From Water Quality to Climate Resilience:
Leveraging the Benefits of Widespread Green Infrastructure in Boston

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Boston Water and Sewer Commission

Agenda

- Introductions
- Boston Water and Sewer Commission Overview
- Boston Green Infrastructure Partners
- Boston Green Infrastructure Resources
- Boston Green Infrastructure Handbook
- Six Key Drivers for GI Implementation in Boston
- Discussion: Widespread Green Infrastructure in Boston

Boston Water and Sewer Commission (BWSC)

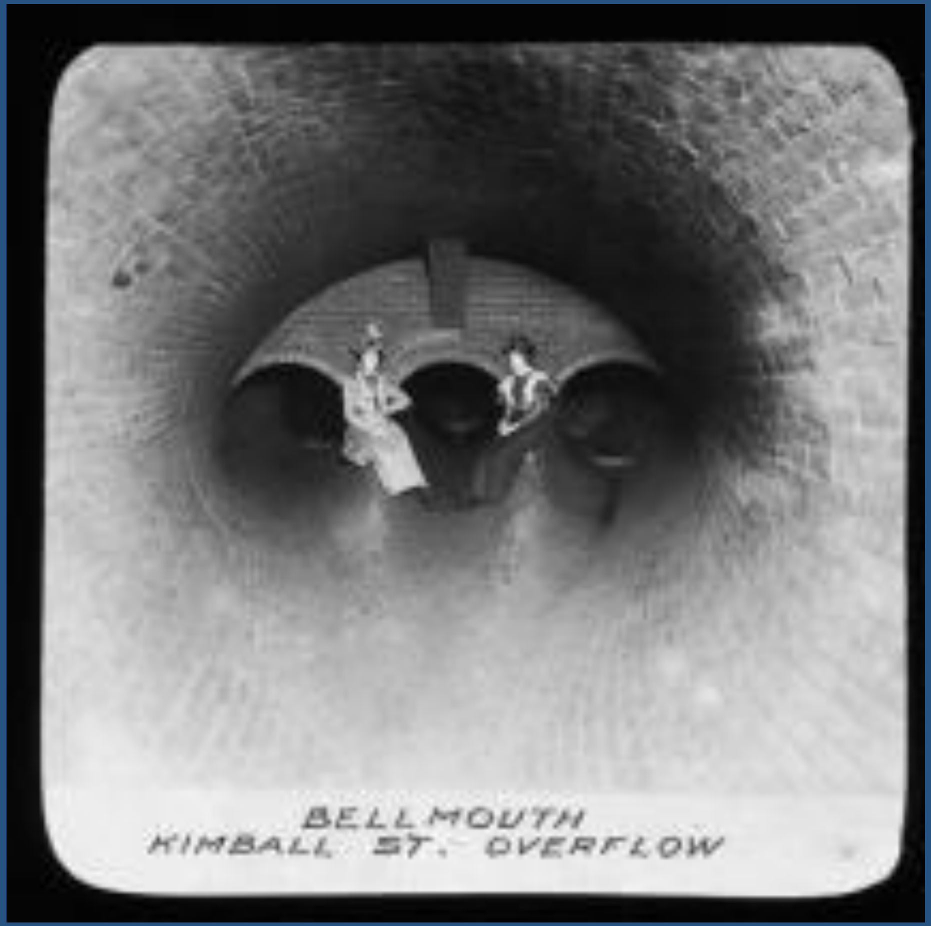
Overview and Initiatives

The Boston Water and Sewer Commission (BWSC) manages the largest and oldest water and sewer system in New England, providing drinking water and sewer services to more than one million people daily

BWSC currently maintains a system including 30,381 catch basins, 50,785 manholes, 142 miles of combined sewer, 709 miles of sanitary sewer, and 664 miles of storm drain

BWSC is subject to state, federal and local regulations, policies and guidelines pertaining to the water, sewer, and storm drain systems, including:

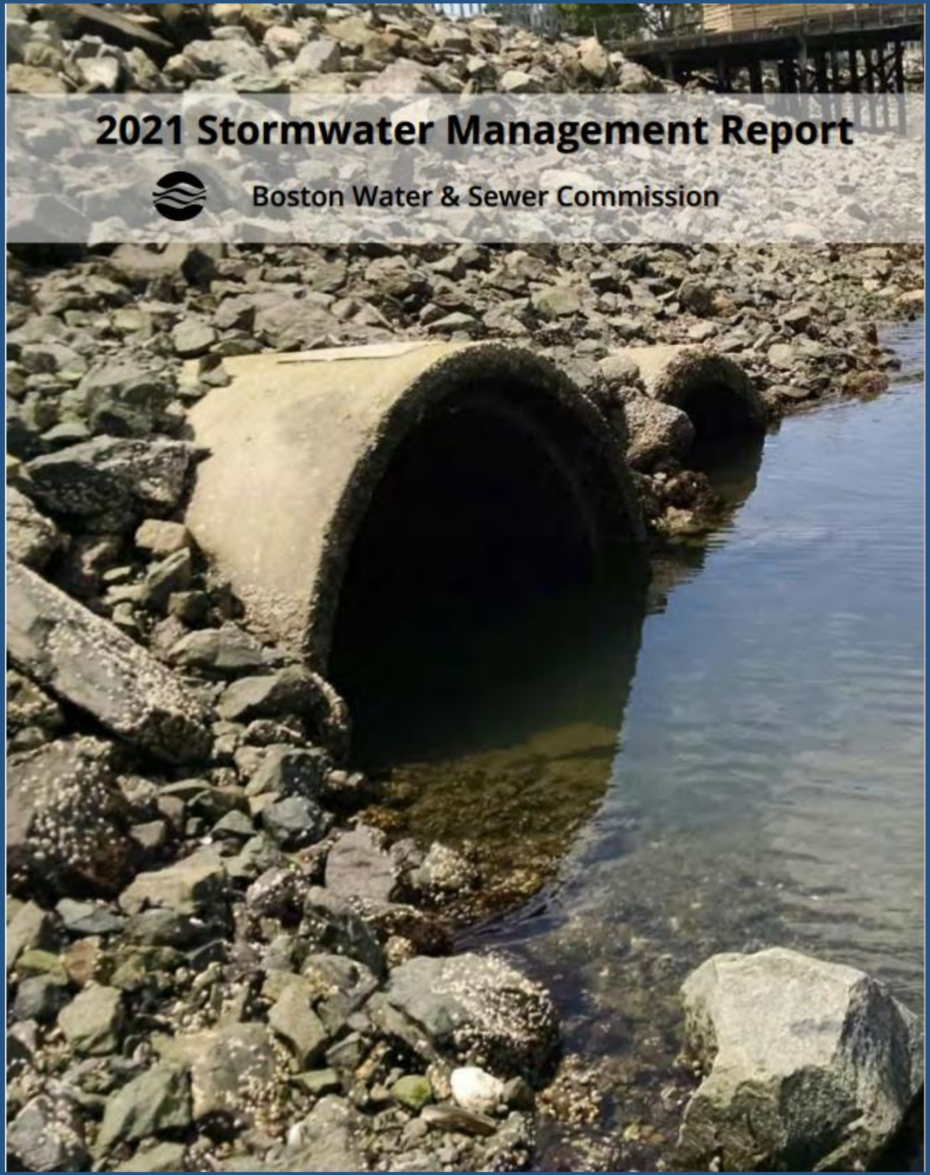
- NPDES MS4 Permit
- Consent Decree Obligations
- Municipal Discharge Permit

