Respiratory Health").

Public Health Benefits

Finally, a GISMP can reduce public health expenses by limiting public recreational exposure to polluted waters and by encouraging healthy lifestyles. CSOs and polluted stormwater runoff pose major health concerns. When people swim in or fish from waters contaminated by sewage, bacteria, or excess fertilizer, gastrointestinal illness and infections are often contracted (Odefy et al., 28). The illnesses caused by polluted stormwater runoff contamination can have substantial economic impacts on public health expenses. For example, "every year, up to 3.5 million people become sick from contact with water contaminated by sewage" (Odefy, et al., 29). In California, a study reported that over 13,000 swimmers in the Santa Monica Bay who were within 100 yards of a CSO outfall experienced increased rates of gastrointestinal illness, with the highest rates concentrated in swimmers who swam closest to the storm drains (Odefy, et al., 29).

Aside from mitigating dangerous exposure to harmful pollutants, a GISMP that promotes Complete Streets has the potential to make a community more livable, providing more opportunities for adults and children to get outside. By integrating pocket parks and prioritizing pedestrians and cyclists, Green Streets can serve as a means to promote recreation, even in a dense city, leading to reduced health costs (Odefy, et al., 29). In general, studies show that "people with access to parks and green space are less stressed and prone to anxiety, have lower blood pressure and cholesterol, have faster recovery from surgery and heart attacks, and show more improvement managing attention and behavioral disorder" (Odefy, et al., 29). A study of Philadelphia's parks evaluating the economic benefits of air and water pollution reduction reported about $70 million in avoided medical expenses due to park use in 2007 (Odefy, et al., 33). Clearly, the right GISMP may reduce public health expenses in more ways than one.

CONCLUSION

Because GISMPs are relatively new, and the relative costs and benefits of green stormwater management only become clearer over time, documentation of these programs is somewhat limited at this time. Because no consistent standard cost-benefit analysis has yet been developed, it is difficult to compare cost-effectiveness within and across municipalities, particularly those in different climates. Finally, cost-benefit analyses are not entirely reliable in that some costs and some benefits are more measurable than others (e.g., Green Streets may have psychological, social, and aesthetic benefits for the community, though these improvements can be difficult to measure).

Nonetheless, all of these studies are beginning to show measurable improvements in grey infrastructure cost savings, socio-economic improvements, and improved urban ecology and environmental health as a result of green infrastructure. As municipalities continue to realize the economic costs and benefits of utilizing green infrastructure, green infrastructure and Green Streets will become even more widespread.

NORTHEAST CITIES WITH GI STORMWATER MANAGEMENT PROGRAMS

Several municipalities in New England have developed green stormwater management programs. Two municipal programs were selected as relevant case studies based on the following criteria relative to Holyoke: population size, median household income, climate, and CSO status.

For Comparison: Holyoke

Population: 41,000 (2012 census)
Median household income: $33,000
Climate: New England
CSO status: Needs separation and reduction

Problem: CSOs, MS4 NPDES regulations, Environmental Justice Population area.
Program Description/Solution: N/A
Findings: N/A

Lancaster, Pennsylvania

Population: 60,000
Median household income: $30,000
Climate: Northeast
CSO status: Needs separation and volume reduction

Context:

- Lancaster is going through a transitional period. The City is investing in the downtown area with the intention to create a tourist destination for arts and culture.
- A historically rich town, Lancaster hosts the oldest operating farmers market in the United States, since 1889.
- Lancaster was once an iron foundry.
- Lancaster has a combined sewer system and is an MS4.

Problem:

- Lancaster faces fines of $37,500 a day for failure to comply with EPA's regulatory requirements.
- Polluted industrial brownfields and site contamination; one of the nation's 40 most air polluted metropolitan areas (U.S. EPA, *Economic Benefits,* 8).
- CSO problem: 750 million gallons of untreated wastewater discharged into the Conestoga River.
- Enlarging the conventional treatment plant will cost the City an estimated $300 million to build and another $750,000 each year for treatment.

Program Description/Solution:

- 2011 Green Infrastructure Plan identifies opportunities for added green infrastructure throughout the city; provides 5-25 year timeline, estimates water quality benefits, and recommends relevant policy and institutional changes.
- The full 25-year GI Plan's estimated cost is $77 million if green infrastructure is implemented during existing planned improvements and $141 million if the projects are stand-alone.
- In 2013, the City passed a stormwater fee (tax), which charges residents and business-owners for impervious surface coverage.
- A credit program will reduce the fee for property owners who reduce their impervious area by taking up pavement, adding green roofs, or take other actions to capture and treat stormwater on-site.
- Created a home-guide for residents to save water and conserve energy.

