6/30/2020

Holyoke Impervious Surfaces Mitigation Plan

City of Holyoke, MA

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GLOSSARY OF TERMS

Abatement - reducing the degree or intensity of, or eliminating, impacts associated with pollution.

Bioretention basin - landscaped depressions or shallow basins used to collect, slow, and treat on-site stormwater runoff

Bioswale – a channel designed to concentrate and convey stormwater runoff while removing debris and pollution, often found along road edges and in parking lots

Combined Sewer Overflow - an underground pipe system that collects sewage, wastewater, and rainwater runoff in the same pipe

Evapotranspiration - the movement of water from land to the atmosphere by the evaporation from the soil and water bodies, and transpiration from plants

Geographic Information System (GIS) - a framework for gathering, managing, and analyzing data, often used for producing maps and analysis

Green Infrastructure - approaches and technologies to infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrologies

Infiltration - the process by which water is absorbed into the ground

Impervious surface - Material or structure on, above, or below the ground that does not allow precipitation to penetrate directly into the soil

Low Impact Design (LID) - a land planning and engineering design approach to manage stormwater runoff as part of green infrastructure. LID emphasizes conservation and use of on-site natural features to protect water quality.

Mitigation - actions and processes to reduce risks from hazards

Pervious surface – a natural surface or manufactured material that allows water to seep into the underlying soil

Road Diet - a technique in transportation planning whereby the number of travel lanes and/or effective width of the road is reduced in order to achieve systemic improvements

Sewershed - the catchment area where all sewers flow to a single endpoint

Stormwater runoff – precipitation that flows across pervious or impervious surfaces

Urban Heat Island effect - the phenomenon of increased air temperatures in densely-developed urban areas. The phenomenon tends to be most pronounced at night, as cities cool down more slowly than green, open-space areas

1 INTRODUCTION

1.1 PURPOSE OF STUDY AND PLAN

The Massachusetts Vulnerability Preparedness (MVP) program awards funding to municipalities looking to plan ahead for the impacts of climate change and to assist with executing priority projects. To be eligible for MVP funding, Holyoke first conducted a vulnerability assessment through a series of Community Resilience Building (CRB) Workshops in 2018. These workshops identified priorities and actions that will help the community build resiliency in the face of climate change. The results of these workshops were used to create an MVP Plan to guide future resiliency and planning initiatives. As a certified MVP Community, Holyoke continues to pursue opportunities to fund these initiatives.

In 2020 the City of Holyoke received MVP Action Grant funding for a planning project from the MVP program through the Massachusetts Executive Office of Environmental Affairs (EEA). This grant allows for the development of extensive impervious surface data, which is being completed independently of this plan, and this Impervious Surface Mitigation Plan. This plan has been developed to describe the impacts of impervious surfaces and recommend technical and regulatory strategies and considerations for mitigating those impacts.

Holyoke's zoning ordinance defines impervious surface as "[m]aterial or structure on, above, or below the ground that does not allow precipitation to penetrate directly into the soil." Buildings, roads, and parking lots are part of any urban landscape. These hard surfaces collect oil, grease, heavy metals, and other contaminants; when it rains, these contaminants flow into Holyoke's stormwater system and end up in local waterways or in the city's sewer system. During wet weather events portions of the sewer system exceed capacity and overflow into the Connecticut River. Combined Sewer Overflows (CSOs) are present in the City and are closely regulated as the City implements actions to reduce their impacts.

Aside from the water quality impacts, impervious surfaces also contribute to shallow flood conditions. When rainwater meets an impervious surface, it cannot be absorbed into the ground. When the city's drainage system cannot handle excessive rain events portions of the city will flood.

Impervious surfaces are known to create or contribute to urban heat islands. These hard surfaces are often dark-colored, absorbing and storing heat during the day, contributing to higher temperatures at night and to the urban heat island effect (UHI). Areas where impervious surfaces are concentrated have poorer air quality due to a lack vegetation and have more automobile traffic and industrial uses which emit pollution. The UHI effect contributes to excessive heat events, abrupt and dramatic temperature increases that can overload utility systems that are taxed by demand for cooling, and cause heat-related illnesses and death.

To mitigate these effects of impervious surfaces, Holyoke relies on a combination of enforcement, permitting, education, and construction of new infrastructure.

In the CRB Workshops of 2018, flooding and heat events were noted as areas of concern. CSOs and the city's stormwater infrastructure were identified as vulnerabilities, as well as air quality. This Impervious Surface Mitigation Plan seeks to address those vulnerabilities and concerns by examining how reducing impervious surfaces can provide relief and resiliency for Holyoke.

1.2 Review of Actions from MVP Plan

The City of Holyoke participated in the MVP planning process in spring 2018. Stakeholders collaborated during the CRB workshop to identify city-specific vulnerabilities, and to develop priority actions that can be implemented to increase the city's resilience to anticipated climate change impacts.

The five top-priority actions identified during the CRB workshop were:

1. Coordinate and implement City plans and ensure certain standards and capacities are met.
2. Install alternative power supplies at critical facilities, including back-up generators and battery storage.
3. Rebuild the right of way for climate resiliency, including complete streets, CSO separation, and burying utilities.
4. Conduct a public education campaign to include an event where information flows in two directions to learn from those that fled Hurricane Maria and create a neighborhood level marketing engagement and training program.
5. Develop a tree management, maintenance, and planting program with appropriate species.

These five actions were identified as the most favorable actions to address both specific and more generalized impacts of climate change. Actions 3 and 5 are directly addressed by this plan.

Overall, the MVP process has identified versatile actions that will address flooding and other natural hazard concerns that are exacerbated by climate change. These actions, in addition to evaluating and mitigating impervious surface, will collectively increase the resilience of the City.

1.3 Overview of Approach to Public Engagement

The overall approach for public engagement for this plan is to develop a digital presence to compensate for the inability to conduct in-person public meetings due to the restrictions on social gatherings put in place in response to the COVID-19 pandemic. This presence includes an ArcGIS Online StoryMap that presents the project and informs the public about the impact of impervious surfaces on the community. In addition, a public internet-based survey was developed and deployed to gauge public opinion on various mitigation strategies. Both the StoryMap and the survey were available in English and Spanish.

The StoryMap describes the goal behind this plan and the problems and challenges posed by impervious surface in the City. A brief introduction is provided on some of the associated impacts with highly impervious areas such as flooding, reduced water quality, urban heat islands, and impaired air quality. The StoryMap includes several interactive maps where residents can explore the level of imperviousness in their neighborhood, flood hazard areas, water quality classifications, and urban heat island areas. The latter part of the StoryMap introduces the tools used to mitigate these impacts and presents the viewer with a brief questionnaire.

The survey presented a series of questions about vulnerabilities and risks related to impervious surfaces, and tasked participants with ranking ideas and opinions related to strategies for reducing imperviousness

To ensure wide disbursement of this engagement tool, stakeholders that could assist in reaching the public were identified. These stakeholders allowed for distribution to different target audiences including school aged children and Spanish speaking populations.

1.4 Review of Other Plans

Combined Sewer Overflow Long-Term Control Plan Update, December 2019 (draft)

A Combined Sewer Overflows (CSO) is an underground pipe system that collects sewage, wastewater, and rainwater runoff in the same pipe. Due to capacity limits in the sewer system and at the wastewater treatment facility, during wet weather events a regulated portion of this combined flow discharges into a downstream waterbody; for Holyoke, this waterbody is the Connecticut River. For the past 20 years Holyoke has been following a long-term strategy to reduce these CSO discharges, as outlined in the City's original Long-Term CSO Control Plan (CSO LTCP). The original 2000 plan is currently being updated and is in draft form.

The CSO LTCP evaluates alternatives for achieving improved water quality and concludes that three sewer separation projects should be implemented. The separations should help reduce overflows at CSO numbers 8 (Springdale Park), 11 (Jackson Street), and 21 (River Terrace). The plan notes that "no further CSO abatement is proposed or required to comply with the federal CSO control policy."

The plan also notes that the Day Brook enters the combined sewer system at the upstream end of CSO 9. Detaining flow peaks during wet weather events are estimated to cost $2 million. By detaining this flow, 6.8 million gallons of overflow would be reduced annually. While removal or abatement of the Day Brook CSO is not part of the final recommendations of the Long Term Control Plan, the Day Brook Watershed is the subject of an Action Plan prepared by the Pioneer Valley Planning Commission (Pioneer Valley Planning Commission, 2019). This plan focuses on using green infrastructure as a strategy for Holyoke to meet the requirements of stormwater discharge permits.

The CSO LTP mentions green infrastructure as an abatement technique on page 8-2 and describes the individual green infrastructure techniques available on pages 8-4 through 8-7. Additionally, the table on page 8-17 indicates that green infrastructure was a CSO abatement alternative evaluated for CSOs 18, 19, 20, 21, and 23.

Notwithstanding the contents of the plan, reduction of impervious surfaces using green infrastructure or open space may be a reasonable method of further improvements in CSO abatement. The question is whether reduction of impervious surfaces should be focused:

- In areas where CSO abatement has already occurred, to make further improvements
- In areas where CSO abatement is recommended (the three sewer separations noted above), in case the projects take several years to be implemented
- In areas where CSO abatement is not proposed (i.e., combined sewers will remain in place)
- In some combination of the above (i.e., Citywide)

During the MVP Plan process stakeholders identified that green infrastructure solutions should be deployed alongside CSO eliminations. Sewer separation and stormwater infrastructure improvements were identified as priorities for reducing the risk of flooding. Therefore, the results of the MVP planning process considered alongside the Long-Term Control Plan Update would imply that reducing imperviousness should be considered citywide, and not only where CSOs have been accomplished.

GREEN STREETS GUIDEBOOK

The Green Streets Guidebook was produced in 2014 in partnership with The Conway School. The Guidebook is intended to assist Holyoke incorporate Green Streets strategies as Holyoke undergoes redevelopment of streetscapes and right of ways. The Guidebook also recognizes that Holyoke's planners need to be cognizant of stormwater management issues like CSOs during redevelopment and renewal. The Holyoke Conservation Commission recognized the opportunity to implement Green Streets as part of this renewal process.

Green Streets combine three principles of design:

- Green Infrastructure: Use natural elements like trees and bioswales to capture and filter stormwater
- Complete Streets: Equitable space on roads for pedestrians, transit, motorists, and cyclists
- Placemaking: Create places and spaces with amenities that encourage people to congregate and enjoy

The Guidebook notes that the eastern part of city with the highest amount of impervious surfaces is considered an Environmental Justice (EJ) area by the Massachusetts Executive Office of Energy and Environmental Affairs. This is defined as an area of low income where the population is greater than 25% minority and 25% or more households are non-English speakers. Green Streets provide social, environmental, and ecological benefits that could positively impact these populations. Green Streets emphasize multiple modes of transportation, including walkability. Natural elements used to filter and capture stormwater also improve air quality.

The Guidebook notes that by reducing impervious surfaces through the implementation of Green Streets, Holyoke hopes to mitigate other issues like an anticipated increase in overall temperature, high heat days, and projections of increased rainfall.

The Green Streets Guidebook includes a comprehensive toolkit that incorporates the three principles of Green Streets design in planning future streetscape projects. The toolkit provides schematics for 14 different green infrastructure designs, along with suggested plantings. Eight different Complete Street design options are provided, along with two Placemaking suggestions. The Guidebook then includes nine different templates that explore how these schematics could be combined when designing a streetscape project.

The Guidebook highlights five specific streets in Holyoke and provides guidance on how to implement a visionary approach to applying Green Street designs. The five streets are strategically located in an area of planned or intended redevelopment.

OPEN SPACE AND RECREATION PLAN 2019–2025

Holyoke's Open Space and Recreation Plan (OSRP) supports the city's commitment to resiliency in the face of climate change. The vision of the OSRP is to increase the quality of life for Holyoke residents through a framework that offers guidance and methods to protect, improve, and preserve the open spaces and recreational opportunities that are treasured by the residents of Holyoke.

The OSRP is intended to as a tool that communicates the priorities of the community and assists with decision-making and planning efforts. The plan recognizes that the impervious nature of the old industrial and mill sites is an environmental hazard and that CSOs present a challenge to the city. The plan notes that parks in the downtown core are perceived to be unsafe or unwelcoming. The plan notes that Holyoke is a "historic, complex, and resilient city" which is starting to grow after a period of population decline.

The OSRP delves into the issue of impervious surfaces. The plan notes that the urban core of the city is highly concentrated with impervious surfaces and notes that the EPA classified a quarter of this area as Directly Connected Impervious Area (DCIA). When impervious surfaces are directly connected, water is not given a chance to infiltrate into the ground but runs directly into systems that convey water into drains, catch basins, or other systems that move water.

The EPA issues National Pollutant Discharge Elimination System (NPDES) water quality permits for the state of Massachusetts. This permit program addresses water pollution by regulating the sources of pollution that discharge into water. Holyoke falls under the purview of these regulations because the municipality operates and manages a stormwater system. The Open Space and Recreation Plan describes how the State of Massachusetts revised its stormwater permit in 2018 and notes that the EPA had singled out Holyoke for CSO discharges into the Connecticut River.

The OSRP offers some suggestions to comply with reducing these discharges using green infrastructure during street reconstruction projects as they occur throughout the city. Green infrastructure is noted in the OSRP for its ability to help water infiltrate into the ground rather than run across an impervious surface. The plan also recommends that the city continue to daylight streams and watercourses as done with Day Brook and prioritizes Tannery Brook due to significant erosion and flooding issues.

Urban ecology is highlighted in the OSRP as another option to mitigate the effects of impervious surfaces. The plan describes how the City of Holyoke has planted 1,500 trees, primarily in the urban core. These trees offer benefits that align with the goals of reducing impervious surfaces: improving air quality and reducing urban heat islands, stormwater flooding, and pollution.

The OSRP includes a number of goals for the city to pursue. First among these goals is that "Natural resources are protected and enjoyed by all" and following closely at number 4 is that "Open space is an integral component of community development at the neighborhood, city-wide, and regional scale". To achieve these goals the OSRP recommends that Holyoke preserve surface and groundwater resources as well as use green infrastructure to infiltrate stormwater and enhance the urban landscape. A selection of actions associated with these two goals is provided to the right.

Green infrastructure projects such as the rain garden at Pulaski Park have been completed recently through public sector and public-private partnerships. The Pioneer Valley Green Infrastructure Plan identifies public projects at Depot Square and the Suffolk Parking Garage as potential locations for new public-sector projects. Green infrastructure projects, strong language promoting green infrastructure, and Low Impact Development (LID) techniques and guidelines could not only reduce stormwater and wastewater pollution, but also have beneficial placemaking and quality of life benefits.

Goal 1: Natural resources are protected and enjoyed by all

B. Preserve surface and groundwater resources

- Review and revise subdivision rules and stormwater ordinance language to encourage low impact development best management practices
- Integrate separation of CSOs into road improvement projects
- Update stormwater infrastructure in areas with flooding and erosion concerns identified in this plan

Goal 4: Open space is an integral component of community development at the neighborhood, city-wide, and regional scale

A. Use green infrastructure to infiltrate stormwater and enhance urban landscape

- Integrate green infrastructure with public funded projects, guided by Holyoke green streets plans and the Pioneer Valley Green Infrastructure Plan
- Maintain existing rain gardens and increase capacity for City maintenance of additional green infrastructure systems
- Increase education of innovative stormwater management including workshops for students on rain garden creation
- Continue tree-planting program in priority tree-planting areas to meet urban tree planting goals
- Increase awareness of tree planting forms and disseminate widely to schools, realtors, tax mailings, etc.
- Reduce impervious surfaces and increase pervious surfaces throughout the city

1.5 Review of NPDES General Permit

As noted in the OSRP, the City of Holyoke filed its National Pollutant Discharge Elimination System (NPDES) General Permit for Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. In July 2018, a revised permit became effective for Massachusetts. The six minimum control measures mandated by this permit include: 1) public education and outreach, 2) public participation in development and implementation of the City's Stormwater Management Program (SWMP), 3) illicit discharge detection and elimination, 4) management of construction site runoff, 5) management of post-construction site runoff (development and redevelopment), and 6) good housekeeping in municipal operations. The scope of work and the permitting requirements established in this document require the Conservation Commission to inspect all stormwater detention basins, generate public education resources, and stencil storm drains.

The OSRP notes that Holyoke's Stormwater Ordinance, adopted in 2009, contains strong requirements for stormwater management; and that according to the Pioneer Valley Green Infrastructure Plan, Holyoke fulfills all of the NPDES regulatory requirements with the exception of a noted lack of strong LID language in subdivision regulations.

1.6 STORMWATER AUTHORITY

Holyoke administers a Stormwater Authority. The City's Stormwater Utility Policy includes a definition of "impervious surface" and provides for levying of fees for all real property in the City. The policy exempts public streets and rights-of-way and railroad rights-of-way. The City's Stormwater Utility Fee Ordinance sets the fees.

Holyoke has proposed a system of stormwater credits that are described in the policy document. The credits will be issued for property owners that make improvements to their properties to reduce stormwater generation. Because these credits are incentives to reduce imperviousness, they should be as aggressive as possible while allowing the Stormwater Authority to collection sufficient revenue to function.

The City's Stormwater Authority *Stormwater Regulations* (May 17, 2010) are separate from the stormwater regulations included in the Zoning Ordinance (addressed below). The Stormwater Authority Stormwater Regulations are likewise separate from the Stormwater Ordinance and the stormwater utility fee documentation. A new development proposed in the City would presumably be subject to the Stormwater Authority Stormwater Regulations and would subsequently be subject to the stormwater utility fees, with credits available by virtue of complying with the regulations. A few ways to strengthen the regulations include:

- The Stormwater Authority Stormwater Regulations includes a definition of "impervious surface" and a definition of "low impact development." The Regulations should be modernized and made consistent with nationwide guidance by adding a definition for "green infrastructure."
- In Section 4.02 (a), number xiv (LID) should be moved up. Including this item last does not serve the overall purpose of the section.
- Section 5.01 is performance standards for large developments, Section 5.02 is design requirements for large developments, and Section 5.03 is performance standards for small developments. The regulations lack design requirements for small developments. Sections 5.01 through 5.03 could be re-written if these are proving to be complicated for developers to navigate. If re-written, the City could consider merging the performance standards and design requirements for large developments, or at least listing the design requirements prior to the performance standards.
- Rain barrels are mentioned as a performance standard, but the regulation may want to note somewhere that they do not provide credit for the stormwater utility fee.

1.7 ZONING ORDINANCE STORMWATER REQUIREMENTS AND STANDARDS

The current City of Holyoke Zoning Ordinance is dated February 19, 2002, although it has been continuously updated as noted in the section listing all revisions and updates. Section 6.1.7.7 of the ordinance includes the *"Stormwater Management Design Criteria and Standards"* under "General Regulations," whereas Section 10.1.8 of the ordinance includes the *"Stormwater Management Design Criteria and Standards"* under "Major Site Plan Review."

The areas of zoning ordinance related to stormwater appear to have not been updated in recent years nor updated to reflect changes in subsequent amendments, making the code disjointed. The code does include the definitions of impervious surface, infiltration, and permeable soils; it does not however include definitions of lot coverage, land coverage, or building coverage. These definitions should be added to ensure clarity.

1.8 Zoning Ordinance

As suggested above in the context of how the Zoning Ordinance addresses stormwater, there is room to be more proactive in the zoning code with regard to impervious surfaces overall. The code specifies maximum building coverage by zone for some sections of the city, but it does not specify a maximum impervious surface coverage. It includes definitions of impervious surface, infiltration, and permeable soils but does not include definitions of lot coverage, land coverage, or building coverage. These definitions should be added to clarify how impervious coverage is measured on a site.

The regulations tie impervious cover requirements to specific zones rather than uses. The zoning code contains a schedule of parking minimums by use, which for many commercials uses appear to be based on gross floor space rather than net floor space or the intensity of the use. Other restrictions include:

- A 20% cap on impervious cover in the Water Resource Protection Overlay District (WRPOD).
- New development limitations in the Flood Plain Overlay District.
- The Entryway Business District (BE Zone) has 90% max building cover.
- The Downtown Residential District (DR Zone) gets maximum lot coverage from the average of the nearest five lots containing structures on the same side of the street on the same block.
- For multi-family developments RM-60 has a maximum coverage of land of 60%; in all other cases it is 40% building coverage.

With the requirements not tying requirements to use, there could be an opportunity to analyze similar uses in different zones to see if zoning *actually* impacts the coverage. An opportunity is apparent for the regulations to tie future impervious cover requirements to uses rather than zones. Adjusting the parking schedule to lower parking requirements (such as the changes in Hartford, Connecticut) or impose maximums could also be an option to reduce impervious surfaces. The BE Zone is also a good candidate for analysist to see if lots are hitting this maximum building coverage, or if this maximum can be lowered.

For many commercial and industrial zones, there is no restriction on maximum building coverage. Developments in the Downtown Residential District (DR Zone) derive maximum lot coverage from the average on the nearest 5 lots containing structures on the same side of the street on the same block. This calculation could be difficult to determine and could result in more impervious surface in the Downtown Residential District than is desirable. 60% of the Downtown Residential District consists of impervious surfaces. This zone in particular should be revisited to provide clarity.

Parking is often a major contributor to impervious coverage on a lot, especially in commercial zones. According to the Urban Land Institute, “Parking can consume 50 percent or more of the building and land area of a development. An oversupply of parking can result in excess storm drainage impacts and unnecessarily high expenses.” (Smith, 2020) The zoning code contains a schedule of parking minimums by use. Many of these minimums for commercial uses are based on the gross floor space rather than net floor space, the anticipated number of visitors, or anticipated intensity, which may result in unnecessary amounts of pavement required. There are opportunities to reduce impervious coverage by revisiting and rethinking this schedule.

Stormwater Management Design Criteria and Standards

In section 10.1.8, the Zoning code describes Stormwater Management measures and Low Impact Development incentives. These incentives could be strengthened to encourage more developers to use them, as discussed in Chapter 7. Overall, the code should be revised to clarify what is being sought during development and redevelopment, including examples from Holyoke. Diagrams would also assist in demonstrating what is desired. The Massachusetts Stormwater Management Guide is referenced within the text. By including the specific excerpts from the Manual that the developers will need in this section, the code can be made more user friendly.

2 CLIMATE CHANGE SCENARIOS

The Massachusetts Climate Change Clearinghouse, or "resilient MA," presents various climate change scenarios that planners, policymakers, and the general public can utilize for scientifically supported planning and policy making regarding climate change impacts.

Projections presented by the Clearinghouse are a product of fourteen Coupled Model Intercomparison Project Phase 5 (CMIP5) models; the same models used to form the basis of projections in the IPCC Fifth Assessment Report (IPCC, 2014). Both the RCP4.5 and RCP8.5, the medium and high greenhouse gas emission scenarios respectively, were used by resilient MA.

resilient MA
Climate Change Clearinghouse for the Commonwealth

The county and basin level projections were developed by statistically downscaling the statewide model results by way of the Local Constructed Analogs (LOCA) method (Pierce et al., 2014). The county datasets presented provide daily precipitation, and maximum and minimum temperatures on a roughly 6 km grid.

Overall, projections for the City of Holyoke and associated regions indicate increased precipitation and warmer temperatures for the coming decades. While statistics vary based on both the models and the size of the area under consideration, the primary take away should be for the City to plan for warmer seasons and increased precipitation in the form of either rain or freezing rain. It is also important to note that the resilient MA projections do not project a prominent increase in the intensity of precipitation events for the City, but that the increase in precipitation is likely to occur as a result of more frequent, smaller events, with more frequent events in warmer, winter months. Note that increased winter precipitation will not necessarily result in more snowfall or snow accumulation, as warmer temperatures will mean more of this precipitation will fall as rain, and snow that does accumulate will melt more rapidly. The specific projections for the State, Hampden County, and the Connecticut River basin are outlined in the following sections, with statistics in Table 2-1. The state report on climate projections is attached to this document as Appendix A.

2.1 STATE PROJECTIONS

Mid-21st century projections (2050), relative to the time frame between 1971-2000, expect an overall increase in statewide average temperatures between 2.8 and 6.2˚F in comparison to recent decades. There is also an expected increase of between seven and 26 more days per year where daily maximum temperatures exceed 90˚F. On the other hand, there may potentially be 19 to 40 days fewer days per year (than recent decades) where temperatures fall below 32˚F. With projections identifying an increase in warmer temperatures, and a decrease in cooler temperature days, the growing season across the state will be longer with a 23% to 52% increase in growing days.

Future precipitation shifts are also identified under these projections. Annual precipitation is likely to increase by 2% to 13% by 2050, with a total winter season increase of up to 21%. However, due to projected warming, this increase in winter precipitation will likely fall in the form of rain or freezing rain versus snow. Annual precipitation averaged 47” per year between 1971 and 2000; this average annual statewide precipitation total may increase by 0.9” to 6” by 2050. Days with over 1” of precipitation may also increase by up to three more days.

2.2 County Projections

The statewide model was statistically downscaled to Hampden County using the LOCA method. Projections for 2050 identify an estimated 4.33˚F increase in mean annual temperature, with an increase of 3.82 ˚F in winter and 3.58 ˚F in summer. Hampden County is projected to experience approximately 14 more days over 90 ˚F, and 24 fewer days with temperatures below 32 ˚F.

The Hampden County annual total precipitation is projected to increase 0.69” by 2050, with an increase of 0.11” during the spring season, and 0.13” during the winter months. With warming trends like those of the statewide projections, precipitation in the region may also fall more frequently as rain or freezing rain during winter. Overall, precipitation is expected to increase, however according to the projections, there is little to no increase expected in the number of days a rain event exceeds 1”, 2”, or 4” of rainfall.