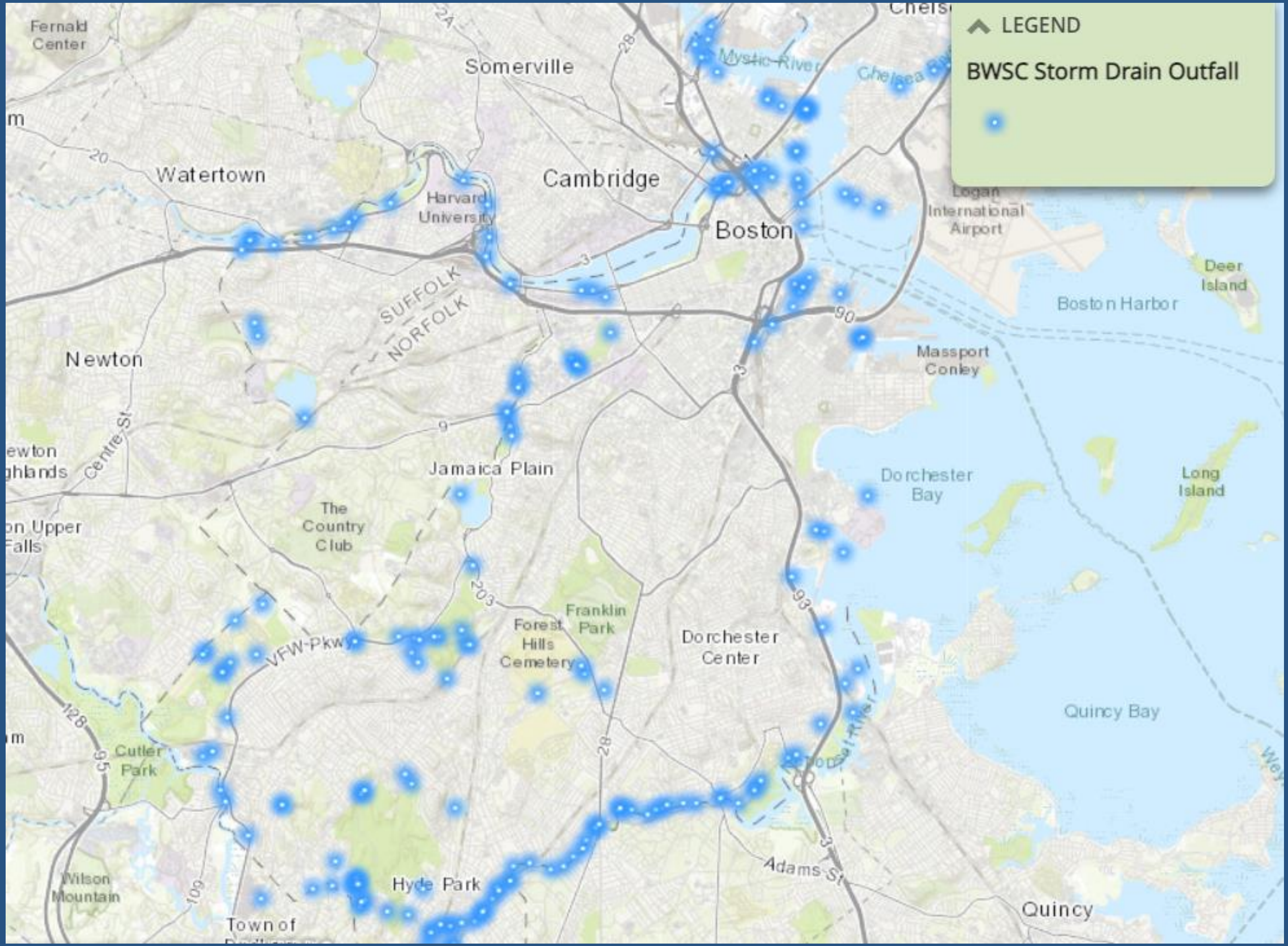


Boston Water and Sewer Commission

Boston Green Infrastructure Demonstration Projects

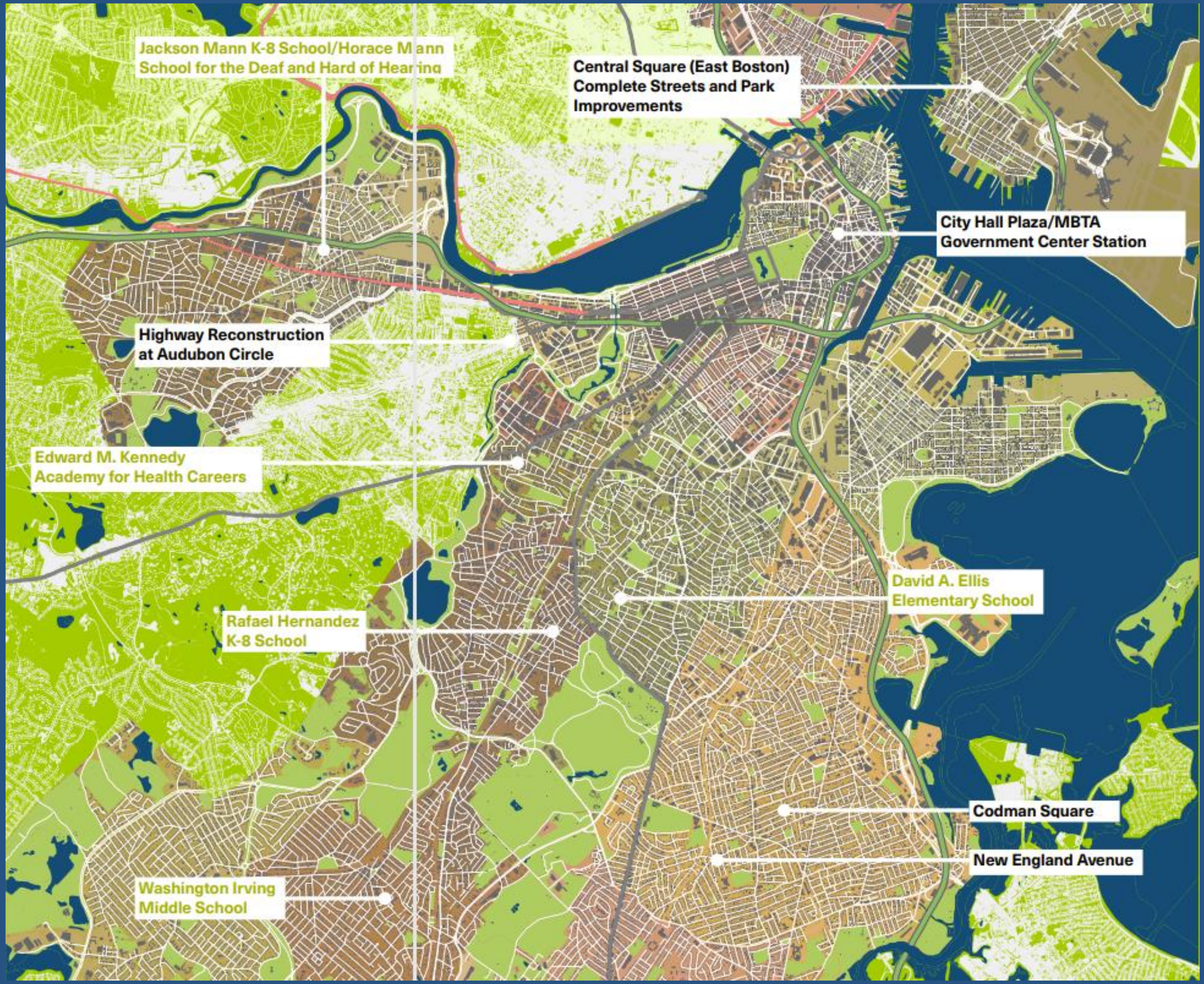
Green Infrastructure is a critical part of the multi-pronged approach to meet the requirements established by the NPDES Stormwater Permit and the obligations of the Consent Decree





Boston Green Infrastructure Demonstration Projects