Current or Predicted Findings:

- Plan is expected to:
  - Contribute $5 million in energy, air quality, and climate-change-related benefits annually after full implementation (U.S. EPA, *The Economic Benefits,* 11).
  - Reduce CSOs by 75 percent (U.S. EPA, *The Economic Benefits* 7).
  - Average annual runoff reduction of 1 billion gallons, after its long-term implementation plan is complete.
  - Reduce gray infrastructure capital costs by $120 million.
  - Reduce wastewater pumping and treatment costs by $661,000 per year.
  - Save the city over $160 million overall (EPA, *The Economic Benefits*, 4).
  - Reduced energy use of $2,368,000 per year due to reduced heating and cooling needs for Lancaster's residents (U.S. EPA, *The Economic Benefits*, 8).
- Residents have so far been supportive of the stormwater tax.
- Stormwater fees are expected to generate $2.6 million in revenue this year; money will be used for urban trees, infiltration islands in parking lots, porous asphalt in alleyways and park basketball courts, and green roofs (Harris).

Pittsburgh, Pennsylvania
Population: 325,000
Median household income: $28,000
Climate: Northeast
CSO status: Confluence of three rivers & CSOs

Context:
- Post-industrial city, former mining center.
- City developed around the confluence of three rivers.
- Collapse of the steel industry led to a population decline.
- Many abandoned lots and large land parcels.

Problem:
- City has been left with brownfields and a CSO problem; 300 CSO outfalls on river upstream of drinking water intakes.
- EPA-requested LTCP and Stormwater Management Plan (SMP).
- City wants a plan to focus on overall watershed management, as opposed to a narrow focus on CSOs.
- City wants flexibility to choose from grey or green infrastructure to manage stormwater.

Program Description/Solution:
- City has undertaken "restorative development" and is buying up lots to remediate brownfields and restore habitat, to raise property value, and beautify the city.
- City entered into a Consent Order and Agreement (COA) with the Pittsburgh Water and Sewer Authority ("Pittsburgh Green Infrastructure") to "ensure that the version of its LTCP submitted to DEP fully consider, and where appropriate, maximize the use of green technologies, practices, and policies that will contribute to the reduction of wet weather flows into the combined sewer system" ("Pittsburgh Green Infrastructure").
- PWSA created the *Greening the Pittsburgh Wet Weather Plan*, which will develop a consensus approach for recommending and reviewing the integration of green infrastructure into its stormwater management plan.
- PWSA will host three charettes with local and national experts and stakeholders on integrating green infrastructure into SMP ("Pittsburgh Green Infrastructure").
- PWSA is working on a Wet Weather Feasibility Study for green infrastructure integration that will propose recommendations and a list of action items for the City of Pittsburgh.
- City is working to develop a cost-benefit analysis and long-term monitoring plan for the new program's efficacy.

Current or Predicted Findings:
- PWSA's Wet Weather Feasibility Study projects it can reduce the volume and frequency of overflows by 95% (PWSA, *Greening the Pittsburgh*).
- PWSA will invest about $2.5 million per year for the next four years in green infrastructure. The information gathered from the green investment will help determine the level and focus of additional investments, which could be as much as $120 million (PWSA, *Greening the Pittsburgh*).

NEXT STEPS

OPERATIONS & MAINTENANCE

Getting it Right

Studies are beginning to consistently show that green infrastructure can reduce the costs of conventional municipal infrastructure and utility maintenance. However, unlike gray wastewater infrastructure, there is no nation-wide standard for operations and maintenance (O&M) of green infrastructure, nor is there a consistent method for its documentation; however, a rapidly growing body of literature is developing. Currently, green infrastructure O&M documentation is "an evolving area that has been steadily gaining importance as the environmental, social, and economic benefits of these types of projects are recognized by a growing number of communities," through which much has already been learned (U.S. EPA, *The Importance*, 4).