2.3 Basin Projections

The Massachusetts portion of the Connecticut River Basin, which extends from the Connecticut border north to the Vermont and New Hampshire borders, is projected to experience similar shifts in temperature and precipitation trends. The annual mean temperature is projected to increase by 4.05 ˚F, with a winter increase of 3.44 ˚F and a summer increase of 3.63 ˚F. The basin region may see approximately 15 more days over 90 ˚F on an annual basis, and an estimated 22 to 23 fewer days with temperatures below 32 ˚F. With similar trends to both the State and Hampden County, the growing season will likely increase also.

Precipitation trends for the Connecticut River Basin are slightly higher than those of Hampden County. There is a projected annual total precipitation increase of 1.48” by 2050, with an increase of 0.37” in winter and 0.34” increase during spring months. The region projections show less than a 1-day increase of events that result in 1”, 2”, or 4” or precipitation. With precipitation intensity trends like those of Hampden County it is likely both regions will experience more frequent, short lived rain events, which ultimately result in an annual increase in precipitation.

Table 2-1: Projection Statistics for the State, Hampden County and Connecticut River Basin from resilient MA for the 2050 Horizon

	Mean Annual Temp. Increase	Winter Temp. Increase	Summer Temp. Increase	Total Annual Precip. Increase (in.)	Total Winter Precip. Increase (in.)	Total Spring Precip. Increase (in.)
State of Massachusetts	2.8 – 6.2	3.52	3.56	0.9 – 6.0	-0.30	-0.20

Hampden County	4.33	3.82	3.58	0.69	0.13	0.11
Connecticut River Basin	4.05	3.44	3.63	1.48	0.37	0.34

3 IMPERVIOUS SURFACE IMPACTS

In any community, whether urban or rural, impervious surfaces may adversely impact the functions of municipal infrastructure, public health, natural resources, and nearby ecosystems. Some of the associated impacts of impervious surfaces may include:

- Stormwater generation and related flooding
- Water quality impairment from nonpoint source pollution in stormwater
- Combined sewer overflows
- Urban heat island effects
- Adverse air quality

Infrared imagery from the US Department of Agriculture's 2018 aerial flight was used to map Holyoke's pervious and impervious surfaces. The City of Holyoke is currently under contract to develop a more precise impervious surface dataset through planimetric mapping. For the purposes of this chapter, a general overview is sufficient to make observations. The general analysis shows that 30% of Holyoke is covered with impervious surfaces. Holyoke's Open Space & Recreation plan indicates that in Holyoke's urban core, impervious surfaces cover 60% of the land area.

The impacts of Holyoke's impervious surfaces, separated into the five categories presented above, are described in the following sections.

3.1 STORMWATER GENERATION AND FLOODING

Typical Impacts
The presence of impervious surfaces reduces the natural process of rainwater infiltration and groundwater recharge. In the absence of this process, increased levels of stormwater runoff are generated as rainwater collects and flows over the surface. This excess runoff, if it does not drain into appropriate drainage systems, can cause flooding by way of pooling in poorly drained areas or over-inundating nearby streams and elevating water levels more rapidly than the stream can handle. The excessive flow and the speed at which stormwater and floodwater move also contributes to erosion, damaging infrastructure and further contributing to harm of natural ecosystems. The more developed a watershed, the greater the potential for more frequent and more severe flooding events.

Observed Impacts in Holyoke
Flooding from storms is listed as a "Highest Risk" vulnerability in the 2016 Holyoke Hazard Mitigation Plan Update (HMP). Flash flooding due to heavy precipitation in a short period of time is more of a concern than long-term flooding that is caused by slow moving storms.

The 1-percent annual chance flood plain covers almost 9% of the city. There are 29 active flood insurance policies within the flood plain and one property is defined as a Repetitive Loss Property. Localized flash flooding, however, occurs outside of the 1-percent annual chance flood plain. The HMP predicts that three to four flash floods will occur each year. The plan notes that "[n]ewly developed areas of the City are less vulnerable to the effects of flash flooding because of the presence of modern storm water management systems."

Areas in Holyoke outside of the 1-percent annual chance flood plain reported to be susceptible to flash flooding are:

- Green Brook, particularly at Green Lane and Longfellow Drive
- Portions of the Great Lakes area
- Tannery Brook between Meadowbrook Road and Whiting Estate on Homestead Avenue
- Unnamed stream at Mt. Tom Avenue at Wyckoff Country Club pond
- Land along the Connecticut River frontage in Smith's Ferry above the Holyoke Dam including areas of the Mt. Tom Power Plant
- A wide strip along the Connecticut River east of Route 5 in the southeastern corners of the city
- Some stretches of Broad Brook in West Holyoke
- Southampton Road, due to an undersized culvert

Specific streets and underpasses listed in the HMP that are also subject to flash floods are:

- Fairmont Street
- Skyview Street
- West Franklin Street
- Cabot Street
- Mosier Street railroad underpass
- Cabot Street railroad underpass
- Sargeant Street railroad underpass
- Jackson Street railroad underpass
- Appleton Street railroad underpass

Figure 3-1: Underpass flooding at Lyman Street

3.2 Water Quality Impairment from Nonpoint Source Pollution in Stormwater

Typical Impacts

The excess runoff caused by impervious surfaces can also result in water quality impairments to both surface and groundwater sources. Stormwater runoff collects pollutants and sediment which ultimately enter watercourses and waterbodies or groundwater. Surrounding land also plays a role in the degree of pollution found in runoff, as heavily commercialized or industrialized areas typically contribute higher levels of pollutants than residential or less-developed areas.

Observed Impacts in Holyoke

Holyoke's drinking water is primarily sourced from the Tighe-Carmody reservoir in Southampton and is blended with water from the McLean Reservoir in Holyoke. Holyoke is able to maintain an unfiltered water supply, one of only a few communities in the state.

However, Section 11 of Holyoke's Watershed Resource Protection Plan (WRPP) indicates that runoff from impervious surfaces can transport contaminants into the water supply. Runoff also causes severe erosion along streams and damages vegetation. By limiting impervious surfaces, water filters into the soil and removes contaminants naturally. Reducing impervious surfaces also protects vegetation and the stability of streams from the rushing force of runoff.

Routes 202 & 66 are noted in the WRPP for their contribution to water runoff. Route 202 is of special concern as this road crosses the northern portion of the Ashley Reservoir. Traffic accidents along this busy route contribute to uncontrolled releases of contaminants that can be carried by runoff. The City reduces salt concentration along Route 202 during the winter and maintains vegetation cover in sensitive areas to act as a barrier to runoff.

Runoff & leakages from fuel storage & septic tanks also pose threats to Holyoke's water supply. Following best management practices, Holyoke Water Works mitigates these impacts through public education about potential contamination leaks from fuel storage tanks and septic systems.

In addition to Holyoke's water supply, waterbodies downstream of the city are susceptible to water quality impacts from runoff. Specifically, the Connecticut River directly receives the bulk of water that flows out of Holyoke, with the city's urban core being the primary contributor (portions of the city that drain into Paucatuck Brook and Broad Brook eventually reach the Connecticut River as well, but less directly; these portions of the city are less developed and have fewer pervious surfaces). According to the *Final Massachusetts Year 2016 Integrated List of Waters* (MA Executive Office of Energy and Environmental Affairs, 2019), the section of the Connecticut River adjacent to Holyoke is impaired for Escherichia Coli (E. Coli) and PCBs In Fish Tissue (above Holyoke dam) and PCBs In Fish Tissue (below Holyoke dam). While these particular pollutants may not be the result of nonpoint source pollution from runoff (i.e., the E. Coli is likely from CSOs and the PCBs are from industrial discharges), this impaired status is important to note in the context of impervious surface mitigation.

3.3 Combined Sewer Overflows

Typical Impacts

Another source of concern is combined sewer overflows (CSO). Many municipalities, including Holyoke, maintain combined sewer systems (CSS) which collect stormwater runoff and sanitary sewage, as well as certain industrial wastes that are discharged to sanitary sewers. While a CSS is adequate for average wastewater disposal and treatment, the volume of wastewater can sometimes exceed the CSS capacity due to excessive stormwater contributions and result in untreated discharge flowing directly into streams or other waterbodies. This discharge may contain untreated or partially treated sewage, debris, and stormwater. Because a highly impervious community will generate runoff to a larger extent in comparison to a community with greater permeable surfaces, the potential for combined sewer overflows may be greater. See Figure 3-2 for a depiction of a CSO.

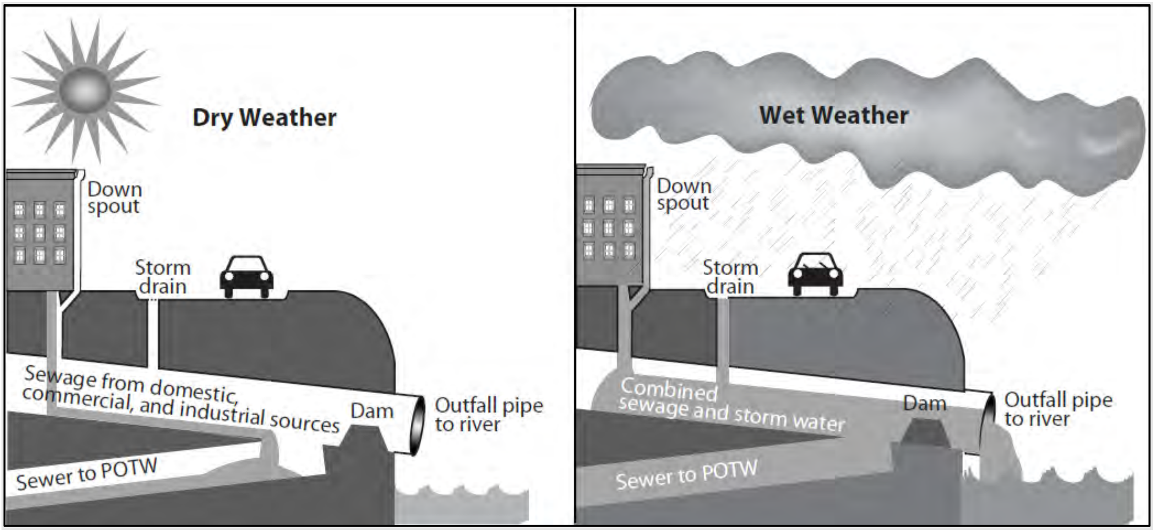

Figure 3-2: How a combined sewage and stormwater system handles wet weather
U.S. Environmental Protection Agency (EPA)

Observed Impacts in Holyoke

Combined Sewer Overflow discharges are a significant source of pollution for the Connecticut River. The City of Holyoke maintains a Long-Term Control Plan (described in Chapter 1) to comply with requirements of EPA and the State of Massachusetts to abate these discharges.

Holyoke has 12 CSO discharge points. The draft of the Long-Term Control Plan notes that they discharge an average of 163 million gallons of combined sewer overflow into the Connecticut River each year. This total will be reduced by 18 million gallons to 145 million gallons due to additional sewer separations. Sewer separation projects are costly infrastructure projects that involve building a second piping system to separate storm water from sewers.

While climate change is not seen to have an impact on the amount of sewage produced, the city of Holyoke has seen rainfall and river flows increase over the past 70 years. The Climate Change Clearinghouse projects that Holyoke will continue to see annual precipitation totals increase by 3-5 inches over the next 50 years as noted in Chapter 2.

3.4 Urban Heat Island Effects

Typical Impacts

The urban heat island (UHI) effect describes the phenomenon of increased air temperatures in densely-developed urban areas. The phenomenon tends to be most pronounced at night, as cities cool down more slowly than green, open-space areas. The UHI effect is caused by a combination of factors, including efficient absorption of sunlight by dark surfaces, high heat capacities allowing urban surfaces to release heat over a longer time period, a lack of evaporative cooling facilitated by vegetation, and a lack of water infiltration into the ground surface, which moves heat downward.

UHI effects may adversely impact runoff water quality, air quality, and raise ambient temperatures. Building materials and pavement emit heat as the daytime temperatures begin to cool, essentially trapping this slowly emitted heat closer to ground level beneath the cooler evening temperatures. Because of the lengthy cooling process, the temperature of stormwater runoff from paved areas is typically higher in relation to runoff from more rural areas. This increasingly warm runoff can adversely impact the ecosystems of the waterbodies into which it drains.

Observed Impacts in Holyoke

The Trust for Public Land, Descartes Labs, and the USGS developed an analysis of Urban Heat Islands (UHI) for cities in the United States in 2020. In this collaborative project, the relative severity of the UHI effect was calculated at a 30-meter scale using Landsat 8 imagery band 10 (ground-level thermal sensor) from the summers of 2018 and 2019. UHI severity is presented on a scale of 1 to 5, with 1 indicating temperatures slightly above the mean for the city, and 5 indicating those significantly above the mean. The absolute heat-above-mean values were classified into these 5 classes using the Jenks Natural Breaks classification method.

In Holyoke, areas with higher urban heat indexes have more impervious coverage. Areas in Holyoke that score a 5 on the urban heat index scale are 99% impervious. The amount of land area classified as an Urban Heat Island is 27%, similar to the 30% impervious coverage in the city as a whole.

3.5 Adverse Air Quality

Typical Impacts

Air quality is impacted by impervious surfaces in several different ways. Typically, a highly impervious developed area equates to conditions that result in higher air pollution emissions with increased activity both from the buildings and roadway traffic. As air temperatures decrease in the evenings while the temperatures of urban surfaces remain elevated, an inversion layer is formed, trapping warmer air at the surface below a layer of cooler air. This inversion layer prevents pollutant dispersal from ground surface levels. There is also the larger concern of overall energy demands for cooling during these warmer times which ultimately increase emissions from power plants.

It is well researched that fine particles in air pollution can aggravate pre-existing asthma and studies are showing that pollution may also contribute to causing asthma as well. However, new research from Johns Hopkins University finds that more coarse particulates, like those from road dust, brakes, tires, and other metals can deposit into airways and cause asthma, respiratory disease, and cardiovascular disease.

Higher air temperatures lead to an increase of pollutants and allergens in the air. Areas with higher amounts of impervious surfaces are typically hotter and create more pollutants from increased human activities like driving and manufacturing. Areas with higher percentages of impervious surfaces lack the vegetation that filters the air and provides cooling shade.

Pollution may pose greater health risks to children than adults because their bodies are growing and developing. These risks likely contribute to incidents of asthma. Minority children have disproportionately higher rates of asthma than non-minorities and within that population there are large disparities among ethnic groups. A fact sheet produced by the EPA states that “Puerto Rican children have the highest rates of asthma at 20%, compared with 7% for Mexican-American children…Hispanic children are almost twice as likely to be hospitalized for asthma as White children” (US Environmental Protection Agency, 2008).

Observed Impacts in Holyoke

Observed impacts can be difficult to characterize, as they often rely on reports of illness rather than direct measurements. The Massachusetts Bureau of Environmental Health (BEH; Massachusetts Department of Public Health, 2020) reports that rates of pediatric asthma and asthma-related emergency department visits are high in Holyoke. Approximately 20% of Holyoke’s K-8 students have asthma, compared to 12% for the state. Asthma department visits in Holyoke (245 per year) are more than three times the state average (67 per year).

Directly measured indicators of poor air quality are available, as well. For example, the MBEH reports that Hampden County had four days with ozone levels above the National Ambient Air Quality Standard limit of 0.070 ppm in 2017.

Holyoke has a high number of polluting businesses and industries in the small geographic area made up of The Flats, South Holyoke, Churchill, and Downtown. These areas also have a high density of development, impervious surfaces, traffic, and population. The colocation of these factors makes adverse air quality a major concern in Holyoke.

4 Techniques to Reduce Impervious Surface Areas

Actions can be taken to mitigate the impacts of impervious surfaces in a heavily developed community. These solutions might include technical approaches that reduce the ratio of impervious surface and create greener areas, provide increased drainage control, and allow for my natural ground infiltration. There are also regulatory actions that can be implemented to guide development and redevelopment standards which will either reduce impervious area or increase applications to offset impervious area. Regulatory changes can also work in conjunction with dynamic incentives to promote green infrastructure, low impact development, and overall reduced impervious pavement.

4.1 Technical Approaches

Given the variation of impervious surface throughout the City, there are several technical applications that may be suitable depending upon further analysis of site characteristics. All of these techniques are described in more detail in the 2014 Green Streets Guidebook. Many of the available approaches work to have co-benefits that reduce impervious surface, manage runoff, and provide an increase in tree canopy or vegetation, ultimately working to reduce ambient temperatures. The Best Management Practices (BMPs) that may be well-suited for the City could include:

> **Low Impact Development (LID)** is an approach to environmentally friendly land use development. It includes landscaping and design techniques that attempt to maintain the natural, pre-developed ability of a site to manage rainfall. LID techniques capture water on site, filter it through vegetation, and let it soak into the ground. – *www.mass.gov*

- Permeable paving systems, including:
    - porous asphalt,
    - porous concrete, and
    - permeable pavers (see Figure 4-1 below)
- Dry wells (see Figure 4-2 below)
- Tree wells
    - Suspended pavement systems e.g., Silva cells (Figure 4-3), or
    - Built with structural soils
- Tree trenches
- Sidewalk planters
- Bioretention basins
- Infiltration swales (Figure 4-4)
- Green roofs
- Underground storage/infiltration systems (Figure 4-2)
- Downspout disconnection to landscaped areas or rain gardens
- Downspout connection to underground storage or infiltration systems
- Road Diets

> **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. – *Green Streets Guidebook*

Development can either be retrofit to include green infrastructure (GI) applications, or development regulations be tailored to promote low impact development (LID). While green infrastructure and low impact development are often thought to be interchangeable, LID does not always include vegetation. The primary goal for LID techniques is to utilize or mimic natural processes, such as infiltration or evapotranspiration, to control stormwater runoff and reduce pollution concerns.[1]

4.1.1 Non-Vegetated Applications

Certain LID applications work to increase infiltration without affecting the current use or reducing the overall paved area. Permeable paving systems are often a sound solution for parking lots, roadside parking spaces, and other trafficked areas. Three commonly implemented applications are porous asphalt, porous concrete, and permeable pavers. All three strategies allow for continued use of the trafficked area, while promoting infiltration beneath the paved area. Table 4-1 shows how these three types of pavers performed over time under high sediment loading conditions during a 2018 USGS-supported experiment. Actual performance of permeable paving systems depends on the specific type and installation method of the system, sediment loading at the surface, and maintenance.

Figure 4-1: Permeable paving system

Table 4-1: Performance of Permeable Paving Systems

Pavement Type	Infiltration Rate (inches/hour)		
	Initial	19 Months	20 Months with Cleaning
Porous Asphalt	244	116	134
Porous Concrete	147	30	19
Permeable Pavers	321	27	192

Adapted from Selbig & Buer, 2018

The suitability of these techniques also depends on the soil type beneath the paved area; the subsurface material should allow for adequate permeability depending on the area needing to infiltrate. Budget and aesthetics are also taken into consideration when choosing an application. For example, the parking lot at Silver Lake Beach (Fig. 5-1) in Wilmington, MA have implemented permeable pavers in the parking spaces, and permeable asphalt in the rights-of-way.

Dry wells are another non-vegetated LID application that can be used to reduce and control stormwater runoff. A dry well is a subgrade structure that collects runoff, typically from parking lots or downspouts, where it is stored and allowed to infiltrate naturally from the well. Overall, this system allows for slow infiltration of runoff and reduces potential for over-exerting drainage systems. Dry well size and construction varies based on the amount of precipitation that falls in the area, along with the area of runoff the structure will receive. For example, a dry well for a residence may be smaller than that of a dry well found

Figure 4-2: Dry well system during installation

[1] https://www.epa.gov/nps/urban-runoff-low-impact-development

controlling runoff of a large shopping plaza. Soil suitability should also be evaluated when considering a dry well to ensure infiltration capabilities.

Like dry wells, there are also larger underground storage or retention and detention systems. These systems allow for large volumes of runoff storage and can be buried beneath roadways, parking lots, or open land. These systems are designed to promote natural infiltration, or to delay delivery into drainage systems to reduce stress during heavy rain events. Underground systems can be designed to receive runoff from roadways and sidewalks, or directly tied to buildings with gutters feeding into the system.

4.1.2 Vegetated Applications

Other LID application types are often a hybrid of hardened infrastructure and vegetation. These green infrastructure applications are beneficial in many ways including providing runoff control, increasing tree canopy and biodiversity, reducing air and runoff temperatures, and providing aesthetic improvements. Many of the applications have similar features with the overall goal of utilizing natural infiltration and vegetation to reduce runoff into drainage systems.

Tree wells and tree trenches are a good example of a GI application that controls runoff with underground storage and increases tree canopy and improves tree health. There are several variations of these applications which are dependent upon the application site. For example, some tree well systems use structural soils, which are engineered soils that have high structural strength but enough pore space for root growth, or suspended soil systems that provide both load bearing capacity and underground storage. A Silva Cell (Fig. 5-3) can be implemented adjacent to a tree well or trench to promote adequate tree root growth, and to support the construction of an impervious roadway, sidewalk, or entry way above. These tree-centric applications can be designs to tie into drainage systems or promote natural infiltration.

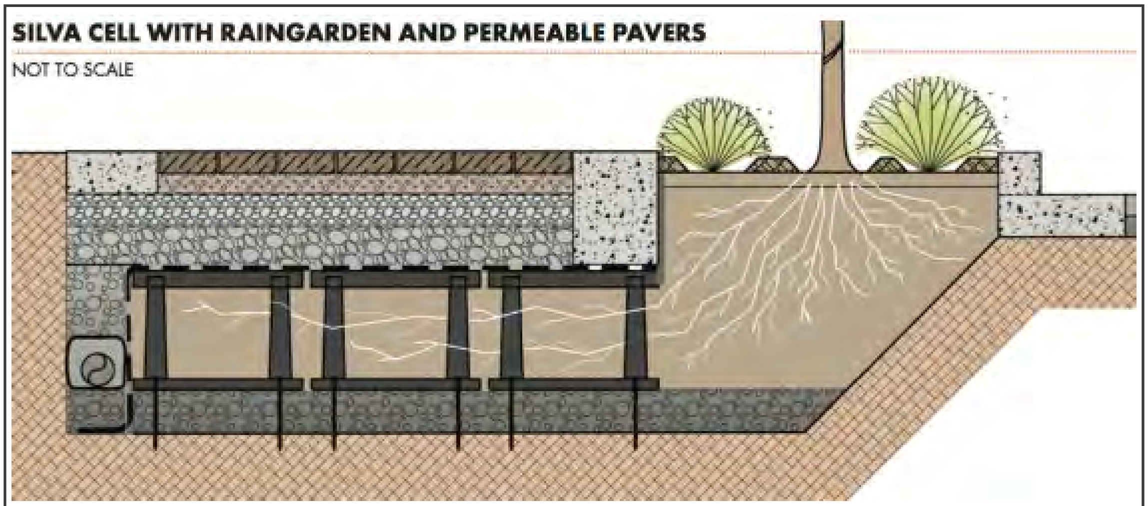

Figure 4-3: Example of a Silva Cell used to support permeable pavers and vegetation (Burien Magazine, Summer 2016)

Sidewalk planters are like tree wells in that they allow for a vegetated application while collecting runoff. This technique can receive runoff from the street, sidewalk, or both and typically has openings to guide runoff into the enclosed planter where it is the removed from the impervious surface and allowed to infiltrate. These planters are often connected to a drainage system which receives overflow from the system; however, the infiltration of the runoff into the vegetation significantly decreases the amount of runoff being sent into the system.

Figure 4-4: Bioswale application in Chicopee, MA

A similar technique to sidewalk planters is bioswales. These too collect runoff from streets, sidewalks, or parking lots, but are typically longer linear features and are similar to rain gardens in design. Bioswales (Figure 4-4) are constructed to have deep subterranean foundations with certain soils types to promote water retention and to slow flow into the drainage system. It is also important to note that bioswales, and other vegetated applications also work to improve water quality. The reduction in water flow allows pollutants to settle out before flowing to water sources or further percolating into the ground. An infiltration swale is similar to a bioswale; however, these do not always include plants and mulch and are often grassy areas. This application type could be considered more inconspicuous and they may appear as "grassy ditches" on roadsides and could be implemented in more rural areas. This type of swale is also designed to promote water retention, improve water quality, and reduce runoff discharge into drainage systems and allow for natural ground infiltration.

Figure 4-5: Roof runoff, Sargeant St

Green roof applications are large vegetated areas that provides numerous benefits. The vegetation both absorbs and slows runoff from the rooftop ultimately reducing runoff from the building. The application also reduces ambient temperatures and helps to improve air quality as green area does not trap the same degree of heat as typical shingles or roof applications. Also, depending on the load capability of the building, a green roof can be constructed with lightweight, low maintenance plants, or provide a green space that can be visited, such as a small scale park, or even utilized as an accessible rooftop garden for flowers and vegetables. Any runoff overflow that is not captured on the roof can also be directed into other applications such as underground storage basins or dry wells to further reduce runoff into the system.

It is important to note that the disconnect of downspout from a sewer or drainage system, and the redirection of runoff into an underground tank, or landscaped areas and rain gardens, can be done on any building type with any roof type, not just a green roof. Buildings comprise a large percentage of impervious surfaces and therefore roof runoff should also be controlled. The direction and control of roof runoff can also reduce runoff water temperature, minimize pollutants in the water ways, and alleviate stress on drainage and sewer systems.