BWSC has partnered with the City of Boston to install Green Infrastructure practices as part of redevelopment projects at schools, streetscapes, parks, and public open space



MBTA Government Center Station Improvements

Build Boston Public Schools (BPS)

Central Square (East Boston) Complete Streets and Park Improvements

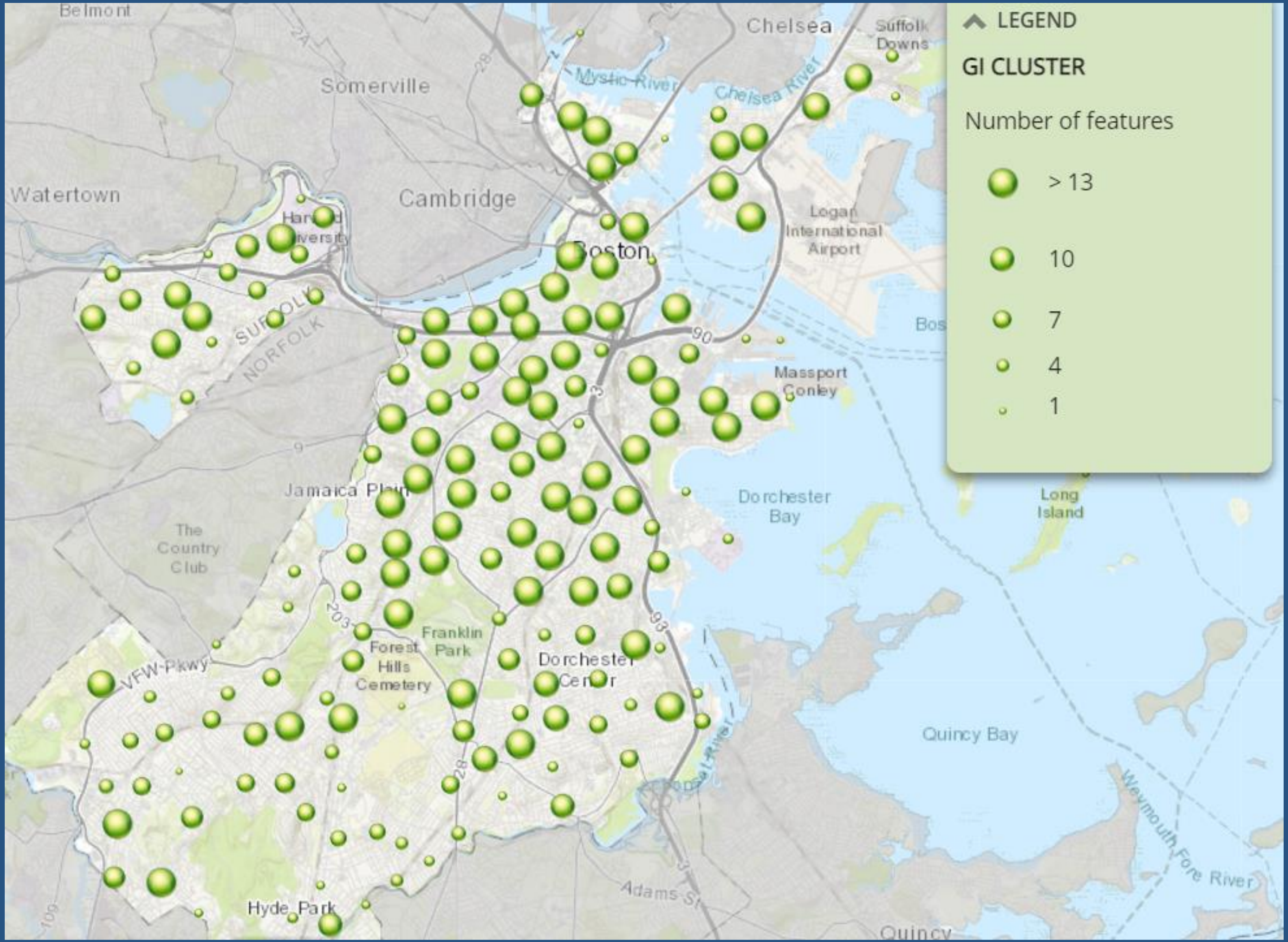
Highway Reconstruction at Audubon Circle