One of the biggest challenges municipalities that are interested in green infrastructure face is the lack of a predetermined method for integrating green infrastructure into stormwater management plans. When a municipality is making stormwater management decisions, how will decision-makers and planners know when it is appropriate to integrate green infrastructure into conventional grey infrastructure? It is true that the construction of green infrastructure strategies may not always be cheaper than that of grey (U.S. EPA, *The Importance,* 8). The appropriateness of a GI strategy must be determined "based on a multitude of variables that may include size and surface area, costs of plant materials and survival rates, proximity to pollution sources, site and slope preparation required, necessary soil amendments, and the complexity of underdrain systems," and last but not least, the extent of maintenance required for different GI strategies (U.S. EPA, *The Importance,* 8). A municipality has much to consider: cost-effectiveness, what the short-and long-term environmental benefits are expected to be, and the anticipated operations and maintenance costs.

Many municipalities are struggling with opposing voices; skeptics question the expenses associated with a long-term maintenance commitment to green infrastructure, as well as initial capital costs of some of the strategies. Indeed, the EPA states that "depending on the project type and scope, green infrastructure can have more intensive maintenance demands due to the need for greater frequency and subsequent additional labor hours necessary for optimal performance" (U.S. EPA, *The Importance,* 7). However, the EPA states that on average, GI "costs 5-30 percent less to construct and is approximately 25 percent less costly to maintain over the life cycle of a project" (U.S. EPA, *The Importance*, 7).

One of the reasons that green infrastructure yields cost savings is that benefits of GI systems may improve over time, compared to grey infrastructure systems which degrade over time, generally yielding a shorter lifespan. For example, a study by the University of New Hampshire Stormwater Center demonstrated that "the installation costs of the pervious pavement were found to be 20-25 percent higher than the costs for standard impervious applications" (U.S. EPA, *The Importance*, 7). In addition, surface infiltration during winter months improved greatly; the permeable pavement required 75 percent less road salt due to minimal standing water and ice (U.S. EPA, *The Importance*, 7). Finally, "the pervious pavement installations have demonstrated life spans that exceed 30 years, as compare to traditional pavement which typically lasts 12-15 years in cold climates" (U.S. EPA, *The Importance*, 7).

A shift away from conventional grey infrastructure also entails a shift away from the traditional ROW operations and maintenance regime. Moving towards a green infrastructure stormwater management plan means redesigning the current operations and maintenance regime for a municipality's ROWs.

What's Worked So Far

Studies show that the success of a GISMP depends largely on the quality of its O&M plan (U.S. EPA, *The Importance*, 6). In *The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure* (2013), the EPA recommends that a successful GISMP integrate:

- **A method of establishing accountability**
  An official city document, such as an GI O&M plan that would help ensure that O&M responsibilities are understood, undertaken by the appropriate group, and carried out to completion. The labor force implementing green infrastructure will be managed by or closely coordinate with those responsible for municipal grey infrastructure systems, in most cases, the Department of Public Works (DPW).

- **Education and GI training**
  Because each green infrastructure strategy requires a slightly different maintenance regime, GI education for both those in charge and those carrying out the labor is a must. This includes City planners and policy makers, the DPW, laborers and volunteers.

- **A documentation and monitoring system**
  A method of recording general maintenance costs including the survival rates of plants, dates of plants replaced, GI strategies' lifespans, labor costs, equipment investments, as well as recording performance standards. Adapting planting plans to species survival rates will help ensure GI system success. Recording costs will allow city departments to assess grey infrastructure and stormwater treatment facility cost savings.

- **Dependable community partnerships**
  Local organizations and non-profit groups can help raise funds and establish an educated and trained volunteer base.

- **A method to encourage compliance**

  As multiple agencies and private partners are involved in construction/redevelopment projects, it will be important to have some authoritative means of ensuring compliance in the form of local ordinances and/or inspection requirements with repercussions for failure to comply.

- **Reallocation of funding and additional funding sources**

  The city will need to invest in some specific equipment in order to ensure the long-term viability of some GI strategies (e.g., a vacuum for permeable pavements). Lack of maintenance and operations funding over time may result in unnecessary GI failures.

Further O&M Recommendations for Holyoke

If implemented, the success of a GISMP/Green Streets Program in Holyoke will be largely influenced by its operations and maintenance regime. The City already has some existing resources which together could serve as a stepping stone for the development of a successful GISMP/Green Streets Program for Holyoke.

For example, the Urban Forestry Subcommittee received a grant from the Department of Recreation and Conservation (DCR) for 250 trees in 2013. If the Urban Forestry Subcommittee were able to coordinate a GISMP/Green Streets Program with the DPW, a small City-run nursery could provide appropriate plant species that would be integrated into various green infrastructure strategies (e.g., a stormwater planter or a bioswale) when the DPW undertakes a ROW redevelopment project. The Urban Forestry Subcommittee could also partner with community activist groups with an interest in improving environmental health. For example, Nuestras Raices received an EPA Community Action for a Renewed Environment (CARE) grant and has an established volunteer base with which it works to address environmental issues such as air quality, brownfields, and water quality.