4.1.3 Hybrid Applications

Many of these applications can be used in tandem to create a hybrid approach. Road diets represent this concept very well by taking existing streets and reducing their width to allow for other GI measures to be installed. Narrower streets and green "islands" can reduce the paved surface area of streets and increase infiltration of rainwater either through plantings or swales. These features often calm traffic, increase safety, and beautify the neighborhood. A well-designed street after a road diet can also encourage walking and biking, reducing pollution from vehicles.

Figure 4-6: Green Traffic Island on Main St, Holyoke

Figure 4-7: La Jolla Boulevard, San Diego, CA from the Project for Public Spaces

4.2 Regulatory Considerations, Case Studies, And Model Ordinances

Reducing impervious surfaces is not a novel idea. Many communities, including Holyoke, have already incorporated impervious surface coverage restrictions. Some communities have extended their ordinances and regulations to incentivize the use of green infrastructure as well. Through amendments, the zoning code can be changed to place a greater emphasis on reducing impervious surfaces and mitigating stormwater generation. Holyoke could improve their policies by taking inspiration from other cities. By adapting these models, Holyoke will not only have stronger incentives for developers to reduce impervious cover and to incorporate sustainable infrastructure, but it will also streamline the zoning process saving staff and developers time, further encouraging their use.

Parking Maximums: In addition to imposing impervious surface maximums, the City of Hartford, Connecticut is addressing a leading cause of impervious surface coverage by mandating parking maximums. For example, for all retail uses other than auto sales, a "maximum 3 [off-street] spaces per 1,000 square feet net floor area devoted to retail space." They also encourage different uses to share parking. Through these changes, Hartford anticipates overall impervious surface reductions. Holyoke has a schedule of parking minimums, which could be modified to appropriate parking maximums for new developments. Building these requirements into the code alerts developers to the city priorities before they submit an application.

Trading Impervious Coverage for Shade: In its zoning code, The City of New Rochelle, New York, considers trees when expanding impervious surface to reduce its harmful effects. *"Mitigation for creating or increasing impervious surface. To mitigate the negative environmental impacts associated with the creation or expansion of impervious surfaces, for every 200 square feet of impervious surface created or expanded or part thereof in excess of the first 200 square feet, the property owner shall plant* *one tree with a minimum DBH [diameter at breast height] of two inches. Trees with a greater DBH may satisfy this requirement in a mathematically proportionate manner, so that, for example, a tree with four-inch DBH may be planted for 400 square feet of newly created or expanded impervious surface beyond the first 200 square feet."* – City of New Rochelle. A regulation like this one could be implemented in Holyoke to address new development and additions.

Bonus System: Pittsburg, PA utilizes an "EcoInnovation District" as an innovative technique for comprehensively promote sustainability and economic development, while preserving the mixed-use nature of the community and encouraging investment to increase the residential population and commercial activity. In addition to general development standards, it includes a bonus system.

Among the general development standards, this zone precludes surface parking on major streets, eliminating a portion of the impervious surface and creating a better pedestrian environment. All new buildings with a gross floor area greater than 10,000 square feet or building additions with a gross floor area greater than 5,000 square feet must have a green building advisory consultation coordinated by the City. This can help guide applicants to stormwater mitigation strategies and the use of permeable materials.

New buildings and renovations in this district can utilize the bonus system. Points earned by satisfying the goals can be utilized in this district to achieve the bonus height. Goals include on-site energy consumption, on-site energy generation, affordable housing, rainwater retention, filtration, and use, and building reuse. Examples of the point system taken from their code can be found in Appendix B.

4.3 Incentives and Benefits for Private and Public Development

Pervious surface reduction in private and public development can be incentivized in a variety of ways, including through financial, regulatory, and permitting, and public relations benefits.

Financial incentives can include grant opportunities or tax and fee reductions. Grants can be made available to developers on the condition that a certain percentage of a lot remains pervious, or LID or GI techniques are utilized. Tax credits or fee reductions can be earned under the same conditions, similar to the stormwater credits described in Section 1.6 of this plan.

Regulatory and permitting incentives can include streamlining the permitting process for projects that will limit impervious surfaces, waving permit fees, or permitting flexibility within certain regulatory requirements in exchange for a reduction in impervious surfaces. An example would be allowing for a development to be constructed above its zone's height limit if a certain amount of the parcel were left as open space.

Public relations incentives leverage a business or organizations interest in positive public perception. This can be done by creating a certificate program, in which developers who minimize impervious surfaces or utilize LID and GI techniques earn a certificate highlighting the benefits of their approach to the public. LEED Certification is an example of this type of incentive. A design competition that publicizes developments that mitigate the effects of impervious surfaces can also incentivize maximization of pervious space by developers. The international LafargeHolcim Foundation runs a global sustainable design competition like this (www.lafargeholcim-foundation.org).

5 EXISTING CONDITIONS

5.1 NEIGHBORHOOD SETTING

Holyoke was developed as one of the first planned industrial cities in America. Emulating the success of textile mills in Lowell, investors purchased 1200 acres on the western bank of the Connecticut River in 1848. These investors constructed the Hadley Fall Dam and the city's canal system. The industrial foundation of the city is still visible in Holyoke. Large brick factories and mills hug the city's canal system and the parallel rail system still functions today.

With the dam and canal system, mills and factories grew along the city's novel grid system of streets. Railways were constructed parallel to the canals to provide access to freight. Holyoke quickly became the most successful paper producer in the country. Its population doubled from 5,000 people in 1860 to more than 10,000 in 1870. By 1920 the city's population was around 60,000. Ninety years later the 2010 population had contracted to just under 40,000. US Census American Community Survey (ACS) population estimates show the population is slowly increasing to 40,376 in 2018.

As the city grew, it incorporated and acquired land from neighboring towns. Between the planned construction around the mills and falls, and the acquisition of land from neighboring communities, distinct neighborhoods took shape. Neighborhood identity is strong in Holyoke and much of the character of these neighborhoods is reflected in development linked to its impervious cover.

ROCK VALLEY (13% Impervious): The western half of the city did not develop with the rapidity of industrialization seen in the east. Rock Valley was settled in the mid 1700's and still retains a pastoral feel, with large housing lots, some agriculture and large areas of undeveloped land.

SMITHS FERRY (14% Impervious): North of Rock Valley is the neighborhood of Smith's Ferry. Most of this neighborhood is taken up by the Mount Tom State Reservation; however, a diverse mix of residential and commercial uses is located between the Connecticut River and Route 5.

> Holyoke's future population growth may be impacted by a large migration of Puerto Rican residents who fled the aftermath of Hurricane Maria in 2017. Holyoke received an MVP Planning Grant in 2018 to review the impact of Hurricane Maria and found that local nonprofits responded 2,150 people (almost 1,000 families) displaced by the storm.
>
> While it is not possible to say for certain how many displaced people remain in Holyoke, school enrollment jumped by 254 students in the 2017-18 school year and increased by another 101 students in 2018-19, an overall increase of 6.5%. 2018 ACS estimates show that people who are Hispanic or Latino (21,054) make up 52% of the population. The number of people who are Hispanic or Latino have increased by 9.5% since the 2010 census.

HIGHLAND PARK (26% Impervious): Highland Park is south from Smith's Ferry and east of I-91 is. This area of Holyoke was designed as a an upper-middle class suburb for the management staff of the city's mills. Highland Park is almost completely residential with the notable exception of the White School and Jones Point Park. The majority of housing is single family residential.

JARVIS AVENUE (21% Impervious): The neighborhood of Jarvis Avenue is located on the western side of I-91 and is the geographically center of Holyoke. This area is largely residential with large lots of open space in the west and smaller lots and apartment complexes lining the main road that gives the neighborhood its name. Scott Tower and Anniversary Hill Park provide a green buffer between Jarvis Ave and I-91.

HOMESTEAD AVENUE (39% Impervious): Southcentral Holyoke is defined by the Homestead Avenue neighborhood. This area of Holyoke is the most developed section of town west of 91, containing Holyoke Community College. Interstate Drive to the south is characterized by industrial uses and retail, with smaller single-family residential lots filling the northern section.

INGLESIDE (40% Impervious): The neighborhood of Ingleside is near the southern border of Holyoke, east of I-91. Ingleside is home to the Holyoke Mall, the Mount Marie Assisted Living Facility, and Providence Behavioral Health Hospital. Ingleside is lightly populated with residential neighborhoods and transitions to more commercial uses as Main Street veers away from Route 5, its northwestern border.

WHITING FARMS (47% Impervious): The neighborhood of Whiting Farms is located on the west side of Route 5 and abutting I-91. The thoroughfare that bisects this neighborhood, named Whiting Farms Road, is a major artery linking the Holyoke Mall, Holyoke Crossing, and the Holyoke Shopping Center. The bulk of residential use in this neighborhood is comprised of apartments with a small section of single-family homes.

Figure 5-1: Holyoke Mall *Image: Google Globe*

ELMWOOD (47% Impervious): Following Route 5 northward is the neighborhood of Elmwood. There is a mix of single family and multifamily homes in this densely residential neighborhood. Elmwood has its own mixed-use commercial center along South Street. Along Beech Street, the northern border of Elmwood, is the William Peck Middle School and Holyoke High School.

OAKDALE (48% Impervious): The neighborhood of Oakdale is between Beech Street and Route 141. Oakdale contains 2 large cemeteries and a large park. It is densely residential, with commercial activity and the Holyoke Medical Center housed on Beech St. More commercial uses follow the northern border of Dwight St.

HIGHLANDS (43% Impervious): The Highlands Neighborhood is on the other side of Dwight Street, from I-91 to the Connecticut River, bordered to the north by the neighborhood of Highlands Park. Highlands has fewer single-family residential homes and a similar number of multifamily homes to Oakdale.

DOWNTOWN (72% Impervious): The Downtown neighborhood lies outside the southeast section of Highlands. Downtown follows the Connecticut River and is bordered by Race St. This is the urban core of the City, home to City Hall and several municipal offices. The gridded streets are dotted with small parks. This neighborhood has many apartments, as well as multi-family homes and some single family. The area around the canals is packed with historic mill buildings and active industrial uses. Pulaski Park is a park that buffers the neighborhood from the Connecticut River. Holyoke Heritage State Park and Holyoke Library Park are also notable.

Figure 5-2: Heritage Park

THE FLATS (66% Impervious): This area is ringed with industrial factories and the Second Level Canal. In the center of that ring is a small residential neighborhood and a local charter school. This area is home to the newly constructed Amtrak station built in 2015 which serves as a stop on the Vermonter line.

SOUTH HOLYOKE (73% Impervious): South Holyoke is adjacent to the Flats and similar to the Flats in terms of architecture with historic brick mills characterizing the neighborhood. There are far fewer single and multifamily homes in South Holyoke than in The Flats, fewer parks and open spaces, and a heavier commercial and retail presence. In December of 2019, a $6.5 million dollar grant was issued through the MassWorks Infrastructure program for streetscape improvements. The Holyoke Housing Authority has plans to build 90 residential units in South Holyoke around Carlos Vega Park. This grant will be used in conjunction the Housing Authority's project to improve traffic flow, install green infrastructure, and improve pedestrian and bike access.

CHURCHILL (69% Impervious): The neighborhood of Churchill is located on the other side of the canals and adjacent to Downton. This neighborhood is heavily urbanized, with factories and industrial uses bordering the canals. The Churchill neighborhood was home to a large housing development project in the early 2000's where over 200 single and multifamily homes were constructed.

SPRINGDALE (43% Impervious): Springdale borders the Connecticut River and is situated between Ingleside and South Holyoke. Springdale Park is a large open space along the river. The bulk of Springdale is home to commercial and industrial properties. The city's Water Pollution Control Facility is located in Springdale. Residential properties curve around the western and northern edge of the neighborhood.

Holyoke's history and development patterns are evident in the impervious surface coverage within each neighborhood. Neighborhoods along the Connecticut River and east of I-91 have more impervious cover and are zoned for more intensive uses. Low-density residential neighborhoods and agricultural neighborhoods west of I-91 have far less impervious cover. While only 30% of the city is covered in impervious materials, some neighborhoods like South Holyoke (73%), Downtown (72%), Churchill (69%), and the Flats (66%) have more than double the citywide average. These neighborhoods are zoned mostly as industrial, Downtown Residential, or Highway Business.

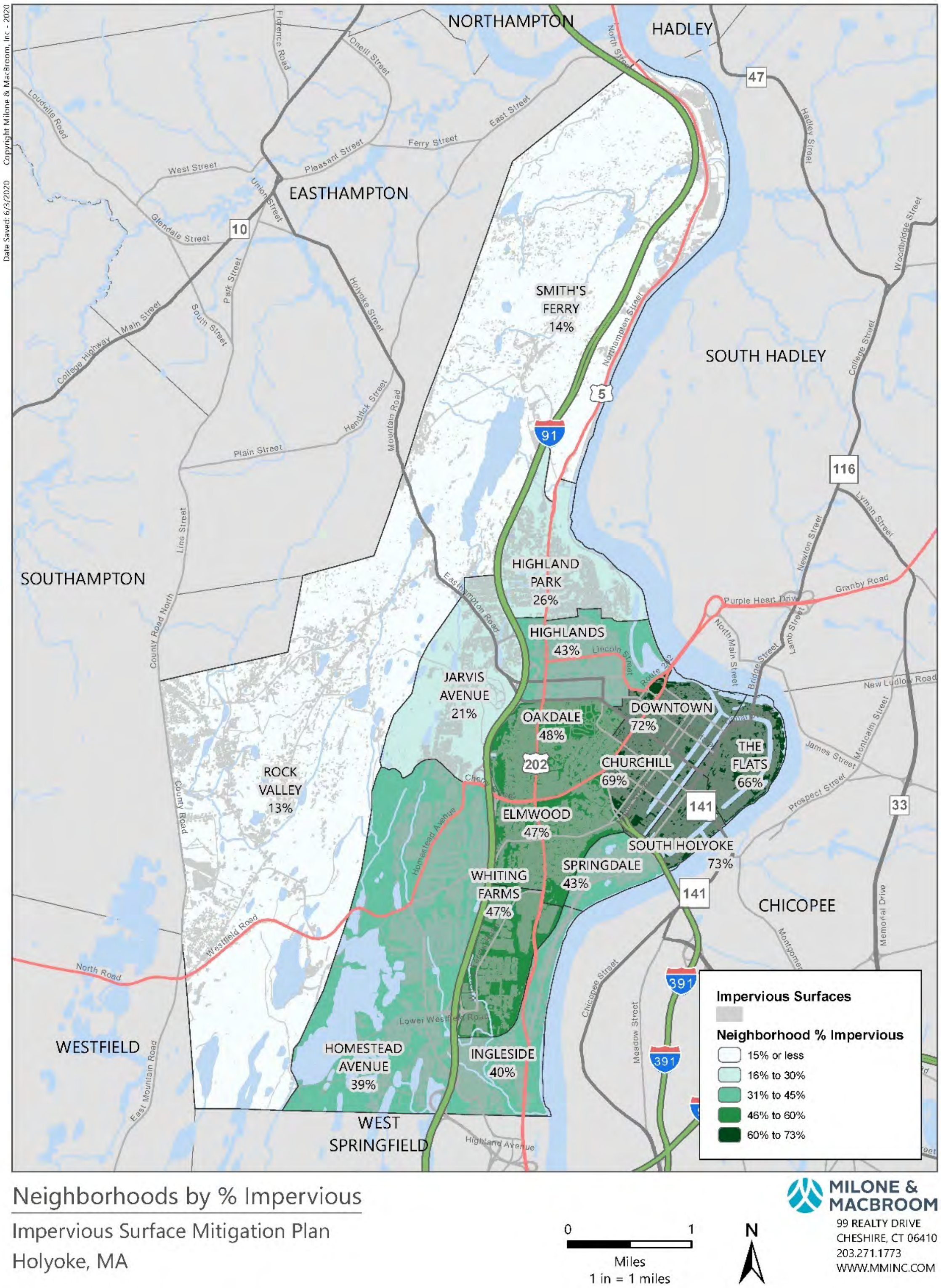

Figure 5-3: Neighborhoods by % Impervious

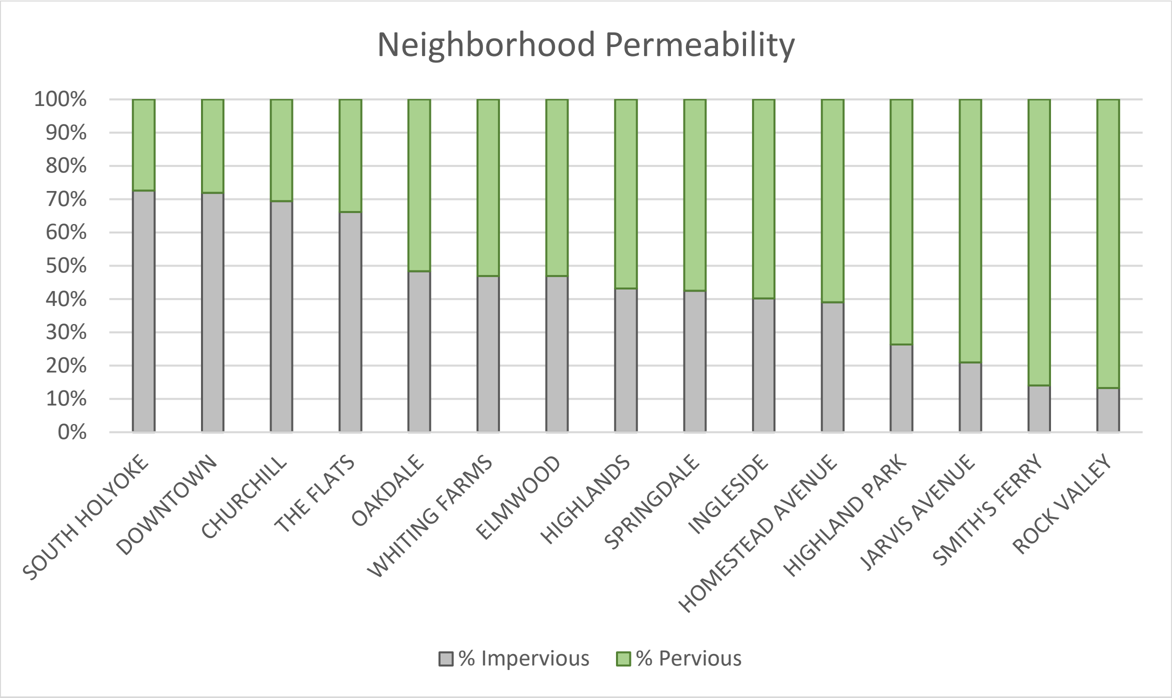

Figure 5-4: Impervious Surface Coverage by Neighborhood

5.1.1 Land Use

Holyoke has well established land use patterns. Industrial and residential uses in the southeast are bordered by commercial and residential uses in the urban core. The geographic center of the city is defined by the open land including the Mount Tom range. Residential use borders these open areas, with a small swath of agricultural uses in the west.

A detailed look from parcel data shows a variety of uses, as typical for a city with a vibrant urban core like Holyoke. Major retail developments sit just outside the urban core, near major highway access. Residential density tends to be single family with multifamily and apartments showing more of a presence east of I-91. Most of the developable land in Holyoke has already been developed, with open space and agricultural uses in the western part of the city protected by regulation and/or land ownership. Redevelopment of historic mill infrastructure for new industries and uses is a possibility of interest to Holyoke.

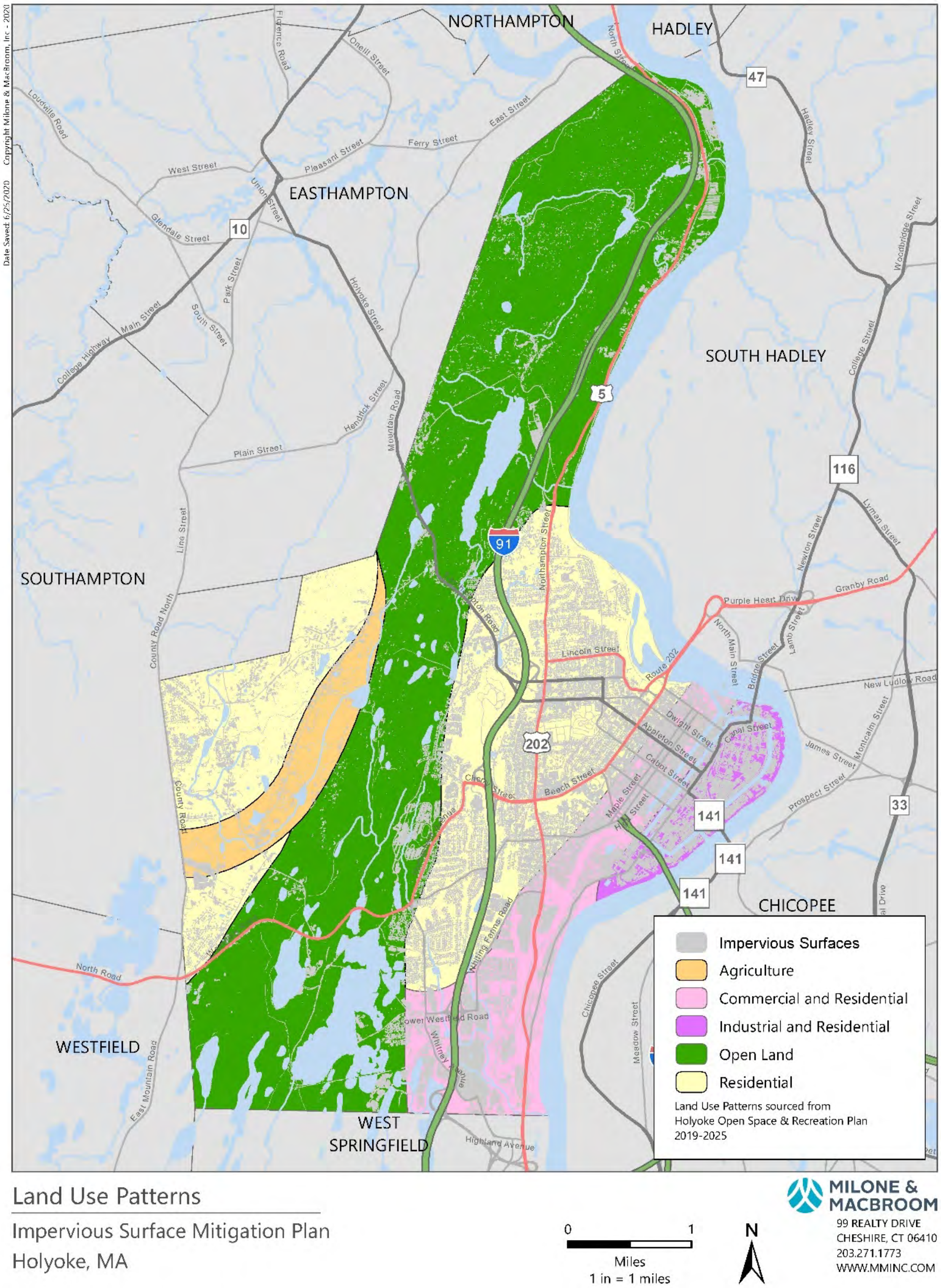

Figure 5-5: Land Use Patterns

5.1.2 Zoning

As noted in Section 1.7, the current City of Holyoke Zoning Ordinance is dated February 19, 2002, although it has been continuously updated as noted in the section listing all revisions and updates. The Zoning Map complements the Zoning Ordinance and sets requirements for development citywide.

Nearly every zoning district in Holyoke exceeds 35% impervious surfaces, with the exception of Single-Family Residence (R-1) and Agriculture and Family Residence (RA), at 31% and 16% coverage, respectively. Research from NASA (Bounoua, et al, 2015) shows that the urban heat island effect becomes most pronounced once the impervious cover in an area exceeds 35% of the land area. The Downtown Business district has the most impervious coverage by far, 88%. This is followed by General Industry (69%), Waste Management (65%), and Highway Business (65%). The entire city, but especially these zones, should be scrutinized for opportunities to reduce coverage in new and existing developments.