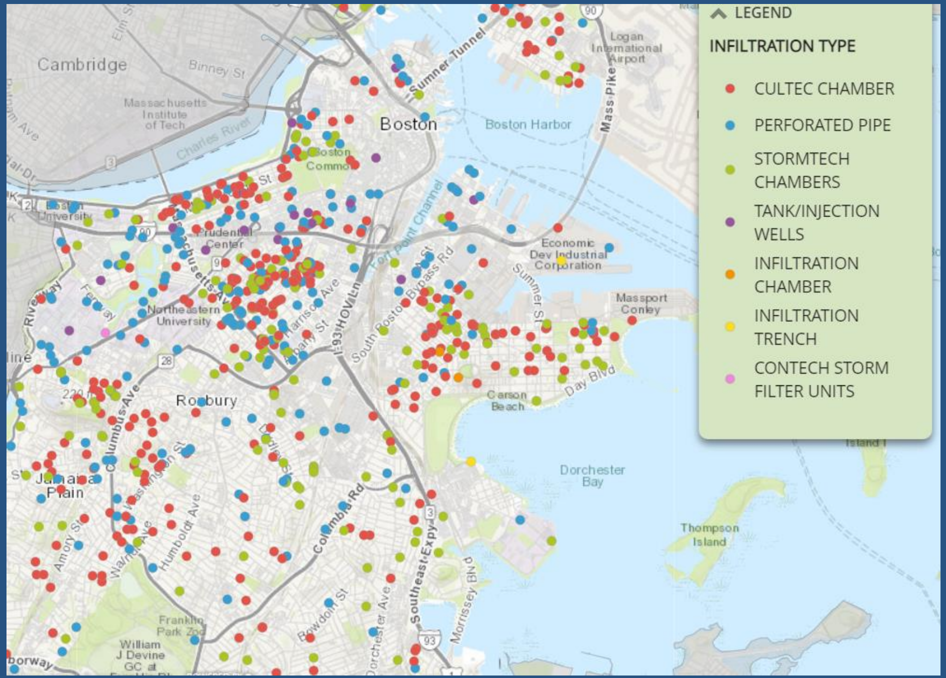
Boston Green Infrastructure Partners

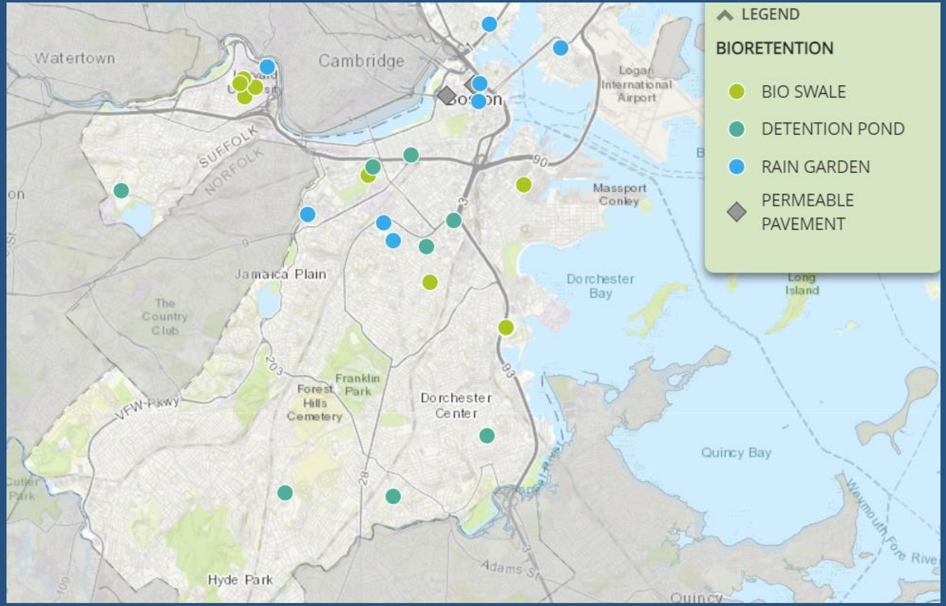
- Boston Transportation Department (BTD)
- Boston Public Works Department (BPWD)
- Boston Environment Department
- Boston Parks and Recreation Department
- Boston Planning and Development Agency (BPDA)
- Boston Public Schools
- Public/Private Universities
- Massachusetts Bay Transportation Authority
- Watershed Groups
- Not-for-Profits
- Neighborhood Groups
- Private Developers

Audubon Circle, Boston

Boston Green Infrastructure Implementation Progress







Boston Green Infrastructure Resources

Boston Water and Sewer Commission Green Infrastructure Planning & Design Handbook

The BWSC Green Infrastructure Planning and Design Handbook provides an in-depth explanation of the terms and tools within green infrastructure.

Boston Parks and Recreation Department Green Stormwater Infrastructure Design & Implementation Guide

Boston Parks and Recreation Department green infrastructure guide for use in Parks projects.