Careful plant care in the first two years of implementation is critical. As healthy plants are the key to the efficacy of green infrastructure systems, an adaptive, well-documented monitoring plan will be very important. (See pages 21-22 for a green infrastructure plant list).

A monitoring plan that also records expenses and reduced annual stormwater treatment facility costs will help identify areas of cost savings and provide the opportunity for the reallocation of stormwater management funds. Holyoke may also want to reconsider adopting the Stormwater Utility Ordinance developed by the Pioneer Valley Planning Commission in order to initiate funding and to further encourage property owners and developers to limit impervious cover.

Finally, the City may benefit from hiring a "Resilient City Coordinator" to manage integrating all of Holyoke's initiatives so that they support each other and share a common mission, while also serving as a point person to educate city departments, stakeholders, and anyone else involved.

NEXT STEPS

It is important to remember that the incorporation of green infrastructure into grey infrastructure systems does not normally happen as a stand-alone project. GI should be a component of any kind of development the city is moving forward with. From park revitalization to housing development, green infrastructure ought to be considered a component of city-wide sustainable development. In addition, by coordinating with grey infrastructure redevelopment projects (e.g., sewershed separation or small-scale flood management projects) or urban revitalization projects (e.g., the Canalwalk or the passenger rail transit-oriented development project), green infrastructure could be simply and easily incorporated in incremental steps, evolving into a more substantial program over time.

FUNDING

As green infrastructure stormwater management programs become more widely recognized, more funding opportunities are beginning to emerge. Possible funding sources for green infrastructure and Green Streets include:

- EPA CARE Grant
- Environmental Workforce Grant
- Community Development Block Grants
- United States Forest Service Community Forest Program Grant
- Chapter 90 funds
- Sewer Enterprise Fund (reallocation)
- Hazard Mitigation Funding
- Clean Water State Revolving Fund bonds

For more information regarding green infrastructure stormwater management plan funding opportunities, please consult the Pioneer Valley Planning Commission Pioneer Valley Green Infrastructure Plan, available in PDF and online at: http://www.sustainableknowledgecorridor.org/site/sites/default/files/uploads/GI/PVPC_DRAFT_GreenInfrastructurePlan_01-25-13.pdf

Streets are some of the most valuable resources that a city has, yet they are assets largely hidden in plain sight.

— Janette Sadik-Khan, Former Transportation Commissioner, NYC

IN CONCLUSION
WHY GREEN STREETS IN HOLYOKE?

Downtown Holyoke has its fair share of obstacles. Stormwater pollution and CSOs are clearly causing environmental degradation of the Connecticut River and making the river unsafe for recreation. Holyoke is not only required by the EPA to treat its polluted stormwater, it is also under a separate Administrative Order to reduce its CSOs. In addition, substantial impervious cover and disproportionately little open space are concentrated downtown, which hosts an environmental justice population. These residents need access to open space and a greener, healthier environment. Compounding this inequity, transportation options are extremely limited and currently centered around motor-vehicle use, causing a number of associated health problems for Holyoke residents.

It is anticipated that climate change will only add to these issues: increased precipitation and warming will increase stormwater pollution and CSOs; impervious surfaces will get hotter, exponentially contributing to the urban heat island effect; fossil-fuel independence and alternative transportation will become more important; less affluent people will be most likely to be subjected to environmental injustices.

Green Streets are designed to treat stormwater at its source and to create more vibrant and livable communities. In Holyoke, Green Streets have the potential to begin the process of addressing the interconnected complexities of these issues.

USING THE GUIDEBOOK

This Guidebook is intended to introduce city planners and policymakers to Green Streets, advocate for Green Streets implementation in Holyoke, and serve as a preliminary set of design guidelines to transform Holyoke's streets into more ecologically, socially, and economically positive spaces. It is our hope that this Guidebook will be consulted when redevelopment is occurring and that Green Streets strategies be integrated into the recreation of streetscapes in Holyoke.

Each section may be independently consulted as needed. The Toolbox encyclopedia serves as a reference with which a user may further investigate a Green Streets strategy. The Templates are conceptual designs that exemplify how the principles and tools can be applied to the variety of streets that exist throughout the city. The site-specific designs demonstrate how Templates and tools can be adapted and applied to specific streets in Holyoke.