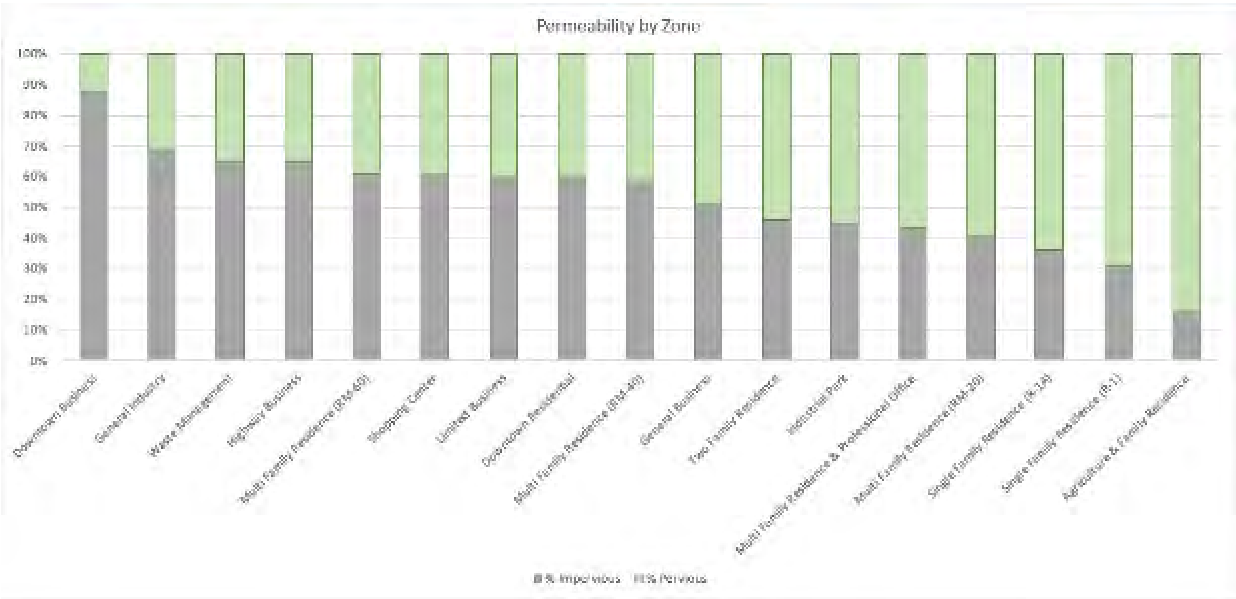

Figure 5-6: Impervious Surface Coverage by Zone

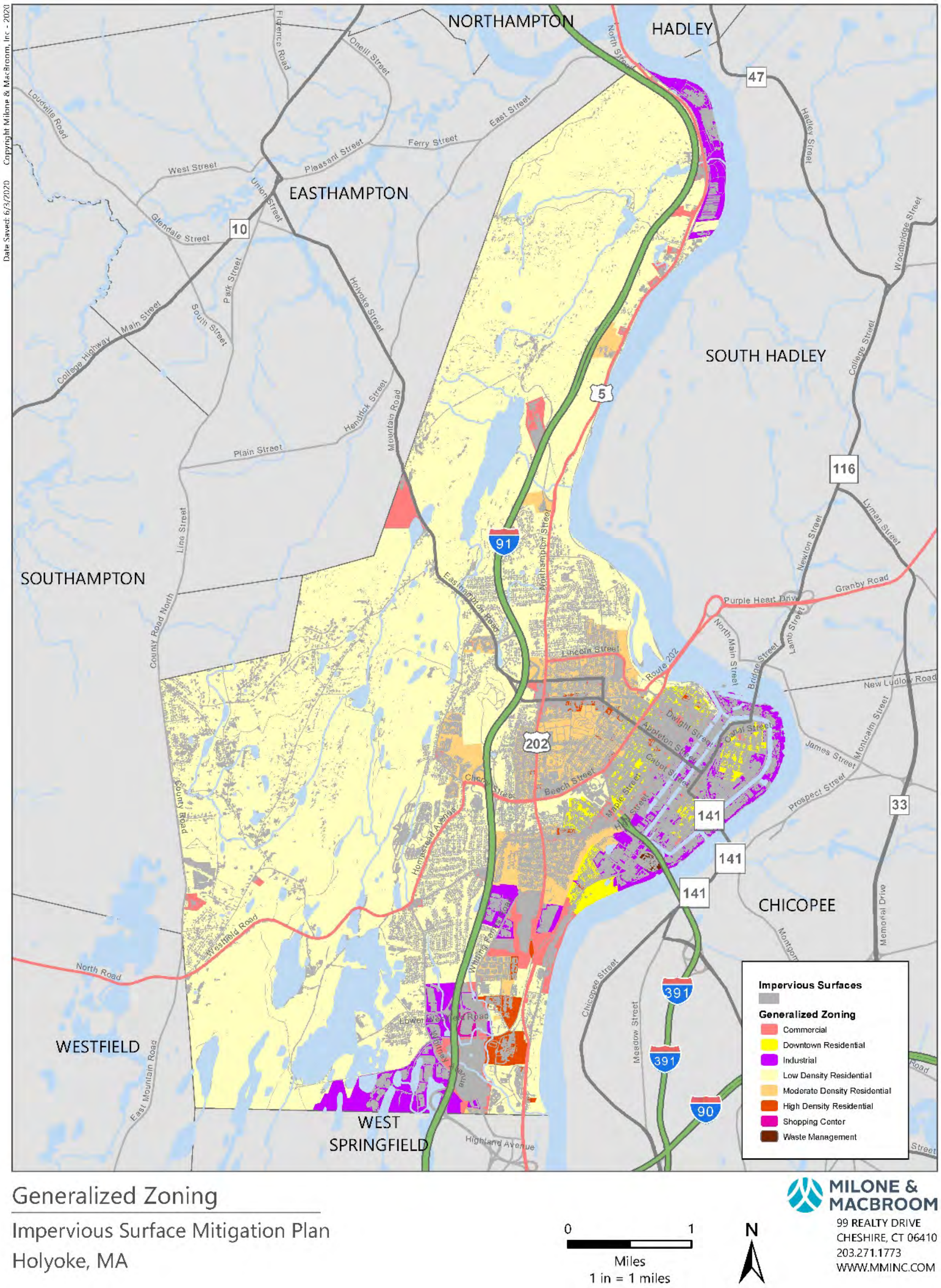

Figure 5-7: Generalized Zoning

Table 5-1: Impervious Coverage and the Holyoke Zoning Code

Zone	Code	% Impervious Coverage	Max % Building Coverage (Table 5.2)	Max % Land Coverage *(Table 7.4.2)*
Low Density Residential		**21%**		
Agriculture & Family Residence	RA	16%	20%	
Single Family Residence	R-1	31%	30%	
Single Family Residence	R-1A	36%	35%	
Moderate Density Residential		**44%**		
Two Family Residence	R-2	46%	40%	
Multi Family Residence (20 units/acre)	RM-20	40%	40%	30%
High Density Residential		**46%**		
Multi Family Residence (40 units/acre)	RM-40	59%	40%	40%
Multi Family Residence (60 units/acre)	RM-60	61%	40% / 60%	60%
Multi Family Residence & Professional Office	RO	43%	50%	
Commercial		**62%**		
Limited Business	BL	60%	35%	
Downtown Business	BC	88%	NA	
General Business	BG	51%	50%	
Highway Business	BH	65%	50%	
Industrial		**62%**		
General Industry	IG	69%	NA	
Industrial Park	IP	45%	33%	
Downtown Residential	DR	60%	NA	
Shopping Center	SC	61%	NA	
Waste Management	WM	65%	NA	
Citywide	**Total**	**30%**		

As previously mentioned, the City of Holyoke specifies the maximum percentage of a lot that buildings can occupy. This differs from the total impervious coverage on a lot, which includes not only buildings but also sidewalks, parking lots, and other paved areas. Due to this difference, one would expect the percentage of actual impervious cover to exceed what is specified in the zoning code. In zones where impervious coverage is below or close to the maximum building coverage, there is the opportunity to amend the code, either lowering the maximum building coverage or changing “maximum percent building coverage” to “maximum percent impervious coverage”.

The Multi Family Residence & Professional Office (RO) and the Agriculture & Family Residence (RA) zones have actual impervious surface coverages below that of the maximum building coverage (7% and 4%, respectively). The Multi Family Residence (RM-20), Single Family Residence (R1 and R1A), and General Business (BG) zones all have actual impervious coverage percentages that match or are within 1% of the maximum building coverage. All of the aforementioned zones could accommodate the zoning changes mentioned above without a significant change to the character of these zones.

The zones with impervious coverage exceeding the maximum building coverage are typically industrial, commercial, or high density residential. The level of excess ranges from 6% to 25% higher. Zones with the highest impervious coverage, Downtown Business (88%), General Industry (69%), Waste Management (65%), and Highway Business (65%), also fall into these categories. Unsurprisingly, the zoning districts with the highest level of impervious surface lack any restriction on maximum building or impervious coverage. The lack of restriction should be reconsidered.

5.1.3 Roadway Network

Figure 5-8: Highway Overpass in Holyoke

Holyoke is crossed by a number of major highways. All of these transportation conduits contribute to impervious surfaces and compacted soils throughout the city.

Interstate 91 runs north-to-south along the eastern edge of the Mt Tom-East Mountain Range, effectively separating the eastern urban core from the rest of the city. I-91 was constructed parallel to Route 5. Just outside the southern portion of the city the Massachusetts Turnpike crosses east-to-west. Within the swatch of land wrapped by these 3 major roads a commercial hub has developed, cradling the Holyoke Mall.

Interstate 391 begins in eastern Holyoke at State Highway 202. State Highway 202 runs east to west through Holyoke from Westfield and curves over the Ashley Reservoir, turning north and east until it crosses the Connecticut River into South Hadley. State Highway 141 enters from the East Hampton town line in the north and crosses the Mt Tom range. It then passes through downtown Holyoke and crosses the Connecticut River into Chicopee. Route 116 wraps around the industrial corner of south east Holyoke providing access across the river to Chicopee in the south and South Hadley to the east.

A recent road maintenance survey analyzed 130 miles of roads maintained by the city, not including private roads and roads maintained by the state. All told, Holyoke contains many miles of heavily-trafficked roads, all of which contribute to the city's impervious surface coverage, nonpoint source pollution to the city's waterways, and air pollution from vehicle emissions.

Railroad tracks follow the Connecticut river from the north to the south until they turn and branch inward at the urban core following the canals. Rail lines exit the city next to the bridge for Route 116 into Chicopee and travel southwest, crossing just to the north of the Holyoke Mall, then passing by the southern end of the Ashley Reservoir and turning into West Springfield.

5.1.4 Private and Public Parking Areas

Holyoke relies on street parking for much of its public parking while most businesses and employers provide parking lots for their customers and employees. In the downtown area there are three public parking garages: Ernest Proulx Municipal Parking Facility on Dwight St, the Suffolk St Municipal parking, and a ProPark garage on 138 Appleton St.

Dense residential neighborhoods around the urban core tend to have off-street parking for residents. Single, two family and multi-dwelling family homes (up to 50 units) require two off-street parking spaces for each dwelling unit. Mobile home parks require two spaces for each unit plus one for every five units. Commercial parking standards are various but tend to be based on floorspace, while parking standards in industrial areas are tabulated by the number of employees. In many cases the Building Commission determines parking standards.

5.1.5 Roof Coverage

Building data provided from Holyoke's GIS system show 13,048 building footprints, covering a total of a full square mile. Commercial and industrial roofs are generally flat while residential roofs are typically peaked. All these roofs contribute to the city's impervious surface coverage. The coloring of roof material varies throughout the city, with white and other light-colored roofs interspersed among black and other dark-colored roofs. Darker roof materials contribute to local UHI effects by more efficiently absorbing sunlight and emitting heat, which can be advantageous in winter. White roofs reflect the sunlight and are cooler in summer.

5.2 SUMMARY

Holyoke's history of development has created two sides of the city; one continues to support the urban and industrial legacy of the city on the eastern side, and one continues to support residential and agricultural character to the west. The difference in development leads to different impacts – and scale of impacts – of impervious surfaces. These differences will be explored in the subsequent chapter. Variation within land use patterns will allow Holyoke to target the areas most adversely affected by impervious surfaces and focus efforts in these neighborhoods and zones.

6 Analysis & Findings

6.1 Grid Approach

In order to guide prioritization of impervious surface reduction and mitigation, a geographical analysis of the negative impacts of impervious surfaces was performed. The entire city of Holyoke was divided into a grid of 400-foot by 200-foot grid-cells, oriented approximately 37 degrees off north in order to be aligned with the street grid in the Downtown and Churchill neighborhoods (see Figure 6-1).

Grid-cells that predominantly cover water were removed from the analysis because the analysis, designed to evaluate land surfaces, would erroneously highlight water-bodies as high-priority for imperviousness mitigation (for example, water bodies have a high flood risk and no tree cover or shade). Grid-cells that predominantly cover the paved areas of Interstate 91 were removed from the analysis because, while the analysis accurately highlights these areas as being extremely high-priority for imperviousness mitigation, such mitigation is beyond the authority of the town and requires state intervention. Note that the presence of Route 91, and specifically emissions from vehicular traffic on the highway, is nevertheless considered in the analysis of adjacent grid-cells.

The total number of grid-cells included in the analysis was 6,971. The analysis was performed using the ESRI ArcMap Geographical Information System (GIS) software. The area within each grid-cell was assessed for a variety of factors, and each grid-cell assigned a relative score or ranking for each factor; this allowed for consistent and unbiased comparison citywide. The factors and analysis are described in more detail in the following sections.

6.2 Metrics

As discussed in Chapter 4, impacts of impervious surfaces may include:

- Increased stormwater generation and flooding
- Water quality impairment
- Combined sewer overflows
- More severe urban heat island effects
- Reduction in air quality

The geographic analysis consisted of mapping and quantifying factors, relevant to these impacts, focusing on those that were consistently measurable, accessible, and informative. These factors were then used to develop a set of metrics to form a framework for prioritizing impervious surface mitigation efforts. The metrics and their constituent factors are summarized below.

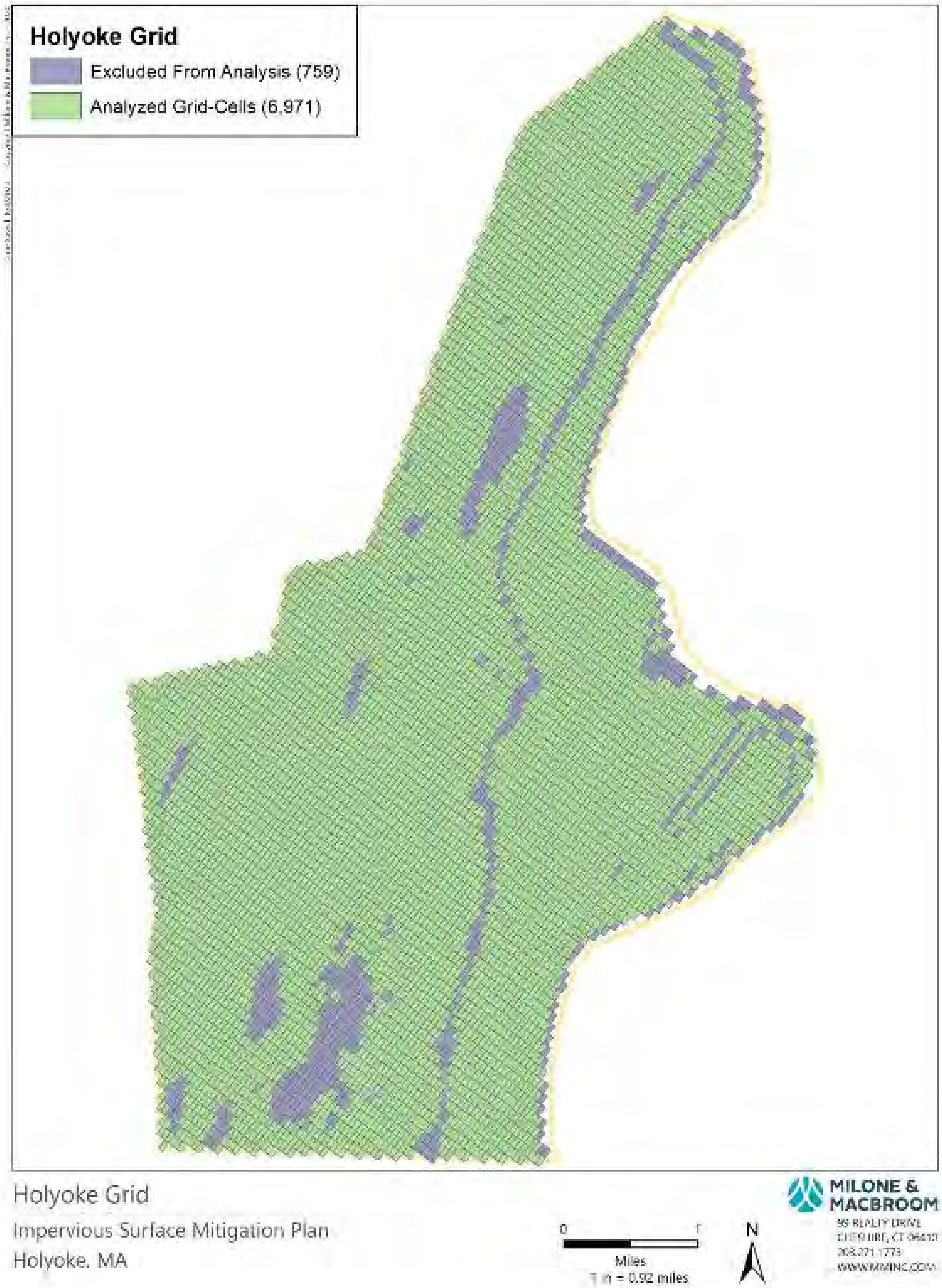

Figure 6-1: Holyoke Grid Map

6.2.1 Water Quality

The Water Quality metric (WQM) quantifies the relative impact each grid-cell has on decreasing the quality of runoff to the Connecticut River (as the water body to which all of Holyoke ultimately drains). The WQM considers two factors: the type of sewer system to which each grid-cell drains, and the percent of each grid-cell that is covered in impervious surfaces that cause nonpoint source pollution.

Sewer Separation Status

The "Sewer Separation Status" factor identifies whether a grid-cell drains primarily to a CSO system that is scheduled to be separated over the long term, a CSO system that is scheduled to be separated over the short term, or a system that is already separated.

The status of the sewer system draining a cell is relevant to the contribution that cell has to downstream water quality. This, in turn, can help prioritize runoff mitigation. Minimizing runoff in a CSO system will decrease stormwater runoff loads to the system and may therefore decrease pollution loads downstream. Minimizing runoff in a system that is scheduled to be separated may decrease the amount of work needed to retrofit that system.

The drainage areas of each sewershed in Holyoke were mapped by the Environmental Consulting firm Tighe & Bond as part of their work on the Holyoke CSO Long-Term Control Plan Update, Phase I.

Grid-cells were assigned to mapped sewershed areas based on which sewershed the grid-cell centroid was located within. This methodology means that some grid-cells that fall partly within a given sewershed were not assigned to that sewershed.

Each grid-cell was assigned a "Sewer Separation Status" score as follows:

- **1:** Separate, Separated, or No System
- **2:** Short Term Separation Planned
- **3:** Long Term Separation Planned

Percent Impervious

The "Percent Impervious" factor is used in the analysis as a surrogate for nonpoint source pollution, based on the observation that the percent of a watershed covered by impervious surfaces is proportional to negative impacts on downstream water quality (pollutants collect on impervious surfaces and are picked up by runoff and carried downstream with no opportunity for infiltration or uptake by vegetation; see Chapter 4). Obviously, imperviousness is also related to stormwater flooding, urban heat, and air quality which are addressed later.

The "Percent Impervious" factor measures the percent of a grid-cell that is covered by artificially impervious surfaces (such as pavement, rooftops, etc.). Naturally, impervious surfaces (such a bedrock outcrops) are not captured, as they are not typically related to nonpoint source pollution. Impervious surfaces were extracted from the Holyoke Black Top GIS layer (provided by the City of Holyoke) and supplemented by evaluation of aerial imagery (from MassGIS). Each grid-cell was assigned a "Percent Impervious value" by directly calculating the percent of each grid cell that was covered by impervious surfaces.

- **1:** 100% of the grid cell is covered by impervious surfaces
- **0:** 0% of the grid cell is covered by impervious surfaces

Calculating the Water Quality Metric

To calculate values for the Water Quality metric, both the Sewer Separation Status and Percent Impervious factors were first normalized to 1.0 (Sewer Separation Status scores were divided by 3.0). The Water Quality metric was then calculated as:

(0.75 * [*Sewer Separation Status*]) + (0.25 * [*Percent Impervious*])

The coefficients weighting each variable were determined through an iterative process to identify values that appropriately reflect the priorities and goals of the city and this plan. Because of the significant impact that sewer separation can have on reducing pollution to waterbodies, that variable was weighted as 75% of the overall value of the Water Quality Metric.

Figure 6-2 depicts the Water Quality Metric grid analysis results.

6.2.2 Flood Risk

The Flood Risk metric identifies the degree to which a given grid-cell is susceptible to different kinds of flooding. It considers flooding from the overtopping of rivers as well as ponding and runoff. Three factors inform the Flood Risk metric: FEMA Flood Zone, Topographical Wetness Index, and Depression Index.

FEMA Flood Zone

The “FEMA Flood Zone” factor identifies whether a grid-cell contains FEMA-mapped flood zones (Special Flood Hazard Area, or SFHA). FEMA-mapped flood zones depict the modeled extent of 1%-annual chance and 0.2% annual-chance flood events, but much of the flooding related to impervious surface impacts occurs during less severe and more frequent precipitation events; therefore the FEMA-mapped flood zones do not correlate exactly with urban and drainage flood-risk areas. Nevertheless, FEMA-mapped flood zones do provide useful information about where flooding is likely to occur.

Shapefiles for flood zones were downloaded from MassGIS. Holyoke flood areas were clipped from a MassGIS file dated September 2017.

Grid cells were assigned to FEMA flood zones based on which zone the grid-cell centroid was located within, with some by-hand corrections made to ensure that grid-cells that fall mostly within a given flood zone but do not have their centroids within that zone were still assigned to that zone.

Each grid-cell was assigned a “FEMA Flood Zone” score as follows:

- **0:** Zone X – Minimal Flood Hazard Zone
- **1:** 0.2% Annual Chance Zone (“500-year flood zone”)
- **2:** 1% Annual Chance Zone (“100-year flood zone”)
- **3:** Floodway

Topographical Wetness Index

The Topographical Wetness Index (TWI) measures the effect of local topography on runoff flow direction and accumulation, highlighting potential areas of ponding and flooding. The TWI is included to show areas not captured by FEMA mapping where flash flooding or flooding due to inadequate drainage may occur.

A high-resolution, LiDAR-derived Digital Elevation Model (DEM) sourced from MassGIS was used to calculate this metric. The ArcGIS flow-routing model tools were used to model flow across the high-resolution DEM and determine flow accumulation at each DEM cell. The slope of each cell was also determined. TWI was calculated as:

Ln([*flow-accumulation*] / tan [*DEM slope*])

This method parallels that used by Ballerine, 2017[2], and is based on the ideas of Beven and Kirkby, 1979[3].

TWI values were assigned to each grid-cell by taking the average of all the DEM cells within it. Grid-cell TWI values were then normalized to 1.0, such that each grid-cell had a "TWI" score ranging from zero to 1.0, with higher numbers indicating a higher chance of ponding or flooding:

- **1:** Highest TWI, highest chance of ponding or flooding
- **0:** Lowest TWI, lowest chance of ponding or flooding

Depression Index

As with the TWI, the "Depression Index" attempts to show areas not captured by FEMA mapping where flash flooding or flooding due to inadequate drainage may occur. This index is based on the degree to which an area would need to be "filled" for water that flows into the area to flow back out of the area without the aid of drainage infrastructure. The Depression Index captures areas where flooding may occur because of insufficient or malfunctioning drainage infrastructure, or because of naturally occurring basins.

The same high-resolution DEM was used to calculate the Depression Index as was used to calculate the Topographical Wetness Index. The ArcGIS "Fill" tool was used to "fill" depressions in the DEM, so that water modeled to be flowing across the landscape would not come across any barriers or "sinks". The Depression Index value reflects the depth of the "fill."

Depression Index values were assigned to each grid-cell by taking the average of the values of all the DEM cells within it. Grid-cell Depression Index values were then normalized to 1.0, such that each grid-cell had a "DI" score ranging from zero to 1.0, with higher numbers indicating a higher chance of ponding or flooding:

- **1:** Highest Depression Index, highest chance of ponding or flooding
- **0:** Lowest Depression Index, lowest chance of ponding or flooding

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[2] Ballerine, Clayton, April 2017. *Topographic Wetness Index Urban Flooding Awareness Act Action Support: Will and DuPage Counties, Illinois*. Illinois State Water Survey, Prairie Research Institute. Contract Report 2017-02

[3] Beven and Kirkby 1979. *A physically based variable contributing area model of basin hydrology*. Hydrological Sciences Bulletin, 24, pp. 43–69

Calculating the Flood Risk Metric

To calculate values for the Flood Risk metric, all three factors were first normalized to 1.0 (FEMA Flood Zone scores were divided by 3.0). The Flood Risk metric was then calculated as:

((0.25 * [*FEMA Flood Zone*]) + (0.25 * [*TWI*]) + (0.5 * ([*Depression Index*]))/0.65

The result of combining the FEMA Flood Zone, TWI, and Depression Index factors was again normalized to 1.0 by dividing by 0.65, the highest calculated value in Holyoke.

The coefficients weighting each variable were determined through an iterative process to identify values that appropriately reflect the priorities and goals of the city and this plan. Because flash flooding in areas outside of the FEMA mapped flood zones have been identified as the primary flood-related concern for Holyoke, and because impervious surfaces most directly impact that type of flooding, the FEMA Flood Zone factor was given a relatively low weight. The Depression Index was assigned a higher weight based on a manual review of locations of high Depression Index values, as compared to reported flood and drainage concern areas. Grid-cells with high TWI values were widespread and less informative than the Depression Index, and so that index was assigned a lower weight.

Figure 6-3 depicts the Flood Risk Metric grid analysis results.

6.2.3 Air Quality and Temperature

Air quality and urban heat considerations were addressed through a single metric because of the close relationship between the two. The Air Quality and Temperature metric captures Tree Cover, Shade, Urban Heat Island Effect, and Vehicle Pollution.

Tree Cover

The "Tree Cover" index measures the percent of a grid-cell that is covered by tree canopy during the leaf-on season. No differentiation is made between tree health, age, or type. Tree Cover is relevant to local temperature, as trees cool the air through evaporative cooling, and air quality, as trees filter air pollution[4]. Tree Cover is also relevant to flooding, as trees take up water and decrease overland runoff.