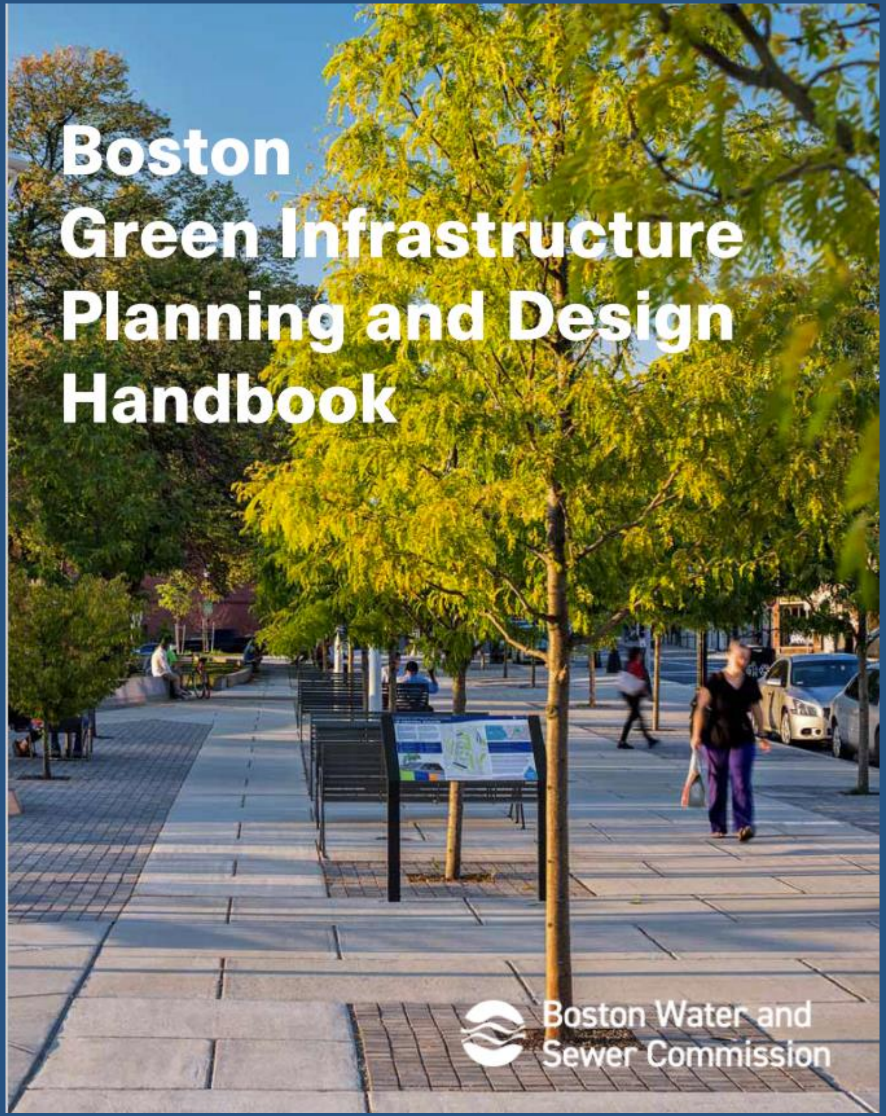
Boston Complete Streets Design Guidelines

The Boston Transportation Department created Boston Complete Streets Design Guidelines.

https://www.boston.gov/streets-and-sanitation/green-infrastructure

Boston Green Infrastructure Handbook (BWSC)

The Green Infrastructure Planning and Design Handbook serves as a guide for both public and private property owners to implement GI techniques to manage stormwater throughout Boston



Chapter 1 Introduction

1.1 The Challenges of Urban Stormwater Runoff
1.2 Green Infrastructure Stormwater Management Benefits
1.3 Co-Benefits of Green Infrastructure

Chapter 2 The Boston Context

2.1 The Boston Water and Sewer Commission (BWSC)
2.2 Key Drivers for Green Infrastructure Implementation in Boston
2.3 BWSC Demonstration Projects

Chapter 3 Design Guidelines

3.1 Research & Site Analysis
3.2 Green Infrastructure Design
3.3 System Sizing

Chapter 4 Toolkit

4.1 Infiltration Practices
4.2 Bioretention Techniques
4.3 Permeable Pavements
4.4 Rooftop Storage

https://www.boston.gov/sites/default/files/file/2022/09/BWSC%20Green%20Infrastructure%20Handbook-02-07-2022.pdf

Boston Green Infrastructure Handbook (BWSC)

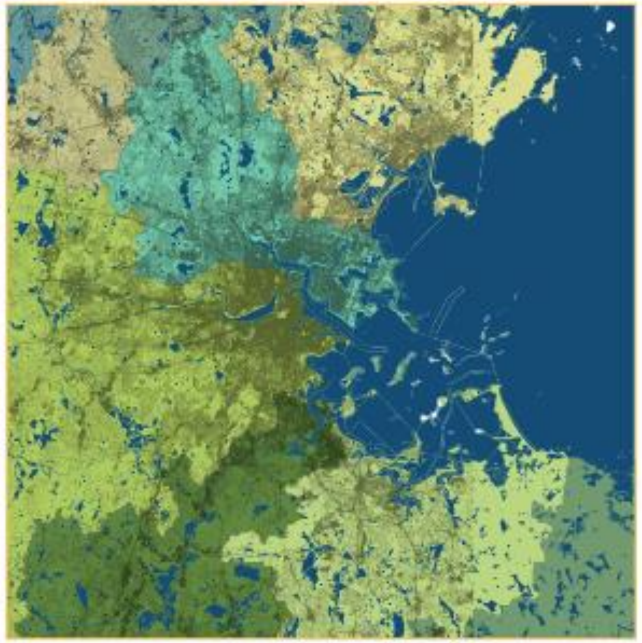
Chapter 1 introduces the benefits and co-benefits of Green Infrastructure

Stormwater Benefits
- Peak Rate Mitigation
- Volume Reduction
- Water Quality Treatment

Co-Benefits
- Heat Island Mitigation
- Improved Air Quality
- Reduced Energy Costs
- Carbon Sequestration
- Habitat Improvement
- Increased Property Values
- Community Engagement
- Job Creation

Boston Green Infrastructure Handbook (BWSC)

Chapter 2 highlights six key drivers for Green Infrastructure implementation in the City of Boston