HOLYOKE'S FUTURE STREETSCAPES

Holyoke's streets were created well before the automobile, wide enough to accommodate horses and carriages and a trolley system. Most of the tracks were just paved over, leaving the downtown with wide, paved streets, covered in impervious surface, transforming the city into the thriving industrial center it later became. Now, one hundred years later, those same streets have the potential to transform the city again, but this time serving to bring Holyoke toward a greener, healthier future.

REFERENCES

Bassuk, Nina, Jason Grabosky, and Peter Trowbridge. *Using CU-Structural Soil™ in the Urban Environment*. Rep. Ithaca, NY: Urban Horticulture Institute of Cornell University, 2005. Print.

Bassuk, Nina, Jason Grabosky, Peter Throwbridge, and James Urban. "Structural Soil: An Innovative Medium Under Pavement That Improves Street Tree Vigor." 183-85. *1998 ASLA (American Society of Landscape Architects) Annual Meeting Proceedings*. Web.

Bassuk, Nina. *Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance*. New York: Cornell University, Urban Horticulture Institute, 2003. Print.

Boston Transportation Department. *Boston Complete Streets: Design Guidelines*. Boston, MA: City of Boston, 2013. Print.

"Channels and Runnels." *SF Better Streets*. City and County of San Francisco, 2012. Web. 28 Mar. 2014.

City of Holyoke Open Space and Recreation Plan 2012-2017. Holyoke, MA: City of Holyoke, 2012. Print.

City of Milwaukee. Office of Environmental Sustainability. *Green Streets Stormwater Management Plan*. Milwaukee: CH2MHILL, 2013. Print.

Clements, Janet, Alexis St. Juliana, Paul David, and Larry Levine. *The Green Edge: How Commercial Property Investment in Green Infrastructure Creates Value*. Issue brief. 13th ed. Vol. IB. New York: Natural Resources Defense Council, 2013. Print. 11-D.

"Climate Change: Basic Information." *Climate Change*. U.S. Environmental Protection Agency, 2014. Web. 25 Mar. 2014.

Department of Fish and Game. Executive Office of Energy and Environmental Affairs. *BioMap2: Conserving the Biodiversity of Massachusetts in a Changing World: Holyoke*. Holyoke, MA: Commonwealth of Massachusetts, 2012. Print.

Donovan, G. H., and J. P. Prestemon. "The Effect of Trees on Crime in Portland, Oregon." *Environment and Behavior* 44.1 (2011): 3-30. Print.

"F.A.Q." *DC Greenworks*. Tisch Creative, 2011. Web. 28 Mar. 2014.

Gartland, Lisa. *Heat Islands: Understanding and Mitigating Heat in Urban Areas*. London: Earthscan, 2008. Print.

"Green Roofs/Blue Roofs." *Reduce Runoff*. CT Fund for the Environment, n.d. Web. 28 Mar. 2014.

Harris, Bernard. "City Property Owners to Pay Stormwater Fees Beginning This Spring." *Lancaster Online*. Lancaster News, 24 Feb. 2014. Web. 28 Mar. 2014.

"History Walk 1924-1937: Turning Point." *Wistariahurst Museum*. N.p., n.d. Web. 28 Mar. 2014.

Holyoke Redevelopment Authority. *Holyoke's Center City Vision Plan: A Plan for the Heart of Our Community*. By Vanasse Hangen Brustlin, Inc. N.p.: n.p., 2009. Print.

Kloss, Christopher, and Crystal Calarusse. *Rooftops to Rivers - Green Strategies for Controlling Stormwater and Combined Sewer Overflows*. Rep. N.p.: Natural Resources Defense Council, 2006. Print.

Massachusetts Bicycle Coalition. *Biking in Holyoke: Needs Assessment*. Rep. N.p.: n.p., n.d. Print.

Milwaukee Metropolitan Sewerage District. *Determining the Potential for Green Infrastructure to Reduce Overflows in Milwaukee*. Milwaukee: 2020 Facilities Plan Team, 2011. Print.

National Association of City Transportation Officials. *Urban Street Design Guide*. Washington: Island, 2013. Print.

New York City Department of Transportation. *Street Design Manual*. 2nd ed. New York City: n.p., 2013. Print.

REFERENCES CONTINUED

New York Department of Environmental Protection. Office of Green Infrastructure. *Standards for Green Infrastructure*. New York City: City of New York, 2013. Print.