The extent of tree canopy in Holyoke was identified by merging information from MassGIS 2016 Land Use GIS data and GIS data from the Greening the Gateway Cities Program (GGCP). Evergreen, Deciduous, and Palustrine Forested Wetland shapes were taken from the 2016 Land Use data and merged with GGCP canopy data to create a comprehensive map of canopy cover. Additionally, GGCP Tree points (a GIS data file that identifies locations for planned tree planting following the GGCP project in 2017) were given a 5-foot buffer to estimate the canopies of these newly planted trees and appended to the canopy data.

Grid cells were assigned a Percent Canopy value by directly calculating the percent of each grid cell that was covered by tree canopy.

[4] Trees and vegetation can directly remove pollutants from the air, and lower local temperatures, which can reduce pollutant emissions and formation. It is important to note, however, that trees can also increase some pollutants by emitting volatile organic compounds (VOCs). The net effect of urban tree canopy on local air quality is uncertain at this time (Eisman, et al., 2019; Nowak & Heisler, 2010).

- **1:** 100% Tree Coverage
- **0:** 0% Tree Coverage

Shade

The "Shade" index estimates the amount of shade available within a grid-cell, as provided by both trees and buildings. This factor captures the impact that shade can have on the temperature at ground level in an area, and the discomfort pedestrians may experience. For example, a completely impervious area with buildings will have shade that will provide some relief when compared to an impervious parking lot with no buildings or shade. Note that the Shade index is very closely connected to the Tree Cover index, as the majority of shade is provided by tree canopy.

To estimate the extent of shade available in a cell, it was assumed that 100% of the area under tree canopy was shaded. Shade from buildings was conservatively approximated by calculating a 5-foot buffer around buildings; more detailed analysis could not be performed because building height data was not available. Tree cover was calculated from the sources described above, and a building shapefile was provided by the city of Holyoke.

Grid cells were assigned a Shade value by directly calculating the percent of each grid cell that was covered by the shade shape.

- **1:** 100% Shaded
- **0:** 0% Shaded

Urban Heat Island Effect

The UHI Effect Index quantifies the relative strength of the UHI effect within each grid-cell. The UHI score reflects the degree to which temperatures within a grid-cell exceed the average temperature in the area around the city. The UHI effect has been found to correlate with lower tree cover and shade, surface albedo, imperviousness, and air pollution from sources such as cars and traffic.

UHI data was sourced from the collaborative mapping project completed by The Trust for Public Land, Descartes Labs, and the USGS, as described in Section 3.4. UHI severity is presented by on a scale of 1 to 5, with 1 indicating temperatures slightly above the mean for the city, and 5 indicating those significantly above the mean.

Each grid-cell was assigned a UHI effect index value equaling the value of the UHI raster map produced by the Trust for Public Land, Descartes Labs, and USGS at the location of the grid-cell centroid. Grid-cells with no data were assigned a value of zero, indicating no UHI effect at that location. Final values were as follows:

- **5:** Highest UHI Effect
- **4:** High UHI Effect
- **3:** Moderate UHI Effect
- **2:** Low UHI Effect
- **1:** Minimal UHI Effect
- **0:** No UHI Effect

Vehicle Pollution

The Vehicle Pollution index estimates the relative amount of air pollution from vehicle emissions expected in a grid-cell. Vehicle emissions lower air quality and can increase local temperatures. Note that this index addresses only air pollution from vehicles, and that nonpoint source pollution to waterbodies from vehicles and roads is not captured by this index; nonpoint source pollution is captured by the Percent Impervious factor under the Water Quality metric.

Pollution from roads was estimated as exponentially decreasing with distance from roads, weighted by the road class such that higher-trafficked roads have higher relative pollution levels. Roads and road class data were sourced from the MassDOT 2016 Statewide Road Inventory.

A 20-foot resolution raster map was created of the estimated relative vehicle pollution levels throughout Holyoke. Relative vehicle pollution scores for each grid-cell was calculated as the average relative vehicle pollution levels of the 20-foot resolution vehicle pollution cells. Vehicle Pollution values ranged from zero to one, with a score of "one" corresponding to high pollution, and a score of zero corresponding to low pollution:

- **1:** Maximum relative Pollution Level
- **0:** Minimum relative Pollution Level

Calculating the Air Quality and Temperature Metric

To calculate values for the Air Quality and Temperature metric, all four factors were first normalized to 1.0 (UHI Effect scores were divided by 5.0). The Air Quality and Temperature metric was then calculated as:

(0.15 * (1 – [*Tree Cover*])) + (0.15 * (1 – [*Shade*])) + (0.55 * [*UHI*]) + (0.15 * [*Vehicle Pollution*])

The coefficients weighting each variable were determined through an iterative process to identify values that appropriately reflect the priorities and goals of the city and this plan. The UHI index was given the greatest weight because it is based on direct measurement of air temperatures, a primary impact of concern for this analysis. The Tree Cover and Shade indexes are closely related (most shade is provided by trees), but also very important in the context of air quality and temperature; these indexes combined were assigned a weight of 30% of the total metric value, split evenly between the two. The Vehicle Pollution index was estimated by road class, rather than being derived from traffic counts or directly measured, and so has more uncertainty than the other factors included in this metric; for that reason, it was assigned a lower weight.

Figure 6-4 depicts the Air Quality and Temperature Metric grid analysis results.

6.2.4 Other Considerations

The "Other Considerations" metric addresses factors that are not directly related to water quality, air quality, or temperature, but are considered important to inform decisions about how to prioritize impervious surface mitigation efforts. The two factors included in this metric are Open Space Proximity and Environmental Justice Status.

Open Space Proximity

The Open Space Proximity index captures the distance from a given grid-cell to an open space location, as mapped by the MassGIS Open Space dataset. This index can help inform decision-making about creation of new, public open spaces, which are typically less impervious; and help pinpoint locations that are underserved with regards to recreational open space. Access to open space also tends to correlate with socioeconomic measures, with socially and economically marginalized communities often having less access to open space.

The MassGIS Open Space dataset was used to map open space locations. The straight-line distance from each grid-cell to the boundaries of open space polygons was calculated using the ArcGIS "Euclidean Distance" function. Barriers between a given location and an open-space polygon (such as highways or waterbodies) and accessibility of open spaces from a given location (such as the presence of sidewalks or public transportation), were not considered.

Each grid-cell was assigned a value representing the distance to an open space polygon based on the average distance of 20-foot resolution cells within the grid-cell. Grid-cell Open Space Proximity values were then normalized to 1.0. Higher values indicate a greater distance from open space.

- 1: Maximum distance (within Holyoke) from Open Space
- 0: Grid-cell is entirely within an Open Space polygon

Environmental Justice Status

The Environmental Justice Status metric summarizes data from the 2010 Census related to three demographic criteria, as developed by the Massachusetts Executive Office of Energy and Environmental Affairs. Environmental Justice communities include those with high minority, non-English speaking, and/or low-income populations.

Environmental Justice data by 2010 Census block-group was downloaded from the MassGIS 2010 U.S. Census Environmental Justice Populations dataset. Environmental Justice Status was quantified based on the number of criteria fulfilled by a Census block-group, and grid-cells were assigned an Environmental Justice Status value based on the maximum value of the Census block-groups that fall within their borders (with some manual corrections). Grid-cell Environmental Justice Status values range from zero to three:

- **3:** Grid-cell mostly contains Census block-groups meeting 3 Environmental Justice criteria (minority, language, income)
- **2:** Grid-cell mostly contains Census block-groups meeting 2 Environmental Justice criteria (minority and language, minority and income, or language and income)
- **1:** Grid-cell mostly contains Census block-groups meeting 1 Environmental Justice criterion
- **0:** Grid-cell mostly contains Census block-groups that do not meet any Environmental Justice criteria

Calculating the Other Considerations Metric

To calculate values for the Other Considerations metric, both the Open Space Proximity and Environmental Justice Status indexes were first normalized to 1.0 (Environmental Justice Status scores were divided by 3.0). The Other Considerations metric was then calculated as:

(0.5 * [*Open Space Proximity*]) + (0.5 * [*Environmental Justice Status*])

Proximity to open space and Environmental Justice Status were weighted equally.

Figure 6-5 depicts the Other Consideration Metric grid analysis results.

6.2.5 Final Grid Scoring

The Water Quality, Flood Risk, Air Quality and Temperature, and Other Considerations metrics for each grid-cell were summed to give a final priority score ranging from zero to four. A higher value indicates that a cell has a higher priority with regards to impervious surface mitigation.

Figure 6-6 depicts the final grid analysis results.

Grid Scoring with Sewer Separation

The Water Quality metric is to a large degree a reflection of the sewer separation status of a grid-cell, which is then also reflected in the final grid score. As the city moves forward with its sewer separation plans, future iterations of the grid analysis would, if undertaken, produce different results. For reference, to help municipal decision-makers understand the impacts of sewer separation, two additional versions of the grid analysis were run:

- Short Term Future: sewer service areas currently planned for separation over the short-term are analyzed as though they have been separated.
- Long Term Future: all sewer service areas are analyzed as though they have been separated.

Maps depicting the Water Quality metric and the Final Grid Scoring under each of these scenarios are included in Appendix D. Note that these maps were created for comparison purposes and are not considered part of the Grid Analysis used to inform recommendations for this plan. Note as well that as sewer systems are separated in the future, other changes in development and climate, as well implementation of impervious surface mitigation actions, would alter the results of the grid analysis as well.

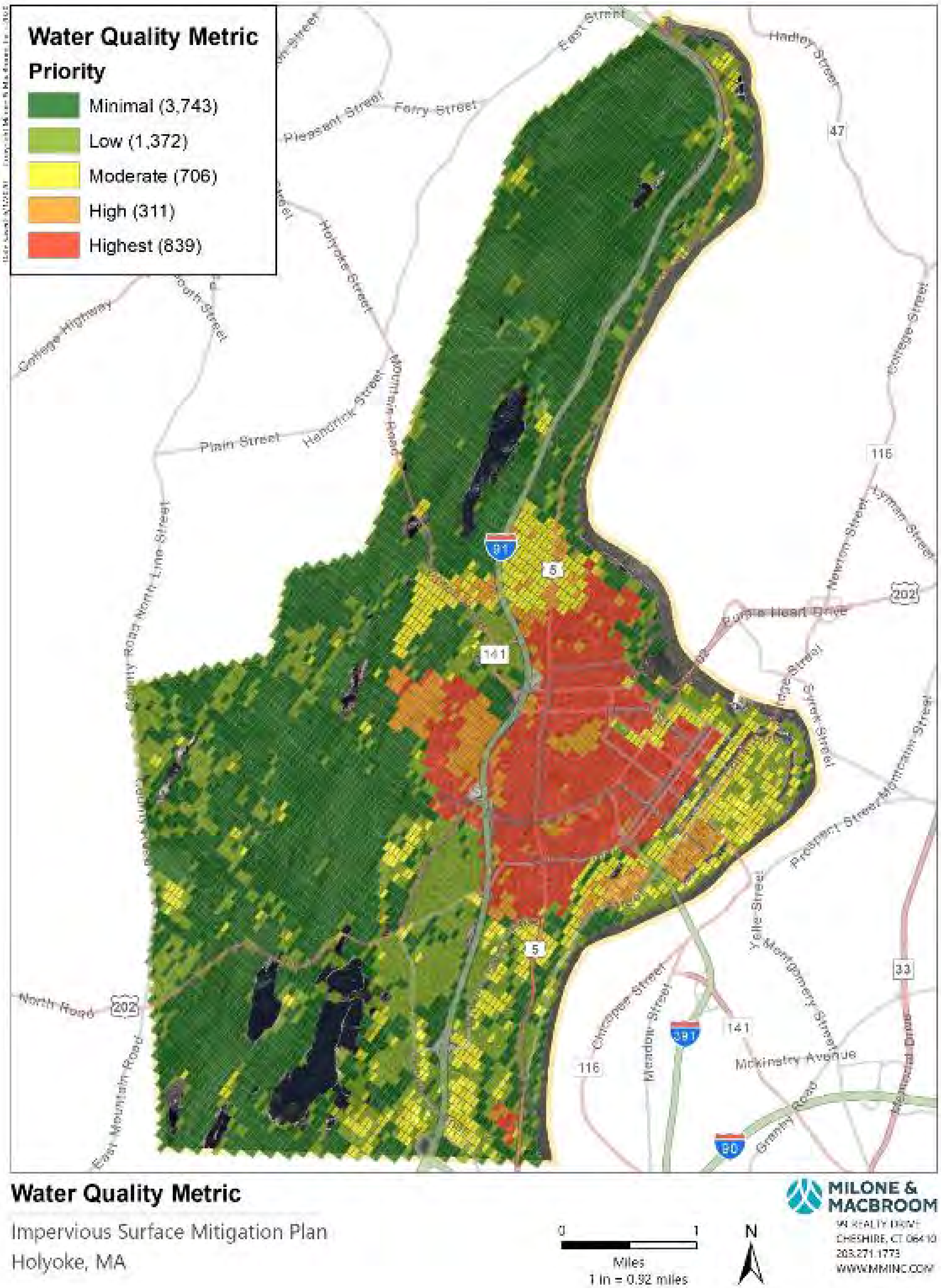

Figure 6-2: Water Quality Metric Results Map

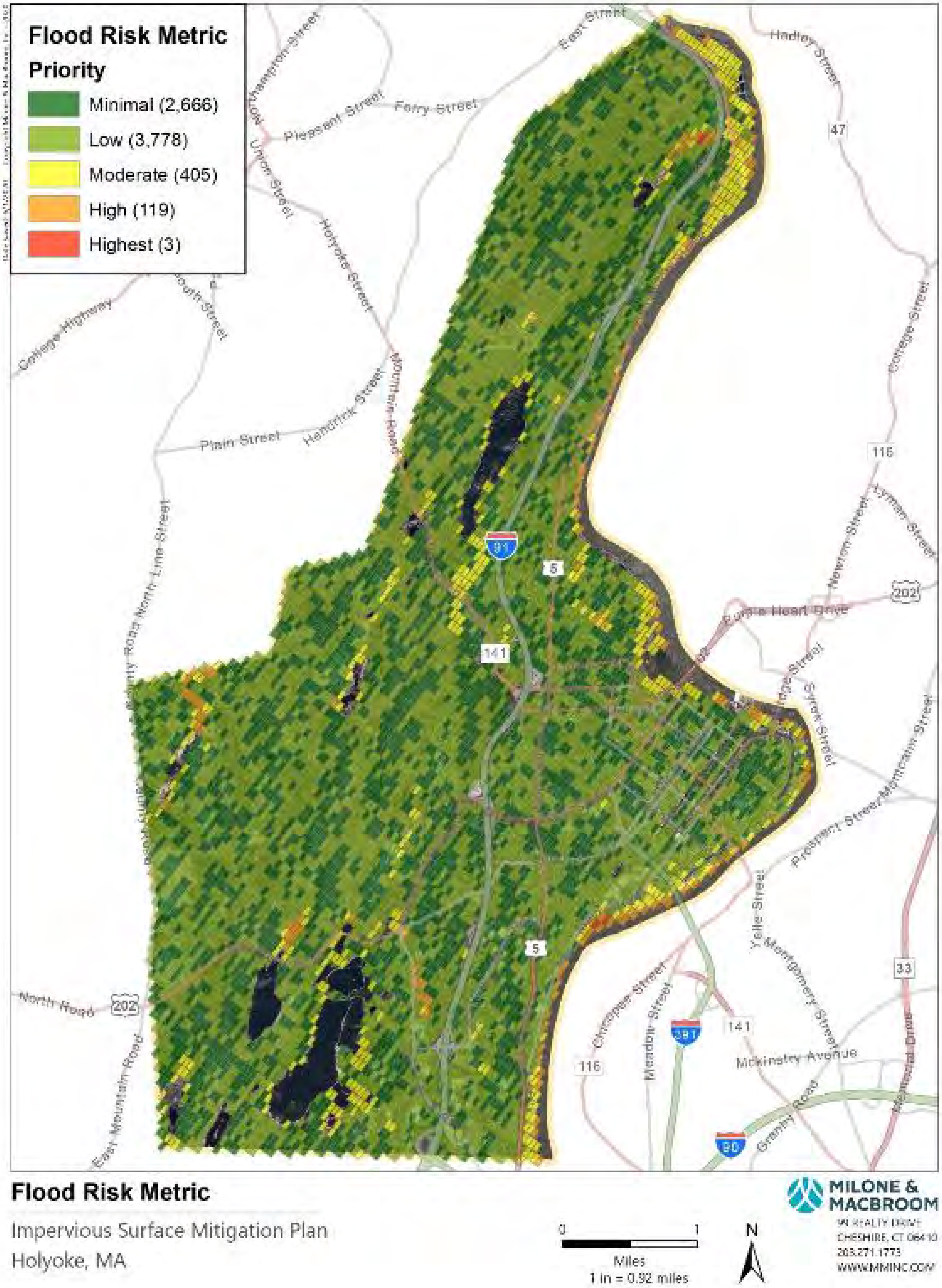

Figure 6-3: Flood Risk Metric Results Map

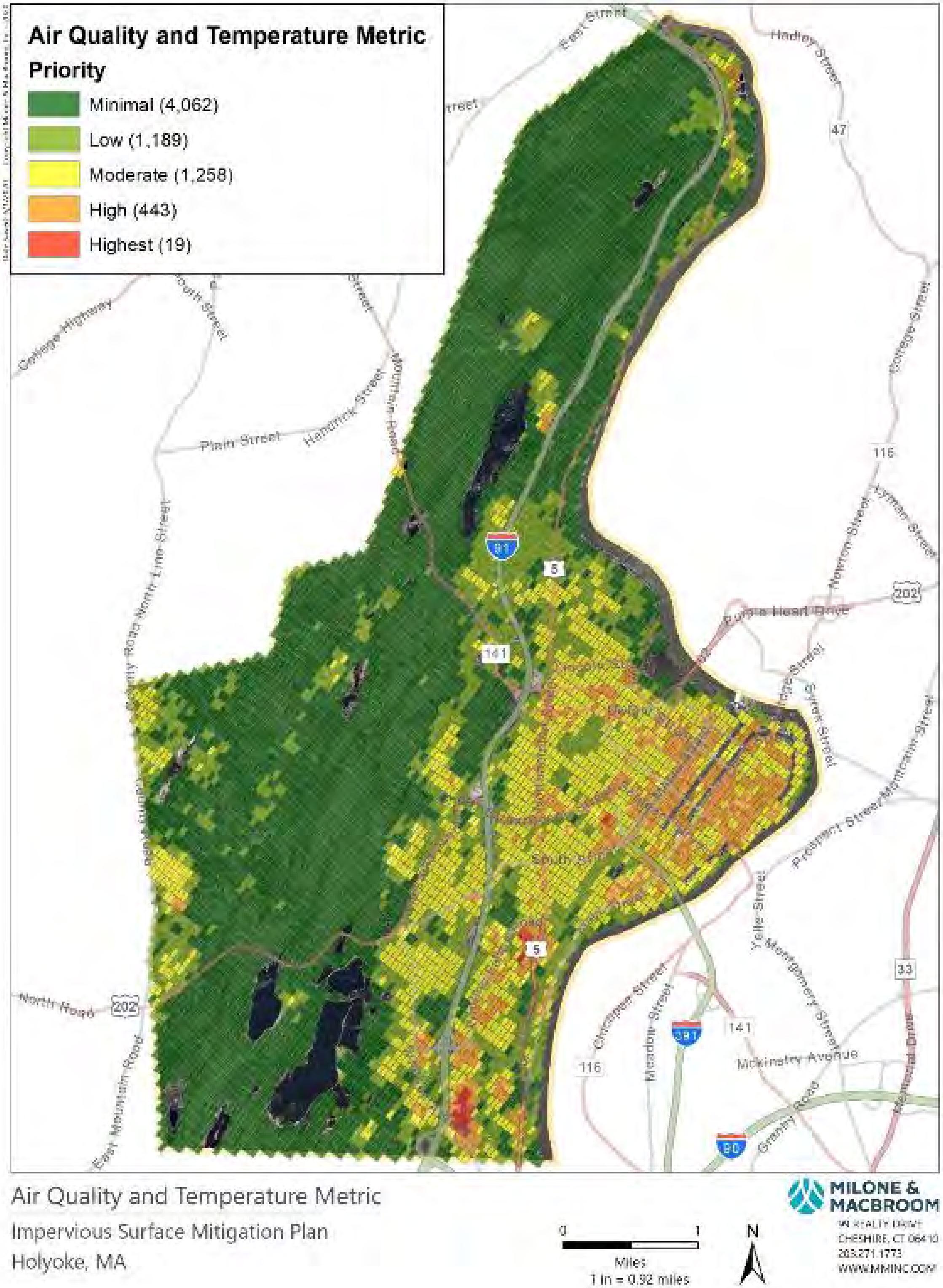

Figure 6-4: Air Quality and Temperature Metric Results Map

Figure 6-5: Other Considerations Metric Results Map

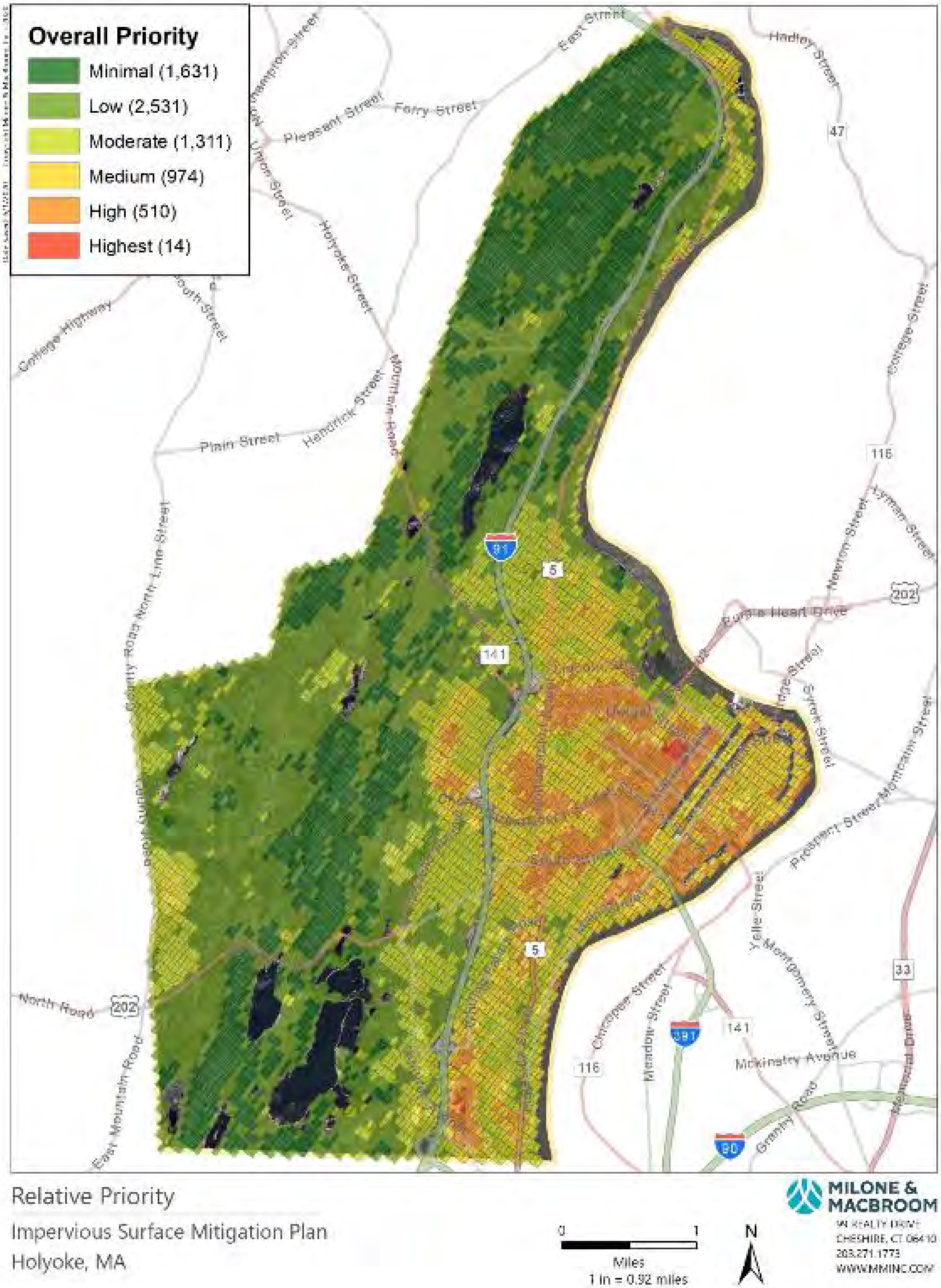

Figure 6-6: Final Grid Scoring Map

6.3 Grid Analysis Results

The Grid Analysis exercise demonstrates that areas of Holyoke that would benefit from impervious surface remediation can be found in many of the neighborhoods on the east side of the city. Every neighborhood except for Smith's Ferry, Rock Valley, Homestead Avenue, and Highland Park contain at least one grid-cell with a "high" priority score (a final grid score greater than 2.0). Only Churchill, Downtown, and Ingleside contain at least one grid-cell with a "highest" priority score (a final grid score greater than 2.5). It is important to note that the priority categories defined here are specific to Holyoke and provide information about the relative priority levels of each grid-cell; the highest possible grid score using the grid-analysis described above is 4.0, and the highest score in Holyoke was less than 3.0.