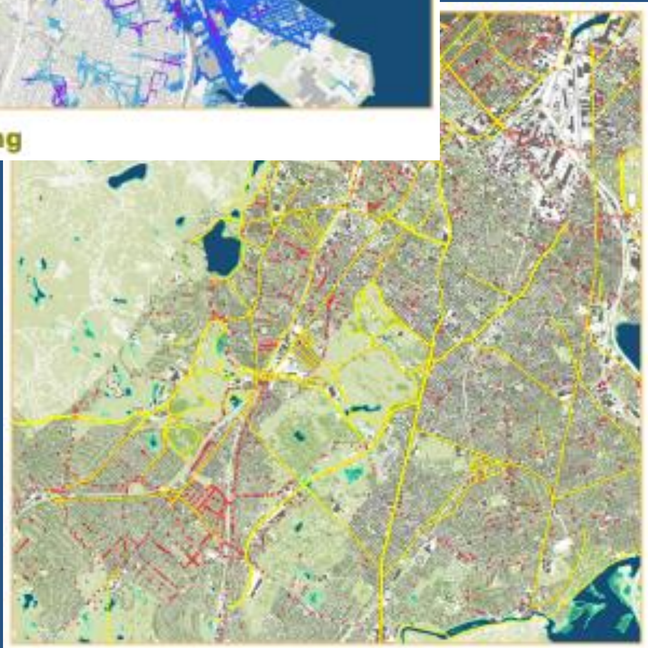

Improving Water Quality


Urban Heat Island


Sea Level Rise


Replenishing Groundwater


Inland Flooding


Habitat and Transportation Connectivity

Boston Green Infrastructure Handbook (BWSC)

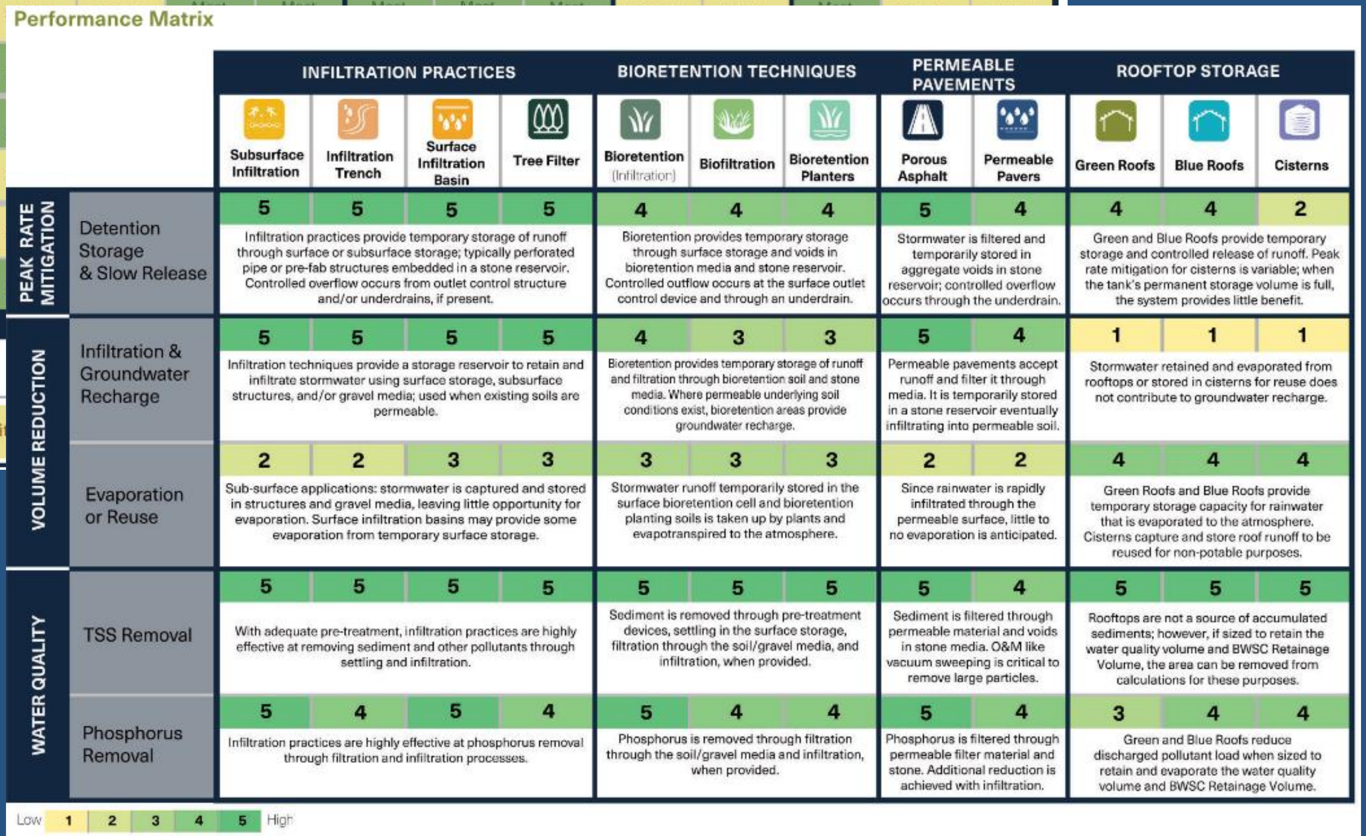
Chapter 3 provides technical guidance for designing Green Infrastructure in Boston

- Research and Collaboration
- Planning and Design Guidelines
- Green Infrastructure Strategies
- Suitability Matrix
- Performance Matrix
- Technical Design Considerations
- O&M Considerations
- System Sizing Recommendations