New York's Streets? Not So Mean Anymore. Perf. Janette Sadik-Khan. Ted Talks, n.d. Web.

Odefey, Jeffrey, Stacey Detwiler, Katie Rousseau, Roxanne Blackwell, Mark Buckley, Kevin O'Hara, and Tom Souhlas. *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide*. Rep. N.p.: American Rivers, the Water Environment Federation, the American Society of Landscape Architects and ECONorthwest, 2012. Print.

Patio/Sidewalk/Plaza On Compacted Aggregate Base. N.p.: Interlocking Pavement Concrete Institute, 2013. PDF.

"Pervious Concrete Pavement." *National Pollutant Discharge Elimination System (NPDES)*. Environmental Protection Agency, 2009. Web. 28 Mar. 2014.

Philadelphia Water Department. *Green City, Clean Waters: The City of Philadelphia's Program for Combined Sewer Overflow Control*. Philadelphia, PA: PWD, 2009. Print.

Pioneer Valley Planning Commission. *CSO Fact Sheet #1: Combined Sewer Overflows (CSOs) and Our Rivers*. Rep. N.p.: n.p., 2005. Print.

"Pittsburgh Green Infrastructure." *Pittsburgh Water and Sewer Authority*. City of Pitsburgh, n.d. Web. 28 Mar. 2014.

Pittsburgh Water and Sewer Authority. *Greening the Pittsburgh Wet Weather Feasibility Study*. PWSA. N.p., 31 July 2013. Web. 28 Mar. 2014.

Planning and Economic Development. *Connect. Construct. Create. A Plan for the Revitalization of Center City Holyoke*. By Vanasse Hangen Brustlin, Inc. N.p.: n.p., 2012. Print.

Porous Asphalt Pavement for Stormwater Management. N.p.: UNH Stormwater Center, n.d. PDF.

"Respiratory Health & Air Pollution." *Centers for Disease Control and Prevention*. National Center for Environmental Health, 9 Oct. 2009. Web. 28 Mar. 2014.

Roseen, Robert M. *Forging the Link*. Rep. Portsmouth, NH: Millerworks, 2011. Print.

Section of Stormwater Planter. N.p.: Oregon State University Extension Service, 2014. PDF.

Simple Infiltration Rain Garden. N.p.: Oregon State University Extension Service, 2014. PDF.

Stone, Brian. *The City and the Coming Climate: Climate Change and the Places We Live*. New York: Cambridge UP, 2012. Print.

Thibodeau, Kate Navarra. *Destination: Holyoke: Immigration and Migration to Holyoke*. Holyoke, MA: Wistariahurst Museum, 2006. Print.

"Tree Box Filter." *University of New Hampshire Stormwater Center 2007 Annual Report*. UNH, 2007. Web. 28 Mar. 2014.

"Tree Facts." *American Forests*. N.p., n.d. Web. 11 Mar. 2014.

U.S. Department of Agriculture. Natural Resources Conservation Service. N.p.: n.p., n.d. *Plants Database*. Web. 27 Mar. 2014. <http://plants.usda.gov/>.

U.S. Department of Transportation. Office of Planning, Environment, and Realty (HEP). *Regional Climate Change Effects: Useful Information for Transportation Agencies*. Washington, DC: Federal Highway Administration, 2014. Print.

U.S. Environmental Protection Agency. *Creating the Community Environmental Health Coalition*. By Giovanna Di Chiro and Marybeth

REFERENCES CONTINUED

Smuts. Holyoke, MA: EPA, 2009. Print.

U.S. Environmental Protection Agency. Office of Water. *The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure*. N.p.: n.p., 2013. Print.

U.S. Environmental Protection Agency. Office of Water. *National Pollutant Discharge Elimination System: Stormwater Phase II Final Rule*. N.p.: EPA, 2005. Print.

U.S. Environmental Protection Agency. Office of Wetlands, Oceans and Watersheds. *Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs*. N.p.: n.p., 2013. Print.

U.S. Environmental Protection Agency. *The Economic Benefits of Green Infrastructure: A Case Study of Lancaster, PA*. Lancaster, PA: EPA, 2014. Print.

U.S. Environmental Protection Agency. Office of Wetlands, Oceans and Watersheds. *Stormwater to Street Trees: Engineering Urban Forests for Stormwater Management*. Washington, DC: n.p., 2013. Print.

U.S. Environmental Protection Agency. *Stormwater Management Handbook Implementing Green Infrastructure in Northern Kentucky Communities*. N.p.: n.p., 2009. Print.