The areas of Holyoke served by combined sewers show the highest priority scores with regards to water quality, as pollutants within those areas are more likely to flow directly into the Connecticut River during a storm event. Specifically, this highlights the neighborhoods of Elmwood, Churchill, Oakdale, Downtown, Highlands, and Jarvis Avenue, as well as the southern portion of Highland Park. The grid-cells containing Providence Hospital in Ingleside also show Highest Priority scores. Springdale, South Holyoke, and The Flats all show Moderate to High water quality priority scores due to the high level of impervious surface coverage in those neighborhoods, but do not achieve the Highest scores because they are served by separated sewer systems.

Overall, the Flood Risk metric shows flood risk to be Low or Minimal throughout most of Holyoke. Areas in FEMA floodplains, such as those along the Connecticut River, along the Reservoirs, and along the more significant streams in Holyoke have higher priority scores despite the 25% weighting described in Section 1.23.2. The Flood Risk metric does not effectively reflect locations with reported street flooding and ponding problems, as identified in Section 3.1; this is due in part due to the resolution of the Flood Risk metric calculation. Known areas of flood risk should be addressed by Holyoke at the city's discretion.

The Air Quality and Temperature metric tends to match the pattern of density in Holyoke. The area of the Churchill, Downtown, The Flats, and South Holyoke neighborhoods shows Moderate and High priority levels. In Elmwood, there is one grid-cell is over the Roberts Field Sports Complex at Holyoke High School that has a Highest Priority level. Other Highest Priority level grid-cells are located at the Holyoke Shopping Center in Whiting Farms, and the Holyoke Mall in Ingleside.

The Other Considerations metric shows Highest Priority grid cells at the Holyoke Mall in Ingleside. High Priority cells are concentrated in Downtown, South Holyoke, The Flats, and a small portion of Churchill.

Figure 6-7 and Table 6-1, below, summarize grid-cell scores city wide for Holyoke.

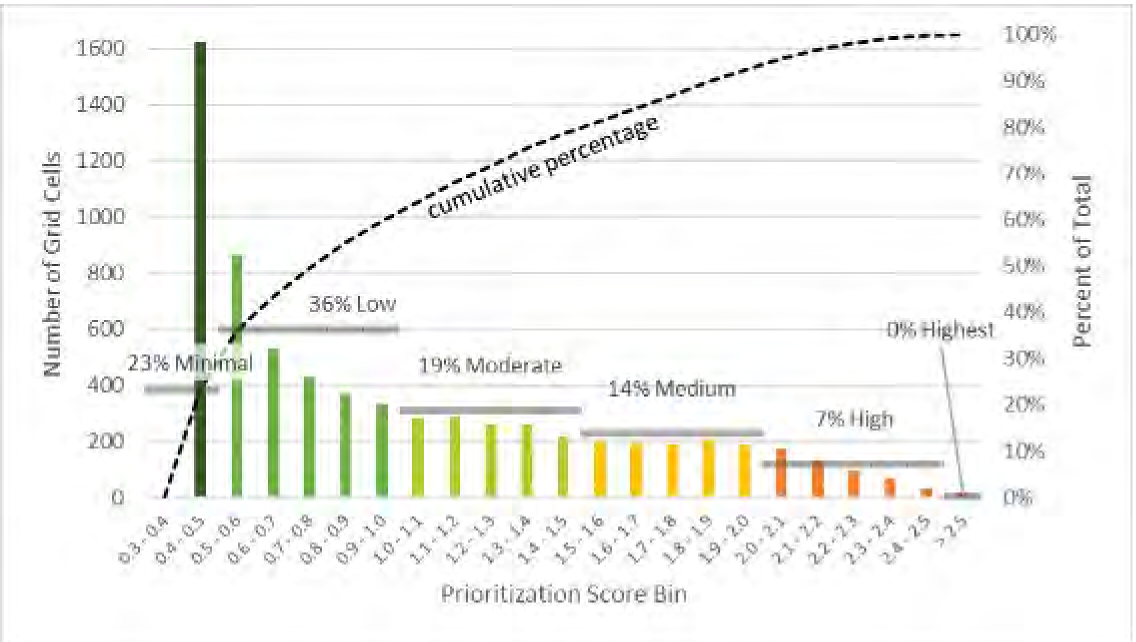

Figure 6-7: Histogram of Grid-Cell Priority Scores in Holyoke

Table 6-1: Citywide Grid-Cell Priority Scores

Priority	Prioritization Score	Number of Grid Cells	Percent of Grid Cells
Minimal	< 0.5	1631	23%
Low	0.5 – 1.0	2531	36%
Moderate	1.0 – 1.5	1311	19%
Medium	1.5 – 2.0	974	14%
High	2.0 – 2.5	510	7%
Highest	> 2.5	14	0%
Total		6971	

6.3.1 Results by Neighborhood

Grid-cell priority levels vary by neighborhood within Holyoke, with neighborhoods located in the eastern portion of the city having higher priority levels than those in the west. High priority grid cells are concentrated in the city's urban core, in around the Churchill, Downtown, and South Holyoke neighborhoods. Ingleside has elevated grid-cell scores as well, due primarily to the presence of large shopping mall and parking complexes. The western and northern parts of the city have lower-priority grid cells.

Figure 6-8, below, summarizes the distribution of grid-cell priority scores by neighborhood. The rest of this section describes the grid-analysis results by neighborhood in more detail.

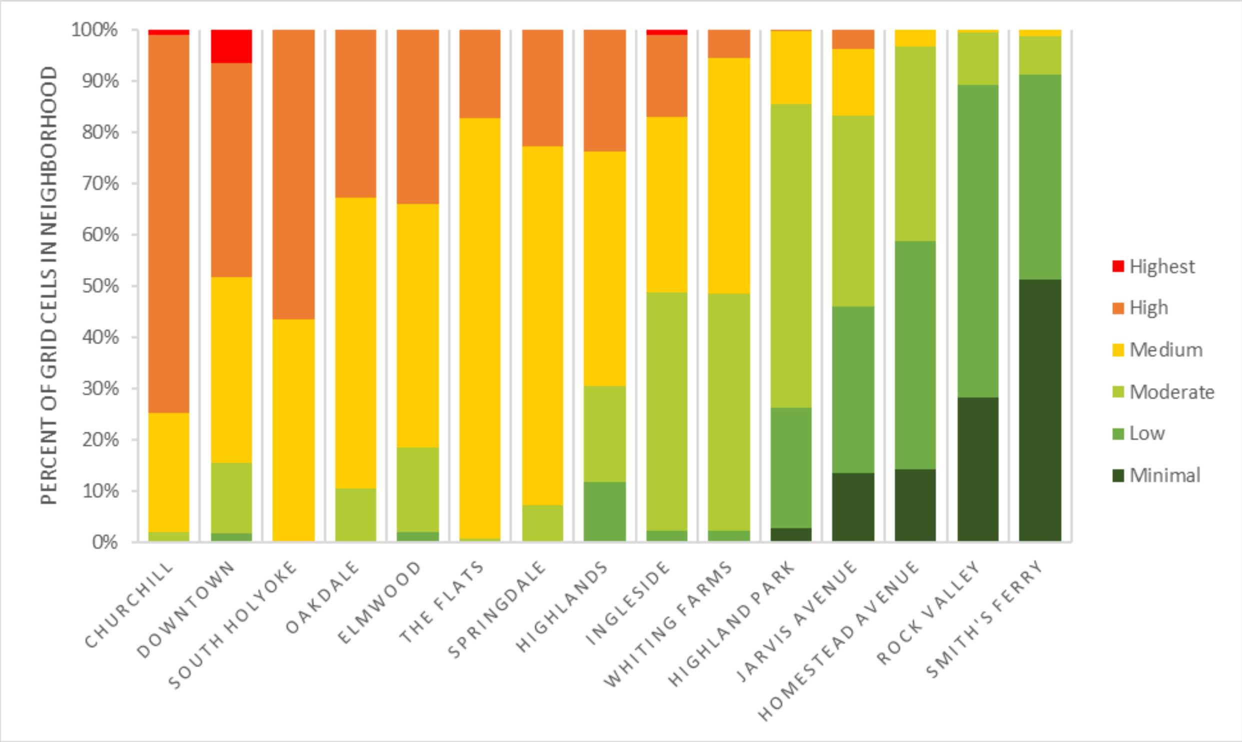

Figure 6-8: Relative Priority of Grid-Cells by Neighborhood

Churchill

The Churchill neighborhood consists almost entirely of grid-cells with High and Highest priority scores. The highest priority cell is located on a residential complex off of Sargeant Street between High and Chestnut streets. Effectively all cells northwest of First Level Canal are High or Highest priority.

Churchill is served by a combined sewer northwest of First Level Canal. The neighborhood has High Air Quality and Temperature metric scores due to the density of development, lack of tree cover or shade, and high measured urban heat island effect levels. Importantly, some areas of the neighborhood have high priority scores for the “Other Considerations” metric due to the presence of multiple Environmental Justice indicators and a relatively high distance from open space.

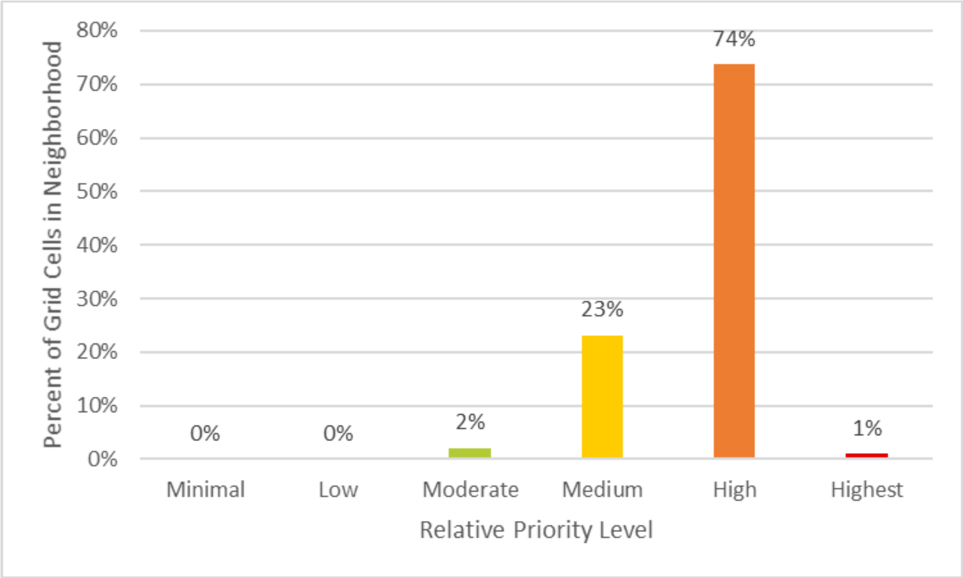

Figure 6-9: Grid-Cell Priority Levels in the Churchill Neighborhood

Table 6-2: Churchill Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	0	0%
Moderate	2	2%
Medium	22	23%
High	70	74%
Highest	1	1%
Total	95	

Downtown

The Downtown neighborhood consists mostly of grid-cells with Medium, High, or Highest priority scores. Moderate and Low priority-score grid cells are present in the sections of the neighborhood that are served by separated sewer systems, located near open space, or have limited to no development (such as adjacent to the Connecticut River). The highest priority grid cells are clustered near Appleton Street and Chestnut street.

Most of the Downtown neighborhood is served by a combined sewer system, with the exceptions being the area between the canals, a corridor along Beech Street northeast of Appleton Street, and areas northeast of Lyman Street. High levels of impervious coverage, busy roads, and a lack of tree coverage and shade give many parts of the neighborhood high priority scores for air quality and temperature. Some of the neighborhood near the intersection of Beech and Appleton Streets have high priority scores for the Other Considerations metric due to the presence of multiple Environmental Justice indicators and relatively high distance from open space.

The Highest priority grid cells are located between Walnut, High, Appleton, and Dwight Streets. A second hot spot is located between High, Maple, Lyman, and Hampden Streets.

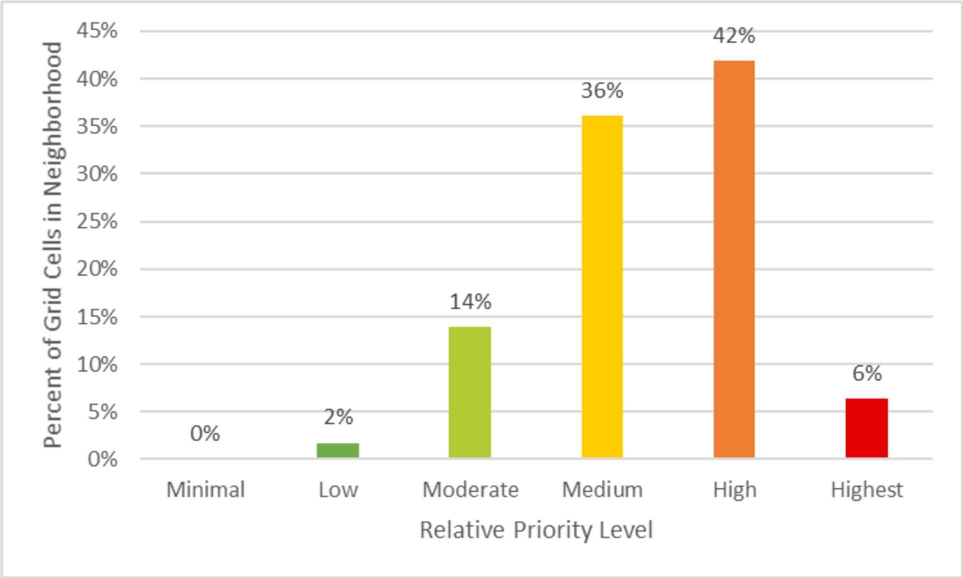

Figure 6-10: Grid Cell Priority Levels in the Downtown Neighborhood

Table 6-3: Downtown Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	3	2%
Moderate	24	14%
Medium	62	36%
High	72	42%
Highest	11	6%
Total	172	

South Holyoke

South Holyoke consists entirely of Medium and High priority grid-cells. High priority cells are concentrated along South Summer Street, South Canal Street, and Cabot Street.

Most of South Holyoke is served by a combined sewer system, which the city plans to separate in the short term. The entire neighborhood has a very high level of impervious surfaces, and overall has a low level of street trees. There are some areas, however, where a large number of street trees lower the priority-ratings for air quality and temperature, thereby lowering the overall priority rating of those areas. The neighborhood shows three Environmental Justice indicators, but is relatively close to public open spaces, as mapped by MassGIS.

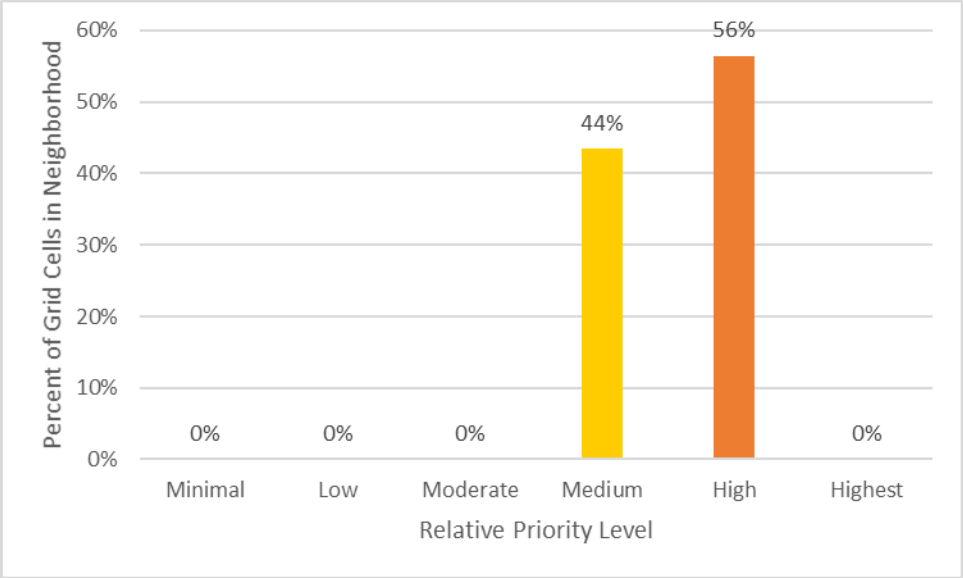

Figure 6-11: Grid Cell Priority Levels in the South Holyoke Neighborhood

Table 6-4: South Holyoke Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	0	0%
Moderate	0	0%
Medium	37	44%
High	48	56%
Highest	0	0%
Total	85	

Figure 6-12: High canopy cover from street-trees on South Summer Street.
Image: Google Street View, captured October 2019.

Oakdale
High-Priority grid cells in Oakdale are located along Dwight Street, near Downtown, and in a cluster around Northampton Road between Beech Street and West Franklin Street.

Oakdale is almost entirely served by a combined sewer system, which the city intends to separate over the long term; this raises the priority level of the neighborhood. The traffic from Northampton Street elevates air quality concerns. Parking lots along Northampton Street, yards with few trees (leading to low tree canopy levels and low amounts of shade), and Environmental Justice indicators coincide in the High priority areas.

The Forestdale Cemetery and St. Jerome Cemetery are two Moderate-Priority areas within this neighborhood. Other Moderate-Priority grid-cells are located at wooded areas near Woods Ave and off Summit Ave near Route 91, and on Pinehurst Road.

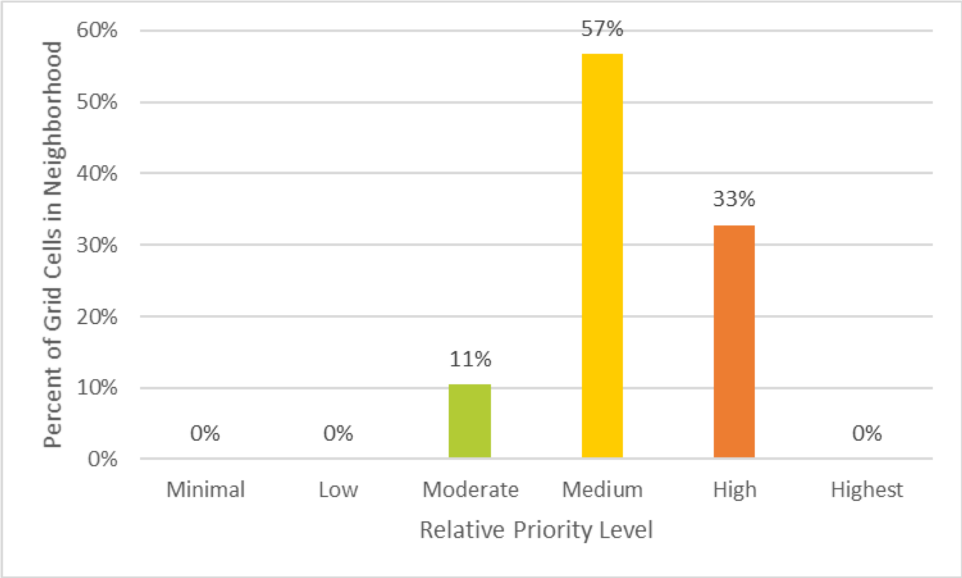

Figure 6-13: Grid Cell Priority Levels in the Oakdale Neighborhood

Table 6-5: Oakdale Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	0	0%
Moderate	26	11%
Medium	140	57%
High	81	33%
Highest	0	0%
Total	247	

Elmwood

Grid-cell priority levels within the Elmwood neighborhood range from Low to High. High-Priority grid-cells are concentrated within a corridor running from Martin Street and West Glen Street northeast to the Fitzpatrick Ice Skating Rink. Scores for the four metrics underlying the priority analysis vary along this corridor, indicating there is not one single factor leading to these High-Priority levels. Multiple Environmental Justice Indicators, and moderate scores for UHI effect, vehicle pollution, and distance from open space, all contribute. Additionally, the areas within the High-Priority cells are served by a combined sewer system, which the city intends to separate over the long term. The neighborhood has low to moderate impervious surface coverage; however, it also has low to moderate tree coverage and shade, leading to higher priority scores for air quality and temperature. Direct measurements of relative heat-island effect show it is high and very high near the Roberts Field Sports Complex at the high school, the Fitzpatrick Ice Skating Rink, and South Street Plaza.

Moderate-Priority grid-cells are located within the forested area southwest of West Glen Street, and Low-Priority grid-cells are located at the cemetery.

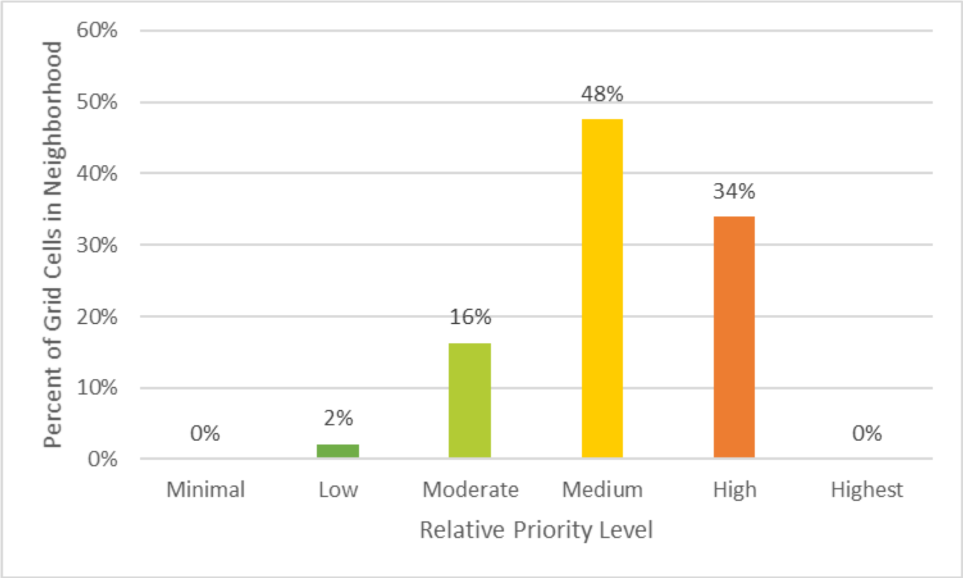

Figure 6-14: Cell Priority Levels in the Elmwood Neighborhood

Table 6-6: Elmwood Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	5	2%
Moderate	38	16%
Medium	111	48%
High	79	34%
Highest	0	0%
Total	233	

The Flats

The Flats is mostly classified as Medium Priority, with some High-Priority grid-cells and a single Moderate-Priority cell. The Moderate-Priority cell is located at Deroy Park, a public open-space parcel with significant tree-cover and shade.

High-Priority cells are located along the Connecticut River in FEMA-mapped flood zones, as well as in the industrial areas around the intersection of Winter Street and Appleton Street, and between North Bridge Street and Canal Street. These areas have very high impervious-surface levels and very low shade and tree canopy levels. They also have multiple Environmental Justice Indicators.

The high-priority grid-cell scores in the Flats exist notwithstanding the fact that the entire neighborhood is served by a separated sewer system.

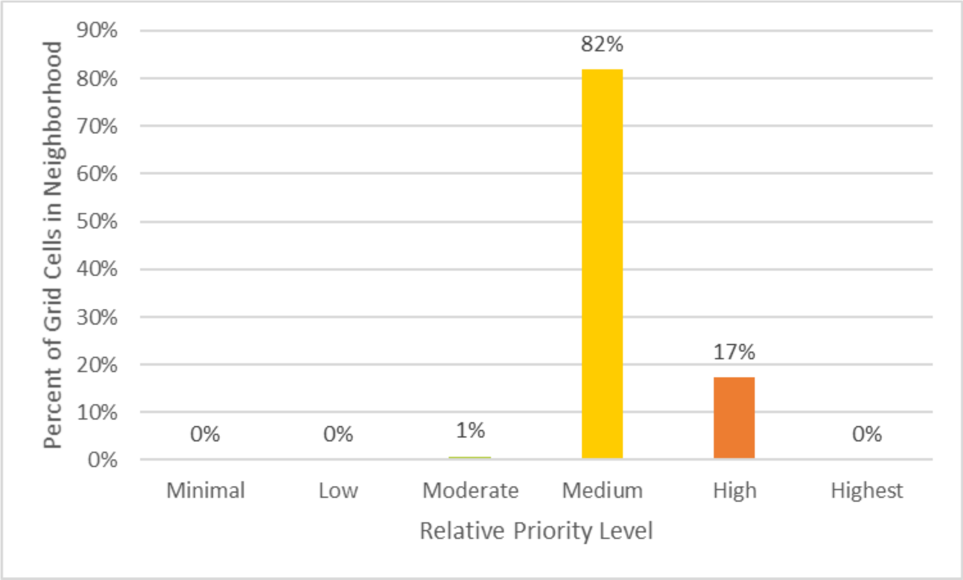

Figure 6-15: Cell Priority Levels in The Flats Neighborhood

Table 6-7: The Flats Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	0	0%
Moderate	1	1%
Medium	109	82%
High	23	17%
Highest	0	0%
Total	133	

Springdale

High-Priority grid-cells in Springdale are located at the industrial buildings northwest of Main Street, due to high imperviousness, low tree cover and shade, and high UHI effect. Springdale Park is rated as Medium Priority, a more elevated priority level than might be expected in an open-space area because the area has a high flood-risk score.

Springdale has no Minimal- or Low-Priority grid-cells. The neighborhood is served mostly by a combined sewer system that the city plans to separate in the short term. The neighborhood has multiple Environmental Justice indicators.