Suitability Matrix

EXISTING SITE CONDITION	RANGE	INFILTRATION PRACTICES: Subsurface Infiltration	Infiltration Trench	Surface Infiltration Basin	Tree Filter	BIORETENTION TECHNIQUES: Bioretention (infiltration)	Biofiltration	Bioretention Planters	PERMEABLE PAVEMENTS: Porous Asphalt	Permeable Pavers	ROOFTOP STORAGE: Green Roofs	Blue Roofs	Cisterns
Development Density	High Density	Most Suitable	Most Suitable	Suitable	Most Suitable	Suitable	Suitable	Most Suitable	Most Suitable	Most Suitable	Most Suitable	Most Suitable	Most Suitable
	Low Density	Suitable	Suitable	Most Suitable	Suitable	Most Suitable	Most Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Existing Soil Permeability	Low	Suitable	Suitable	Suitable	Most Suitable	Suitable	Most Suitable	Most Suitable	Suitable	Suitable	Most Suitable	Most Suitable	Most Suitable
	High	Most Suitable	Most Suitable	Most Suitable	Suitable	Most Suitable	Suitable	Suitable	Most Suitable	Most Suitable	Suitable	Suitable	Suitable
Microclimate	Full Sun												
	Full Shade												
Slope	Moderate (<6%)												
	Steep (6-10%)												
Treatment Train Location	Overland Flow												
	Piped Inflow												
OTHER CONSIDERATIONS													
Avg. Annual Maintenance Cost													

Suitability: Most Suitable Sui



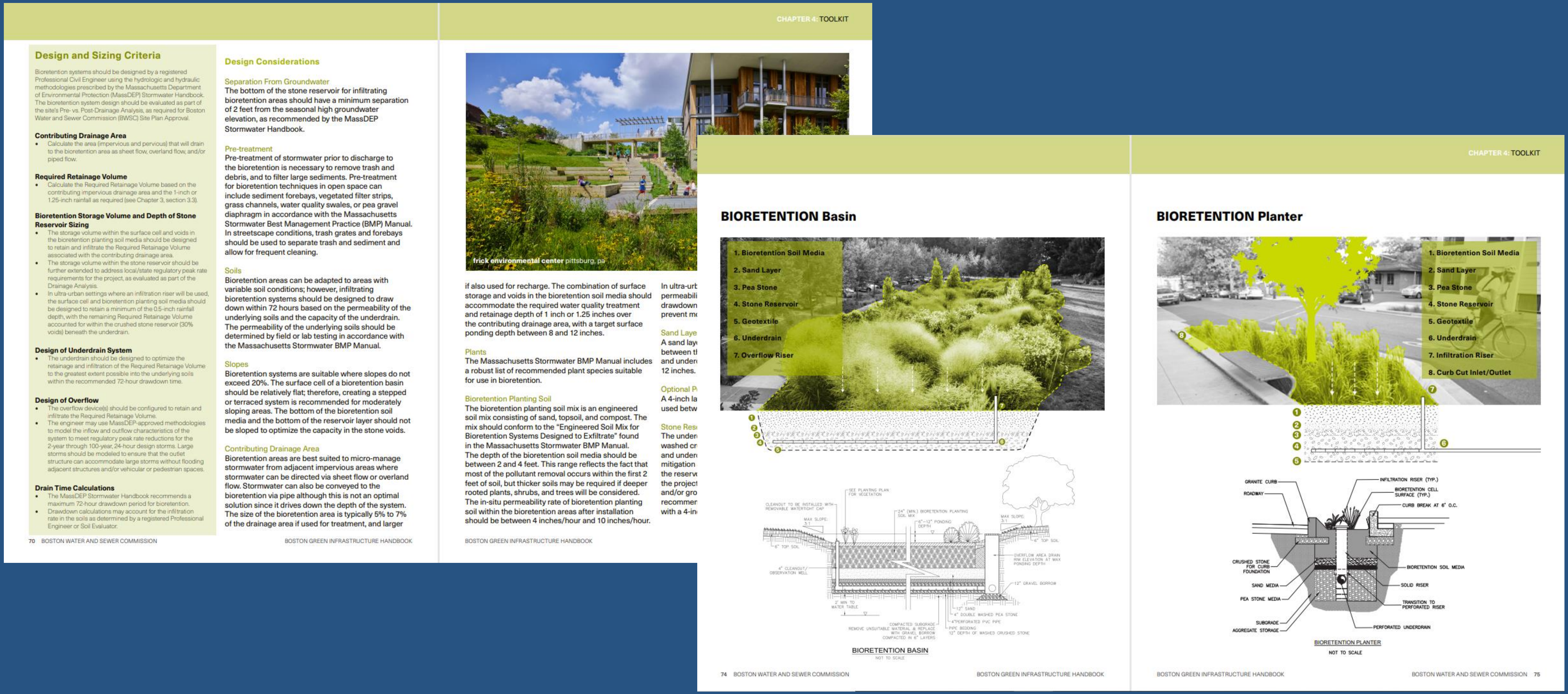
Performance Matrix

		INFILTRATION PRACTICES: Subsurface Infiltration	Infiltration Trench	Surface Infiltration Basin	Tree Filter	BIORETENTION TECHNIQUES: Bioretention (Infiltration)	Biofiltration	Bioretention Planters	PERMEABLE PAVEMENTS: Porous Asphalt	Permeable Pavers	ROOFTOP STORAGE: Green Roofs	Blue Roofs	Cisterns
PEAK RATE MITIGATION	Detention Storage & Slow Release	5	5	5	5	4	4	4	5	4	4	4	2
		Infiltration practices provide temporary storage of runoff through surface or subsurface storage; typically perforated pipe or pre-fab structures embedded in a stone reservoir. Controlled overflow occurs from outlet control structure and/or underdrains, if present.				Bioretention provides temporary storage through surface storage and voids in bioretention media and stone reservoir. Controlled outflow occurs at the surface outlet control device and through an underdrain.			Stormwater is filtered and temporarily stored in aggregate voids in stone reservoir; controlled overflow occurs through the underdrain.		Green and Blue Roofs provide temporary storage and controlled release of runoff. Peak rate mitigation for cisterns is variable; when the tank's permanent storage volume is full, the system provides little benefit.		
VOLUME REDUCTION	Infiltration & Groundwater Recharge	5	5	5	5	4	3	3	5	4	1	1	1
		Infiltration techniques provide a storage reservoir to retain and infiltrate stormwater using surface storage, subsurface structures, and/or gravel media; used when existing soils are permeable.				Bioretention provides temporary storage of runoff and filtration through bioretention soil and stone media. Where permeable underlying soil conditions exist, bioretention areas provide groundwater recharge.			Permeable pavements accept runoff and filter it through media. It is temporarily stored in a stone reservoir eventually infiltrating into permeable soil.		Stormwater retained and evaporated from rooftops or stored in cisterns for reuse does not contribute to groundwater recharge.		
	Evaporation or Reuse	2	2	3	3	3	3	3	2	2	4	4	4
		Sub-surface applications: stormwater is captured and stored in structures and gravel media, leaving little opportunity for evaporation. Surface infiltration basins may provide some evaporation from temporary surface storage.				Stormwater runoff temporarily stored in the surface bioretention cell and bioretention planting soils is taken up by plants and evapotranspired to the atmosphere.			Since rainwater is rapidly infiltrated through the permeable surface, little to no evaporation is anticipated.		Green Roofs and Blue Roofs provide temporary storage capacity for rainwater that is evaporated to the atmosphere. Cisterns capture and store roof runoff to be reused for non-potable purposes.		
WATER QUALITY	TSS Removal	5	5	5	5	5	5	5	5	4	5	5	5
		With adequate pre-treatment, infiltration practices are highly effective at removing sediment and other pollutants through settling and infiltration.				Sediment is removed through pre-treatment devices, settling in the surface storage, filtration through the soil/gravel media, and infiltration, when provided.			Sediment is filtered through permeable material and voids in stone media. O&M like vacuum sweeping is critical to remove large particles.		Rooftops are not a source of accumulated sediments; however, if sized to retain the water quality volume and BWSC Retainage Volume, the area can be removed from calculations for these purposes.		
	Phosphorus Removal	5	4	5	4	5	4	4	5	4	3	4	4
		Infiltration practices are highly effective at phosphorus removal through filtration and infiltration processes.				Phosphorus is removed through filtration through the soil/gravel media and infiltration, when provided.			Phosphorus is filtered through permeable filter material and stone. Additional reduction is achieved with infiltration.		Green and Blue Roofs reduce discharged pollutant load when sized to retain and evaporate the water quality volume and BWSC Retainage Volume.		