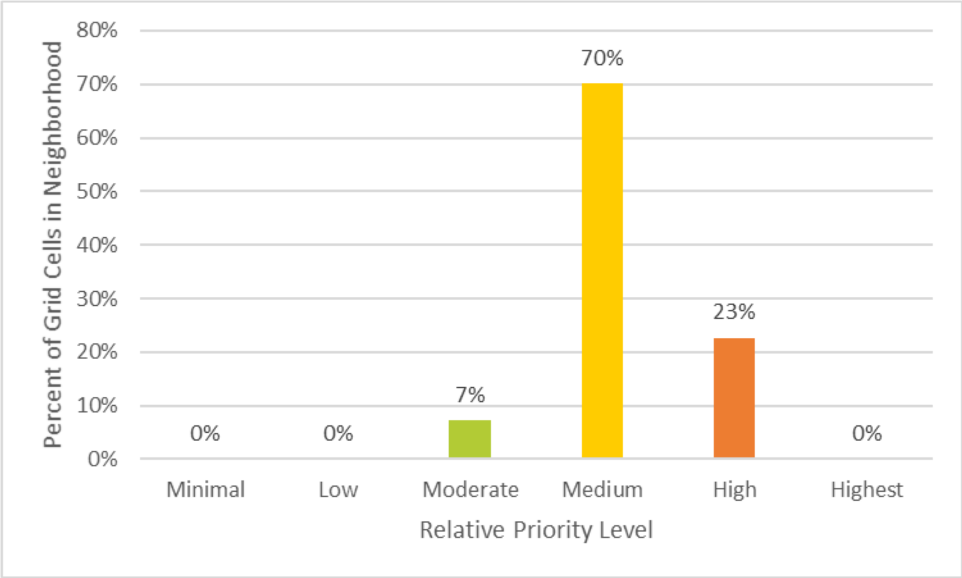

Figure 6-16: Grid Cell Priority Levels in the Springdale Neighborhood

Table 6-8: Springdale Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	0	0%
Moderate	7	7%
Medium	68	70%
High	22	23%
Highest	0	0%
Total	97	

Highlands

Grid-cell priority levels within the Highlands neighborhood tend to increase toward the south as the neighborhood becomes more dense and impervious surfaces increase, while tree canopy decreases. High-Priority grid-cells are located south of Hampden Street, with some northward extensions along main roads, and an additional pocket at the Stop and Shop plaza on Lincoln Street. Low- and Moderate-priority grid-cells are located in the undeveloped areas near the Connecticut River to the east, and along the wooded buffer of I-91 to the west. A pocket of Moderate-Priority grid-cells is located in the area around Morgan Street because of high tree cover and proximity to open spaces. This entire neighborhood is served by a combined sewer system that the city plans to separate in the long-term.

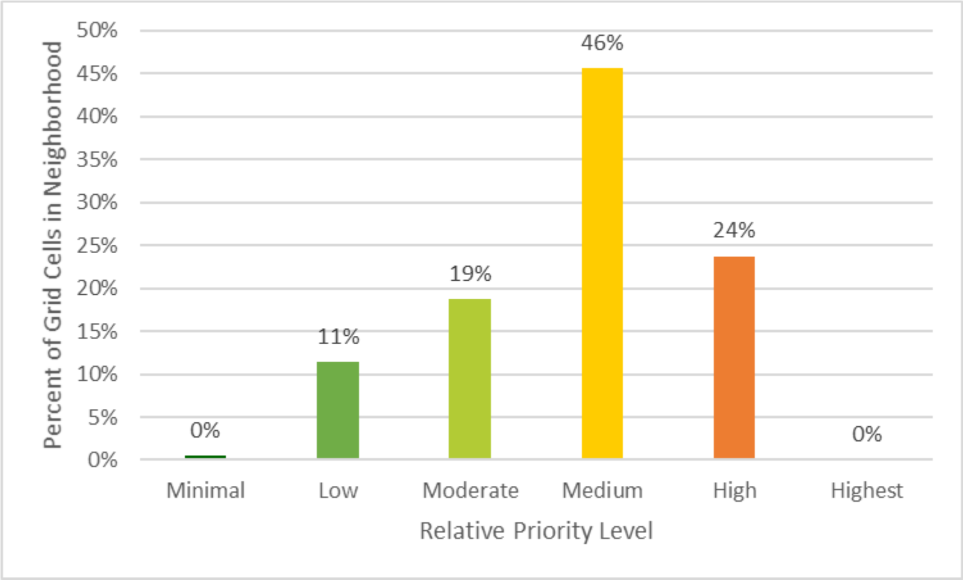

Figure 6-17: Grid Cell Priority Levels in the Highlands Neighborhood

Table 6-9: Highlands Priority Levels

Priority	Count	Percent
Minimal	1	0%
Low	25	11%
Moderate	41	19%
Medium	100	46%
High	52	24%
Highest	0	0%
Total	219	

Figure 6-18: A vegetated divider in the Stop & Shop Parking Lot
Image: Google Street View, August 2018

Ingleside

The Ingleside neighborhood shows grid-cells with elevated priority levels in the northeast corner along Main Street (partly due to some flood risk from the Connecticut River), around Providence Hospital, and at the Holyoke Mall. All these locations have higher priority due to impervious surfaces and lack of tree canopy and shade.

The Holyoke Mall includes two Highest-Priority grid-cells that have priority scores that are among the highest in Holyoke. The Urban Heat Island effect has a strong impact here as expected due to the size of the building and the parking area, but possibly exacerbated by the mall's dark roof.

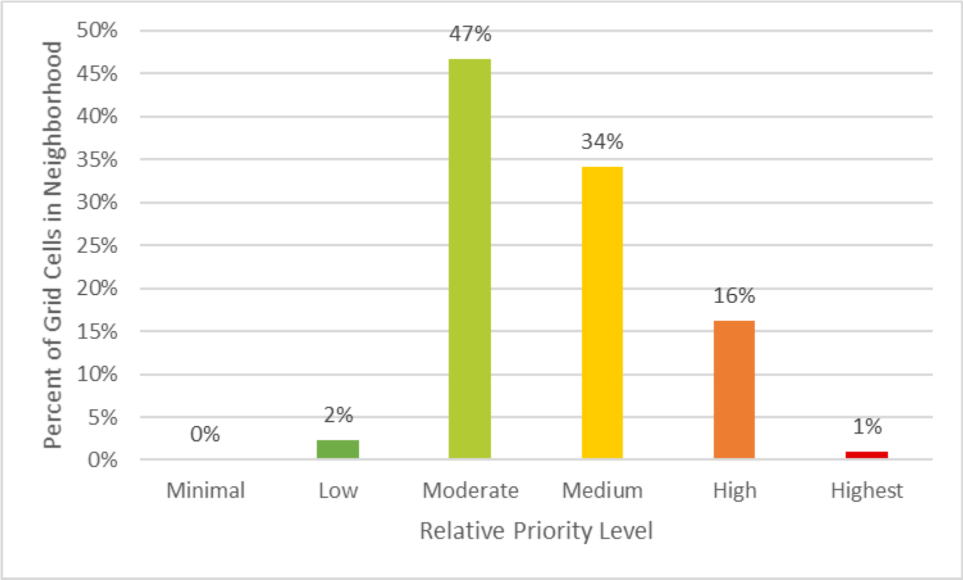

Figure 6-19: Grid-Cell Priority Levels in the Ingleside Neighborhood

Table 6-10: Ingleside Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	5	2%
Moderate	104	47%
Medium	76	34%
High	36	16%
Highest	2	1%
Total	223	

Whiting Farms

High-priority grid-cells in Whiting Farms are concentrated around Holyoke Crossing in the southwest and the Holyoke Shopping Center in the northeast. Both areas have extensive parking and limited tree canopy and shade. Dark-colored roofs and busy roads also contribute to high priority levels. Low-Priority grid-cells are present in a couple of wooded areas within the neighborhood. no Minimal-Priority grid-cells are present.

The Holyoke Farms development shows Medium priority levels due in part to a relatively low amount of tree canopy. It is noted that there appear to be many relatively young trees planted in that neighborhood that over the coming years will provide more shade, possibly lowering the grid-cell priority scores here in the future.

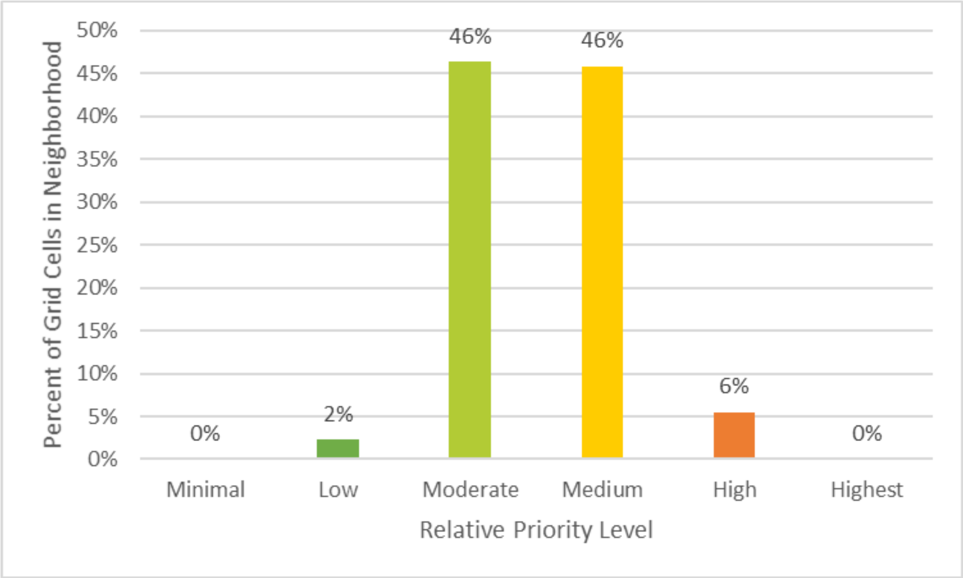

Figure 6-20: Grid-Cell Priority Levels in the Whiting Farms Neighborhood

Table 6-11: Whiting Farms Priority Levels

Priority	Count	Percent
Minimal	0	0%
Low	5	2%
Moderate	101	46%
Medium	100	46%
High	12	6%
Highest	0	0%
Total	218	

Figure 6-21: Streetside Trees at Holyoke Farms
Mature trees along Tokeneke Rd to the right, young trees along Whiting Farms Road to the left.
Image: Google Street View, October 2019

Highland Park

Within the Highland Park neighborhood, grid-cell priority ratings tend to increase toward the south as density increases, with higher-priority areas extending north along Route 5 and along Pleasant Street and Wellesley Road. The area along Pleasant Street and Wellesley Road is served by a combined sewer that the city plans to separate over the long term.

There is one High-Priority grid-cell at the intersection of Dartmouth and Jefferson, where a Moderate score for the Flood Risk metric pushes up the overall priority score. The Flood Risk Metric is High at Hampton Knolls Road, but the overall priority level here is Medium. High tree cover, low impervious surface levels, and low Environmental Justice metrics create Minimal, Low, or Moderate priority scores for the rest of the neighborhood, despite many areas being far from public open space.

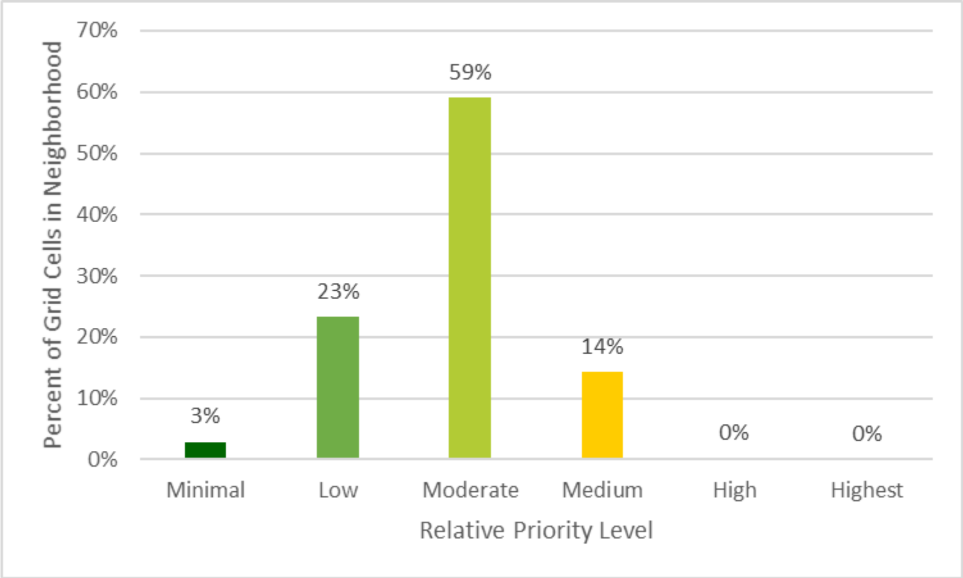

Figure 6-22: Grid-Cell Priority Levels in the Highland Park Neighborhood

Table 6-12: Highland Park Priority Levels

Priority	Count	Percent
Minimal	8	3%
Low	64	23%
Moderate	162	59%
Medium	39	14%
High	1	0%
Highest	0	0%
Total	274	

Jarvis Avenue

Much of the Jarvis Avenue neighborhood is undeveloped, particularly the western portion and the area around Scott Tower; grid-cells in these areas have Minimal and Low Priority scores. High-Priority grid cells are found in the areas of Day Brook Village Senior Living, Jarvis Heights, and the Leary Drive development. These areas are served by a combined sewer that the city plans to separate over the long term, and have relatively low tree coverage and shade, despite also having low levels of imperviousness. Residential areas to the north (Lindor Heights, Burns Way, University Heights, and Bemis Road) are mapped as Moderate-Priority; these areas are served by sewer systems that are either planned for separation over the short term (Bemis Road) or already separated.

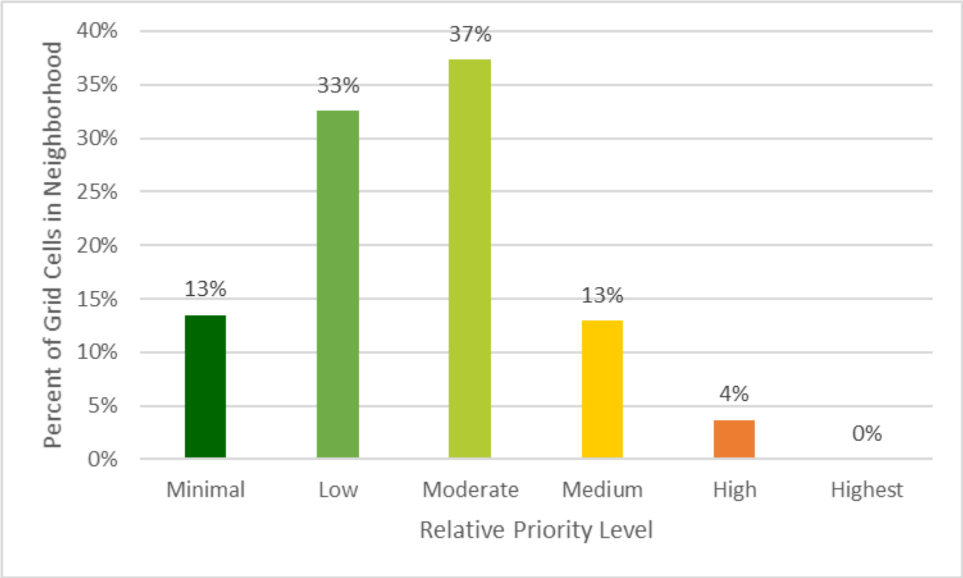

Figure 6-23: Grid-Cell Priority Levels in the Jarvis Avenue Neighborhood

Table 6-13: Jarvis Avenue Priority Levels

Priority	Count	Percent
Minimal	51	13%
Low	123	33%
Moderate	141	37%
Medium	49	13%
High	14	4%
Highest	0	0%
Total	378	

Homestead Avenue

The western half of the Homestead Avenue neighborhood is largely undeveloped, with Minimal- or Low-Priority grid-cell scores. The low-density residential areas making up most of the eastern part of the neighborhood have predominantly Moderate-Priority grid-cell ratings. Medium Priority grid-cells are located at the north end of Homestead Avenue near Cherry Street, at Cherry Hill Condominiums and Soldiers' Home. There are no High Priority grid-cells in this neighborhood, although High-Priority cells in the adjacent Jarvis Avenue neighborhood partly overlap.

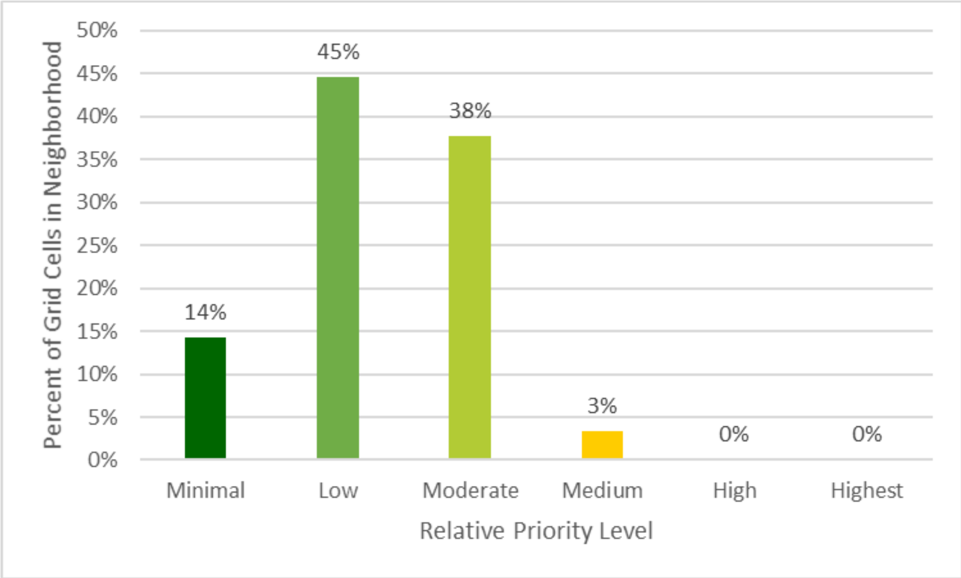

Figure 6-24: Grid-Cell Priority Levels in the Homestead Avenue Neighborhood

Table 6-14: Homestead Avenue Priority Levels

Priority	Count	Percent
Minimal	123	14%
Low	384	45%
Moderate	325	38%
Medium	29	3%
High	0	0%
Highest	0	0%
Total	861	

Rock Valley

The Rock Valley neighborhood consists primarily of Low-Priority grid-cells, and nearly 90% of the neighborhood is rated as Minimal- or Low-priority. The highest priority grid-cells (ten Medium-Priority cells) are located at the solar farm off County Road. A solar farm is a special case of land use that need not be targeted for reducing impervious surfaces as a result of this analysis. Many of the large swathes of forested area in Rock Valley are rated as Low-Priority, rather than Minimal-Priority; this may in part be due to the fact that many of these areas are privately-owned, and so do not necessarily provide public access to open space (one of the factors considered in the “Other Considerations” metric.

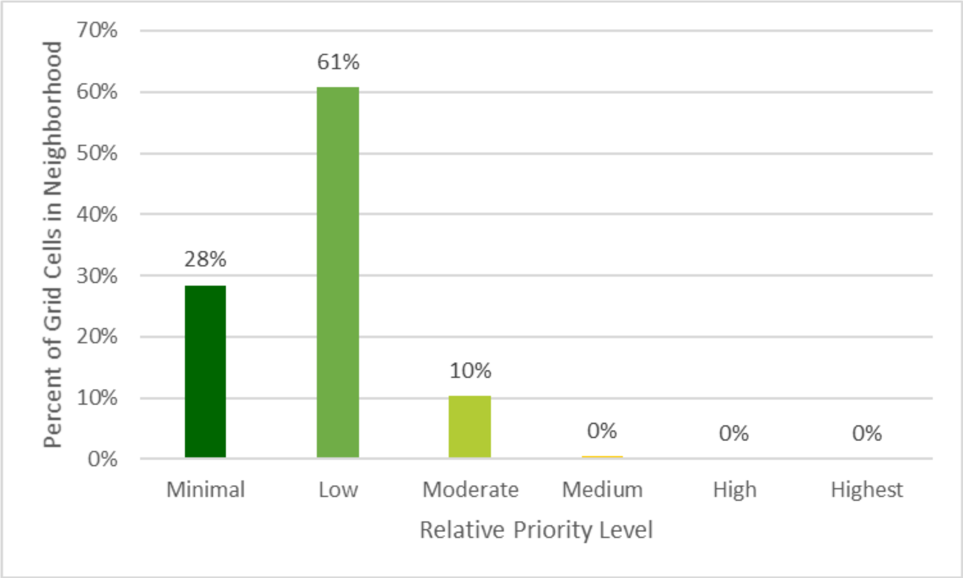

Figure 6-25: Grid Cell Priority Levels in the Rock Valley Neighborhood

Table 6-15: Rock Valley Priority Levels

Priority	Count	Percent
Minimal	575	28%
Low	1228	61%
Moderate	210	10%
Medium	10	0%
High	0	0%
Highest	0	0%
Total	2023	

Smith's Ferry

The majority of grid-cells in Smith's Ferry are rated as Minimal Priority, and over 90% of the neighborhood is Minimal- or Low-Priority. The highest-priority cells (rated as Medium-Priority) are located at the northern tip of Smith's Ferry, around the old coal power plant. A second cluster of Medium-Priority cells is found along Route 5, south of Old Ferry Road. Both areas are influenced by flood risks from the Connecticut River.

Overall, Smith's Ferry shows a minimal need for impervious surface mitigation.

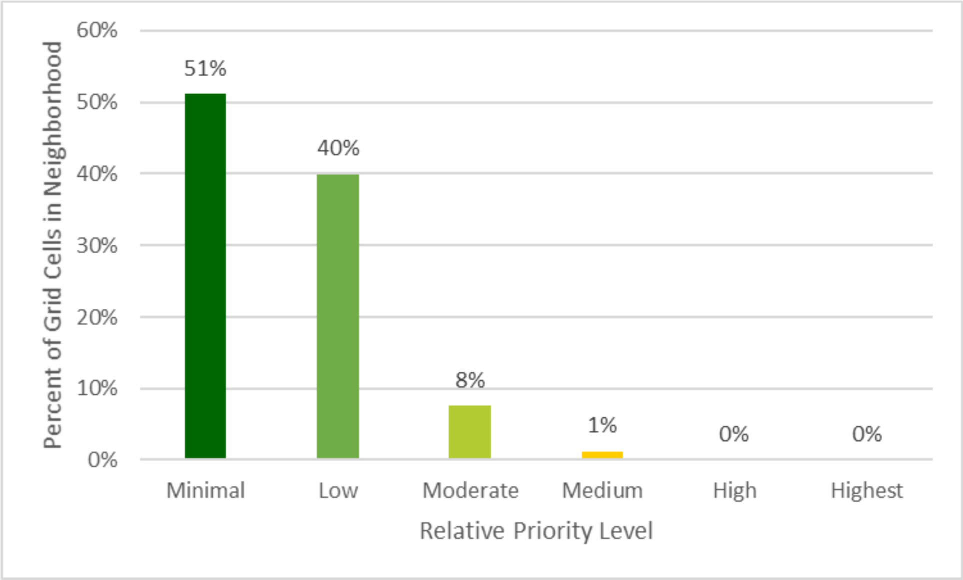

Figure 6-26: Grid Cell Priority Levels in the Smith's Ferry Neighborhood

Table 6-16: Smith's Ferry Priority Levels

Priority	Count	Percent
Minimal	873	51%
Low	681	40%
Moderate	129	8%
Medium	21	1%
High	0	0%
Highest	0	0%
Total	1704	

6.3.2 Top-Ranked Areas of Need

Overall, the grid analysis finds seven main clusters of higher-priority cells.

1. **The City Center Cluster** encompasses Downtown and Churchill, extending into the Oakdale and Elmwood neighborhoods. This cluster is characterized by high imperviousness, moderate road-pollution, low tree cover, and two to three indicators for Environmental Justice populations. The city center cluster is within the sewersheds of combined sewer systems, which the city intends to separate over the long term.
2. **The Industrial Zone Cluster** encompasses the industrial areas of Springdale, South Holyoke, and The Flats. This cluster is characterized by a range of imperviousness levels, with low tree coverage and shade, and moderate to high vehicle pollution levels. The industrial zone cluster is predominantly made up of grid cells with three Environmental Justice indicators, with some two-indicator areas. The cluster is served by a combined sewer system, which the city plans to separate in the short term, or else by an already separated system.
3. **The Mall Cluster** is the area around the Holyoke Mall, extending along Route 5 and Whiting Farms Road to the Holyoke Shopping Center. This cluster is characterized by nearly 100% imperviousness, an almost complete lack of shade, and relatively far distances to open space.
4. **The Route 5 Cluster** is located along Route 5 in Oakdale. It is characterized by moderate to high vehicle pollution, moderate distance from open space, low tree cover, and one to two indicators for Environmental Justice populations. It is within a combined sewer system sewershed, which the city intends to separate over the long term.
5. **The Dwight Street Cluster** is located along Dwight Street in the Highlands neighborhood, extending north to Hampden Street and south into the Oakdale and Downtown neighborhoods. It is characterized by low tree cover and shade levels, two to three indicators for Environmental Justice populations, moderate vehicle pollution, and moderate distance from open space. It is in a combined sewer system sewershed, which the city intends to separate over the long term.
6. **The South Street Cluster** is located in the Elmwood neighborhood, roughly running along South Street. It is characterized by moderate to very high UHI effect levels, low tree cover and shade, and one to two indicators for Environmental Justice populations. It is within a combined sewer system sewershed, which the city intends to separate over the long term.
7. **The Jarvis Avenue Cluster** is located along Cherry Street and Jarvis Avenue in the Jarvis Avenue neighborhood. While most of the area has relatively low priority scores, some pockets have very low tree cover or shade, two Environmental Justice indicators, and moderate vehicle pollution. The area is served by a combined sewer system, which the city intends to separate over the long term.

A list of the one-hundred top-priority grid cells identified in this analysis can be found in Appendix E.

Four high-priority focus areas have been identified:

- The Churchill Neighborhood
- The City Center Area
- North of Veteran's Memorial Park
- The Holyoke Mall

One-page factsheets for each of these focus areas can be found in Appendix F: Focus Area Factsheets.

6.4 Public Outreach Results

Due to the ongoing pandemic, public response is believed to be somewhat muted. However, those who did participate lent interesting insights to the process. Approximately 88% of respondents identified themselves as city residents but only 42% identified as residential property owners. This is in line with the Census estimates for the number of homeowners in the City.

Their Experience

Approximately 79% of respondents noted localized flooding on Holyoke's streets, especially under the underpasses. However, only a small portion of respondents agreed that flooding has worsened in recent years. Respondents were much more likely to have observed an increase in summer heat, development of impervious surfaces, and a worsening of air quality.

Most respondents had not directly experienced an impact of poor air quality but 30% said they had experienced a respiratory illness caused or aggravated by air pollution, including asthma and bronchitis.

Their Concerns

Of all of the environmental impacts of impervious surfaces, water pollution and sewer overflows topped the list. This was followed by air pollution, stormwater flooding, and the Urban Heat Island Effect. When looking at quality of life impacts, respondents expressed similar levels of concern for all of the possibilities.

Their Reaction to Strategies

Respondents were asked to select options to be prioritized or incorporated in future strategies. The most popular were permeable paving systems, sidewalk planters, infiltration swales, and directing downspouts to pervious surfaces. When asked to rank strategies preserving open space and/ or wetlands, the highest-ranked included:

- Incorporating green spaces between and among buildings
- Clustering new buildings together to set aside open space when land is developed

A full report of survey responses can be found in the Appendix G.

7 Mitigation Strategies

There are many creative ways Holyoke can mitigate the negative impacts impervious surfaces in new and existing developments. Measures to reduce impervious surfaces may range from minor adjustments in small projects to implementing major projects depending on the will of the City and its residents.

Recall that 60% of Holyoke's urban core is covered with impervious surfaces, while the average city-wide is 30%. This disparity enables Holyoke to focus its efforts and pilot new strategies in the urban core. Lessons applied in the urban core to mitigate the impacts of impervious surfaces can eventually help to maintain the greenery and open spaces for the rest of city as small pockets are developed.

7.1 Ordinances and Regulations

Holyoke's municipal ordinances and zoning and subdivision regulations provide a powerful tool by which the city can both incentivize reduction in impervious surfaces and discourage, or even prohibit creation of new pervious surfaces. Given the current structure of ordinances and regulations relevant to impervious surfaces and stormwater, the following list of possible actions has been determined to be appropriate for Holyoke.

Subdivision Regulations

While Holyoke's subdivision regulations address stormwater retention and detention, they do not include strong language about Low Impact Development (LID). LID is a powerful technique to manage stormwater runoff while achieving mutual benefits such as habitat restoration; however, as currently written it is not necessary for a developer to consider LID in order to meet minimum subdivision requirements, and it is therefore unlikely a developer will spend the additional time, money, and effort to do so.

In addition to the general zoning changes detailed in 8.2, Holyoke can promote future subdivisions or subdivision developments of a certain size must be designed as "Cluster Developments." Cluster Developments reduce impervious surfaces by concentrating developments in one section of a parcel. This reduces the need for pavement and utilities. The green space that is saved is protected and can possibly be designated as public open space by the developer. This strategy would generally apply to lower density residential areas. To encourage the design of subdivisions as cluster developments, zoning could be changed to allow for greater density of dwelling units in cluster developments.

Stormwater Utility Policy and Stormwater Utility Fee Ordinance

Holyoke's Stormwater Utility Policy allows the city to levy fees on real property to pay for management of stormwater runoff generated by those properties. The city can leverage this Stormwater Utility Fee to encourage property owners to reduce stormwater generation on their properties in exchange for lowered costs. Holyoke can set up a system of credits that property owners earn by completing runoff reduction projects, such as reduction in pervious surfaces and installation of rain gardens and swales. These credits should be valued aggressively to create a meaningful incentive, though this will need to be balanced with the needs of the Stormwater Authority to collect sufficient revenue to function. Stormwater Utility Fees, before application of credits, can be increased to establish this balance.

Stormwater Authority Stormwater Regulations

- Holyoke can make a number of changes to its Stormwater Authority Stormwater Regulations to modernize them and to have them more actively promote mitigation of impervious surfaces. The Regulations should add a definition for "green infrastructure," in addition to "impervious surface" and "low impact development." This will make the regulations consistent with nationwide guidance and improve clarity for property owners installing green infrastructure. In Section 4.02 (a), number xiv (LID) should be moved up to highlight its importance.
- The performance and design standards are broken out by scale. Large developments have both (Section 5.01and 5.02), while small developments only have performance standards (5.03). Sections 5.01 through 5.03 could be re-written if these are proving to be complicated for developers to navigate. If re-written, the City could consider merging the performance standards and design requirements for large developments, or at least listing the design requirements prior to the performance standards to assist the reader. Within the performance standards, rain barrels are mentioned but they do not provide credit for the stormwater utility fee. This should either be mentioned in the texted or change to provide credit.

Zoning Ordinance

Holyoke's Zoning Ordinances apply to all new development and redevelopment projects, with exceptions. They control the extent of a parcel that can be covered in impervious surfaces, the amount of parking required for a given structure, and more. A number of changes to zoning ordinances can be made to reduce impervious surfaces.

The zoning ordinances have been continually updated over time, creating a situation where some sections are recent and up-to-date, while others are out of date and do not fully incorporate more recent changes. Updating older sections of the ordinances, or performing an update of the entire ordinance at once, will improve consistency and enforceability. Additionally, adding definitions of lot coverage, land coverage, and building coverage will help improve consistency and enforcement of maximum and minimum coverage requirements.

Revisiting parking requirements for buildings may allow the city to identify locations where minimum requirements can be lowered, or where limits on maximum parking amounts can be imposed. One approach to lowering parking requirements is to revise parking minimums to be based on net floor space (the actual floor space of a building) rather than gross floor space (calculated in a way that includes structural elements and unusable or inaccessible spaces). Calculating parking minimums based on usable and functional floor space (which removes circulation space, such as hallways, from the floor space calculation) can reduce parking requirements further. Holyoke can also simply lower parking requirements overall, or eliminate them entirely, as was done in Hartford CT in 2017.

Holyoke can explore tying impervious cover requirements to uses rather than zones. The city can also review building cover maximums by zone to determine whether lowering those maximums is feasible (The BE Zone is also a good candidate for analysist to see if lots are hitting this maximum building coverage, or if this maximum can be lowered.

7.2 Development Review Process

Without a straightforward and policy-driven development review process, developers are unlikely to take advantage of incentives offered to them. Amending the zoning code to make it clear and consistent throughout will save city staff and developers time and money, and improve outcomes for all parties. Beyond those basic changes, Holyoke should go further to lessen the time to review application and reward projects that contribute to the City's goals of reducing and mitigating impervious surfaces.

The EcoInnovation District in Pittsburgh is an excellent example of combining incentives and efficiency. By establishing a way for developers to implement green infrastructure in exchange for attractive design standard bonuses such as an increase in maximum height or lot coverage, staff can determine when to award the bonuses. With this system, developers can forgo the special permit or special exception process, and the city can have more mitigation measures installed on private property. This type of system is most effective where there is opportunity for large development and investments, such as high density residential, commercial, and industrial zones. In combination with LID standards, a bonus system can reasonably push the maximum impervious coverage lower in the applicable zones. This give and take benefits both parties.

For smaller scale and less dense residential development, the city could implement a tradeoff system like in New Rochelle, where developers can increase impervious surface if they plant a corresponding amount of shade trees. While much simpler, this too reduces the amount of time boards, commissions, and staff are reviewing applications.

7.3 Public Works Projects

Holyoke should incorporate impervious surface mitigation techniques into road reconstruction projects as those projects take place, in accordance with the city's existing road priority list. Additionally, it is recommended that the city consider impervious surface mitigation and the results of this report's analysis when updating the road priority list in the future.

Another opportunity for implementation of impervious surface mitigation into the city's infrastructure is presented by the ongoing system-wide improvements to the city's drinking water infrastructure. Holyoke has plans to replace over three miles of piping over the next year; the city can capitalize on the road disturbance and reconstruction that this will entail to incorporate mitigation measures.

Impervious surface mitigation approaches appropriate to Holyoke Streets may include installation of tree wells and trenches, sidewalk planters, bioretention basins and infiltration swales, and road diets. In some cases, construction of underground storage systems may be feasible. Utilization of permeable pavers may be beneficial in select locations, depending on underground infrastructure, soil characteristics, and depth to the groundwater table. All of these techniques are described in more detail, including some recommended locations for implementation, in the 2014 Green Streets Guidebook.

7.4 Dimensional & Design Standards

Changes to design standards within the zoning code can reduce the amount of impervious surface in new developments. Based on the findings of this report, the City should review dimensional requirements of the zoning districts in the most impacted neighborhoods in order to identify opportunities to reduce lot coverages. For example, the Downtown Business zone may present an opportunity to reduce imperviousness while still meeting the needs of the businesses and development community.

In addition to including the following definition of impervious coverage in the code, the schedule below should also be considered to replace the existing maximum building coverage column. This revision will also reduce the confusion regarding the Downtown Residential zone calculation.

Impervious Surface Coverage - The percentage of the total Lot occupied by Structures, Roads, Parking Areas, and other impermeable construction materials.

Table 7-1: Possible New Dimension Requirements

Zone	District	Maximum % Impervious Surface Coverage
Agriculture & Family Residence	RA	20%
Single Family Residence	R-1	30%
Single Family Residence	R-1A	35%
Two Family Residence	R-2	40%
Multi Family Residence (20 units/acre)	RM-20	40%
Multi Family Residence (40 units/acre)	RM-40	50%
Multi Family Residence (60 units/acre)	RM-60	60%
Multi Family Residence & Professional Office	RO	50%
Limited Business	BL	55%
Downtown Business	BC	75%
General Business	BG	55%
Highway Business	BH	55%
General Industry	IG	65%
Industrial Park	IP	40%
Downtown Residential	DR	60%
Shopping Center	SC	55%
Waste Management	WM	60%

The zoning code should be amended to remove the parking minimums and introduce parking maximums in appropriate zones and for certain uses. Appropriate zones include those with ample public parking, transit, and/or active transportation infrastructure.

Parking requirements for each use should be studied and, where necessary, amended to better reflect the needs of each. This especially applies to commercial uses. For many commercial uses, the parking minimums are calculated using gross floor area, which ends up driving up parking requirements by including all the ''unhabitable" spaces like stairways, hallways, and mechanical closets. By changing this calculation, where appropriate, the amount of impervious surface used for parking can be reduced.

The zoning code can also be used to reduce heat islands and improve rainwater retention in parking lots by adding more LID requirements to the parking standards. LID requirements may address the number and types of plants required as part of vegetated strips and tree islands, the use of permeable pavers, installation of solar covers, and construction of raingardens and bioswales.

The code should also incorporate a provision for shared parking. This would allow multiple uses with different hours of operation to count each-other's parking toward any remaining minimum parking requirements. Not only would this encourage a "park once and walk" environment but it would also assist properties that are changing use. Shared parking provisions can apply to any zone but will yield the most benefit in developed areas and areas ripe for redevelopment. If the city has not done so, a parking study of the Downtown and business districts should be undertaken to determine capacity, surplus (if any), peak hours, and complementary uses.

A more in-depth change would involve developing more fine-tuned metrics by which to estimate the amount of parking actually required for each use type. Rather than basing parking requirements on flood space, they could be based on maximum occupant capacities, number of chairs or tables, number of vendor booths, or other metrics relevant to different types of uses. For example, parking requirements for restaurants could be changed from a parking minimum of 1 space for each 40 square feet of gross floor space to a parking maximum of 3 spaces for every 5 persons based on maximum capacity. A change of this nature will likely reduce impervious surface by much more and would modernize the code. Other examples of changes to commercial uses are included in Table 7-2, below.

If a developer must exceed the maximum parking requirements, the code should also specify that they can take steps to mitigate the impacts of impervious surfaces on their property through LID measures, or they can make a payment in lieu of seeking a special permit or exception. Fees could be put into a fund to mitigate the impacts of impervious surfaces throughout the city.

Table 7-2: Possible New Parking Maximums

Use	Maximum allowable parking spaces
C. COMMERCIAL USES	
3. Animal clinic or hospital; kennel	**5** spaces per cage or kennel
9. Retail stores & services not elsewhere set forth	**3** spaces per 1,000 square foot of net floor area devoted to customer service
11. Personal service establishment	**2** spaces per client chair or table
12. Motor vehicle, trailer, or boat sales and rental	**1.5** spaces for every 400 square feet of net floor area devoted to customer service
17. Restaurant, fast-food, or drive-in	**3** spaces for every 5 persons based on maximum capacity
18. Business or professional office; bank, financial agency, or institution	**1.5** spaces for each 300 square feet of net floor area devoted to customer service
20. Medical office building, clinic, or testing laboratory	**2** spaces per bed (excluding bassinets)
23. Indoor commercial recreation	**1.5** for each 150 square feet of net floor area devoted to customer service
24. Arcade	**5** spaces per gaming console
27. Membership club, civic, social, professional, or fraternal organization	**1.5** spaces for each 60 square feet of net floor space
31. Flea market	**2.5** per vendor stall

To review and change parking ordinances, the Urban Land Institute (Smith, 2020) recommends the following steps:

1. Determine general development characteristics (land uses employment densities, modes of travel, parking fees etc.)
2. Review parking experience elsewhere (relevant literature and case studies)
3. Survey the parking generation of existing uses
4. Establish parking policy
5. Develop zoning requirements
6. Monitor parking standards

There are many approaches to lowering parking requirements, all of which could contribute not only to reduction in impervious surface coverage, but also to improving the fabric of Holyoke by making it more pedestrian-focused and vibrant, and by enabling the exchange of parking spaces for uses with more economic utility. Revisiting the city's design standards, or adopting new standards, in order to reduce parking specifically, or to reduce impervious coverage more generally, can help Holyoke achieve its goals.

7.5 Summary

Holyoke should consider drafting and adopting specific LID regulations in the Downtown Business, General Industrial, and Highway Business zones. Over time, these regulations should be adapted and applied to additional districts as appropriate. By targeting these zones, Holyoke will feel a greater benefit and can pilot new ideas.

Zoning Regulations should include a "bonus system" to incentivize and reward developers for using LID in their projects. Not only will this encourage the creation of more green infrastructure on private property but it will also speed the review process.

In addition to making these changes, Holyoke should continue to take the lead and seek to guide the development community, educating them on when and where to use these new tools, and why they benefit the city and the developers' bottom line.

8 IMPLEMENTATION PLAN

8.1 ACTION MATRIX

Action	Responsible Party	Potential Partners	Timeline
Capital Improvement Actions			
Implement the "Green Streets Vision" proposed in the 2014 Green Streets Guidebook for High Street, Division Street, Suffolk Street, and Appleton Street. (This document includes recommendations about operations and maintenance planning, including developing a Green Infrastructure O&M plan, and acquiring a vacuum street cleaner to maintain permeable surfaces).	DPW	DCS	Near-Term
Implement Actions in the 2019 Open Space and Recreation Plan, especially those associated with Objective 4A: Use green infrastructure to infiltrate stormwater and enhance urban landscape.	DCS	DPW P&R	Near-Term
Install either planters of swales in the median on the municipal section of street leading to the Holyoke Mall	DPW	Holyoke Mall	Near-Term
Reduce imperviousness and implement other measures described in this report as roads come up for reconstruction, as per the Holyoke Pavement Management Summary (last updated January 2020). Prioritize the following roads in need of rehabilitation located in high-priority areas: • High Street from Appleton Street to Lyman Street • High Street from Resnic Boulevard to Cabot Street • Avon Place • Worcester Place • South Street from Davis to Chapin • Davis Street from South to South Elm • Stebbins Street • Isabella Street	DPW		Immediate
Create recreational open space access in forested area northwest of Whitney Ave	P&R	Holyoke Mall DCS	Med Term
Convert War Memorial Parking on Chestnut St to open space / park	DCS	P&R DPW SMC	Med Term
William S Taupier Municipal Parking Garage: Install solar panels above parking spaces on top floor	DPW	DCS	Med Term
William S Taupier Municipal Parking Garage: Add levels to increase capacity & reduce parking needs elsewhere	DPW	GHCC	Long Term
Convert Heritage Street between garage and Heritage Park to pedestrian area and improve access to park from garage	DPW	DCS P&R	Long Term
Create community parks and gardens in high need neighborhoods	P&R	DPW DCS OPED	Med Term

Action	Responsible Party	Potential Partners	Timeline
Implement recommendations from the updated Long-Term CSO Control Plan	DPW		Long Term
Policy Actions			
Amend zoning definition to incorporate green infrastructure terminology	OPED	BD	Near-Term
Amend zoning design standards to incorporate maximum lot coverage	OPED	BD	Near-Term
Amend zoning to incorporate developer incentives for green infrastructure. (i.e. Pittsburg, PA "EcoInnovation District" or New Rochelle, NY). Consider a trade-off calculation or point system for impervious surface development and/or mitigation strategies.	OPED	BD	Near-Term
Amend zoning to include shared parking provisions	OPED	BD GCC	Near-Term
Amend zoning to incorporate parking maximums	OPED	BD GCC	Near-Term
Amend the Holyoke Stormwater Authority Stormwater Regulations to include definitions for "green infrastructure," "impervious surface," and "low impact development," and move up the LID section in Section 4.02(a)	DPW	OPED	Near-Term
Amend the Holyoke Stormwater Authority Stormwater Regulations to clarify performance and design standards and credits	DPW	OPED	Near-Term
Increase incentives for use stormwater utility fee credits and adjust stormwater utility fees accordingly	DPW	OPED	Near-Term
Develop community tree planting program focusing on hotspots and target neighborhoods: • Commercial Street from Jackson to Cabot • Maple Street from Jackson to Hampshire • Elm Street from Appleton to Hampden • Chestnut Street from Appleton to Hampden • Maple Street from Appleton to Lyman • Appleton Street from Nick Cosmos Way to Walnut • Lyman Street from High to Chestnut • High Street from Dwight to Lyman • Hampden Street from Maple to Chestnut	DCS	BOH P&R DPW	Immediate
Key			
BD: Building Department **BOH:** Board of Health **DCS:** Department of Conservation & Sustainability **DPW:** Department of Public Works **GHCC:** Greater Holyoke Chamber of Commerce **HPS:** Holyoke Public Schools **OCD:** Office of Community Development **OPED:** Office of Planning & Economic Development **P&R:** Parks and Recreation **SMC:** Soldiers' Memorial Commission	**Immediate:** Complete by 2025 **Near Term:** Complete by 2030 **Med Term:** Complete by 2050 **Long Term:** Complete by 2100		

8.2 Funding Sources

There are many financial resources that can be used to fund impervious surface mitigation projects.

8.2.1 Potential City Funding Programs

Capital Improvement Project Budgets: green infrastructure installation and maintenance are valid expenditures of large road, utility, or facility improvement projects. Green infrastructure can be included as a part of right-of-way improvement projects.

Stormwater Utility Fees: Stormwater fees are assessed to all property owners, including those that would be exempt from taxes.

Permit and Inspection Fees: To the extent permitted under state and municipal codes, permit and inspection fees can be a significant source of funding. A stormwater mitigation program could be reimbursed for the administrative time to review development permits applications, review plans, and make site inspections.

Compensatory Payment, Land Development Mitigation, and Environmental Fines: When trees, other natural resources, and existing green infrastructure are damaged or removed (whether by an accident or a planned economic development project), municipalities should be compensated. Generally, this requirement and the compensation method should be codified, and should be clear about its applicability. Many cities across the U.S. have ordinances that stipulate this, and as a result have funds where compensatory payments, mitigation, or "in lieu of" fees and environmental fines are deposited for a variety of uses and management projects.

8.2.2 Grants

Sources for grants include the US Department of Agriculture's Urban & Community Forestry Challenge Cost Share Grants, US Department of Transportation's grant program, US Department of Housing and Urban Development's Community Development Block Grant, The Foundation Center, and the Alliance for Community Trees. Additionally, U. S. EPA's Urban Waters Small Grants, Environmental Justice and 319 grants. Mass.gov hosts a list of community grants at https://www.mass.gov/lists/community-grant-finder. The business community and private foundations can be a potential source of funding. Foundationcenter.org maintains a list of private funding sources. A list of potential funding sources is provided in Table 8-1.Massachusetts provides the MVP Action Grant program which offers financial resources to municipalities that are seeking to advance priority climate adaptation actions to address climate change impacts resulting from extreme weather, sea level rise, inland and coastal flooding, severe heat, and other climate impacts.

Table 8-1: Possible Funding Sources

Grant Name	Source	Eligibility	Project Description	Project Size	Match	Website
MVP Action Grant	MA DCR	Municipalities	Nature-based Solutions for Ecological and Public Health; Resilient Redesigns and Retrofits	Annual, $25,000 - $2M	25%	https://www.mass.gov/service-details/mv

Grant Name	Source	Eligibility	Project Description	Project Size	Match	Website
			for Critical Facilities and Infrastructure			p-action-grant
Community Forest Grant Program	MA DCR	Local governments, qualified nonprofit organizations	To acquire and establish community forests that provide community benefits. including economic benefits through active forest management, clean water, wildlife habitat, educational opportunities, and public access for recreation.	Annual, > $600,000	50%	https://www.mass.gov/guides/community-forest-grant-program#-application-informatio n-
Urban and Community Forestry Challenge Grants	MA DCR	Municipalities and nonprofit groups	Projects that develop, strengthen, or sustain citizen groups or nonprofit organizations that advocate and/or act to promote excellent urban and community forestry management.	Annual, Varies	50%, 25% in EJ	https://www.mass.gov/guides/urban-and-community-forestry-challenge-grants
TD Green Space Grants	TD Bank	Municipalities	Support green infrastructure development, tree planting, forestry stewardship, and community green space expansion as a way to advance environmental and economic benefits toward a low-carbon economy.	Annual, > $20,000	N/A	https://www.arborday.org/programs/TDGreenSpaceGrants/
Urban Waters Small Grants	US EPA	States, local governments, Indian Tribes, Universities, and colleges, public or private nonprofit institutions/ organizations, intertribal	Address local water quality issues related to urban runoff pollution; Provide additional community benefits; Actively engage underserved communities; and Foster partnership.	Every 2 years, > $60,000		https://www.epa.gov/urbanwaters/urban-waters-small-grants

Grant Name	Source	Eligibility	Project Description	Project Size	Match	Website
		consortia, and interstate agencies				
319 Grant Program for States and Territories	US EPA	States, territories, and tribes	Technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source implementation projects.	Varies		https://www.epa.gov/nps/319-grant-program-states-and-territories
Five Star and Urban Waters Restoration Grant Program	National Fish and Wildlife Foundation	Non-profit organizations, state government agencies, local governments, municipal governments, Indian tribes, and educational institutions.	Address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development.	Annual, $20,000 - $50,000	100%	https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program/five-star-and-urban-waters

8.2.3 Non-Profit Partners

The Nature Conservancy (TNC) in Massachusetts regularly seeks to support a variety of projects that achieve environmental restoration and conservation goals. TNC provided matching funds to the City of Holyoke to complete an impervious surfaces mapping project as part of the city's ongoing efforts to mitigate the impacts of those surfaces. The city should continue to monitor grant or grant-matching opportunities from TNC.

8.2.4 Creative Solutions

In addition to city funding and grants, some cities have created innovative programs to support tree planting. The Chicago Park District has a Green Deed Tree Dedication Program. This program allows donors to select the type of tree planted and planting location. Once planted, donors receive a certificate detailing the person or event being honored, the tree type planted, and the location. The Green Deed Tree Dedication Program has proven to be an innovative way of planting additional trees as part of the Chicago Trees Initiative. Other potential sources could include Adopt-A-Street programs, wood product sales, utility bill donations, community or organizational fund-raising events, revenues from municipally-owned concessions and recreational facilities, and cash and in-kind donations.

Through a series of partnerships lead by the non-profit Urban Resources Initiative (URI), the City of New Haven has program to install bioswales and street trees while training and employing high school students and formerly incarcerated people at little cost to the city. Since 2007 this program has planted nearly 30,000 trees and installed over 210 bioswales. URI coordinates not only the work crews, sites, and materials, but also the finding which is often a mixture of public grants and private donations.

8.3 Alignment with Other Plans

The 2019 Open Space and Recreation Plan (OSRP) details the city's goals for through 2025. Their objectives include preserving surfaces and groundwater, and using green infrastructure to infiltrate stormwater and enhance the urban landscape. The actions documented in the OSRP inform and are supported by the actions listed here. This document further the efforts of the City and contributes to overall vision of sustainability.

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Appendix A

Massachusetts Climate Change Projections

MILONE & MACBROOM

Appendix B

EcoInnovation District Point System Selection

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Appendix C

Review of Data Sources

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Appendix D

Water Quality and Overall Prioritization Results with Completed Sewer Separation

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Appendix E

One Hundred Top-Priority Grid-Cells

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Appendix F

Focus Area Factsheets

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Appendix G

Public Survey Report

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