Low 1 2 3 4 5 High

Boston Green Infrastructure Handbook (BWSC)

The Green Infrastructure Toolkit is an easy-to-use reference guide for designing green infrastructure



CHAPTER 4: TOOLKIT

Design and Sizing Criteria

Bioretention systems should be designed by a registered Professional Civil Engineer using the hydrologic and hydraulic methodologies prescribed by the Massachusetts Department of Environmental Protection (MassDEP) Stormwater Handbook. The bioretention system design should be evaluated as part of the site's Pre- vs. Post-Drainage Analysis, as required for Boston Water and Sewer Commission (BWSC) Site Plan Approval.

Contributing Drainage Area

- Calculate the area (impervious and pervious) that will drain to the bioretention area as sheet flow, overland flow, and/or piped flow.

Required Retainage Volume

- Calculate the Required Retainage Volume based on the contributing impervious drainage area and the 1-inch or 1.25-inch rainfall as required (see Chapter 3, section 3.3).

Bioretention Storage Volume and Depth of Stone Reservoir Sizing

- The storage volume within the surface cell and voids in the bioretention planting soil media should be designed to retain and infiltrate the Required Retainage Volume associated with the contributing drainage area.
- The storage volume within the stone reservoir should be further extended to address local/state regulatory peak rate requirements for the project, as evaluated as part of the Drainage Analysis.
- In ultra-urban settings where an infiltration riser will be used, the surface cell and bioretention planting soil media should be designed to retain a minimum of the 0.5-inch rainfall depth, with the remaining Required Retainage Volume accounted for within the crushed stone reservoir (30% voids) beneath the underdrain.

Design of Underdrain System

- The underdrain should be designed to optimize the retainage and infiltration of the Required Retainage Volume to the greatest extent possible into the underlying soils within the recommended 72-hour drawdown time.

Design of Overflow

- The overflow device(s) should be configured to retain and infiltrate the Required Retainage Volume.
- The engineer may use MassDEP-approved methodologies to model the inflow and outflow characteristics of the system to meet regulatory peak rate reductions for the 2-year through 100-year, 24-hour design storms. Large storms should be modeled to ensure that the outlet structure can accommodate large storms without flooding adjacent structures and/or vehicular or pedestrian spaces.

Drain Time Calculations

- The MassDEP Stormwater Handbook recommends a maximum 72-hour drawdown period for bioretention.
- Drawdown calculations may account for the infiltration rate in the soils as determined by a registered Professional Engineer or Soil Evaluator.

Design Considerations

Separation From Groundwater
The bottom of the stone reservoir for infiltrating bioretention areas should have a minimum separation of 2 feet from the seasonal high groundwater elevation, as recommended by the MassDEP Stormwater Handbook.

Pre-treatment
Pre-treatment of stormwater prior to discharge to the bioretention is necessary to remove trash and debris, and to filter large sediments. Pre-treatment for bioretention techniques in open space can include sediment forebays, vegetated filter strips, grass channels, water quality swales, or pea gravel diaphragm in accordance with the Massachusetts Stormwater Best Management Practice (BMP) Manual. In streetscape conditions, trash grates and forebays should be used to separate trash and sediment and allow for frequent cleaning.

Soils
Bioretention areas can be adapted to areas with variable soil conditions; however, infiltrating bioretention systems should be designed to draw down within 72 hours based on the permeability of the underlying soils and the capacity of the underdrain. The permeability of the underlying soils should be determined by field or lab testing in accordance with the Massachusetts Stormwater BMP Manual.

Slopes
Bioretention systems are suitable where slopes do not exceed 20%. The surface cell of a bioretention basin should be relatively flat; therefore, creating a stepped or terraced system is recommended for moderately sloping areas. The bottom of the bioretention soil media and the bottom of the reservoir layer should not be sloped to optimize the capacity in the stone voids.

Contributing Drainage Area
Bioretention areas are best suited to micro-manage stormwater from adjacent impervious areas where stormwater can be directed via sheet flow or overland flow. Stormwater can also be conveyed to the bioretention via pipe although this is not an optimal solution since it drives down the depth of the system. The size of the bioretention area is typically 5% to 7% of the drainage area if used for treatment, and larger

frick environmental center pittsburg, pa

if also used for recharge. The combination of surface storage and voids in the bioretention soil media should accommodate the required water quality treatment and retainage depth of 1 inch or 1.25 inches over the contributing drainage area, with a target surface ponding depth between 8 and 12 inches.

Plants
The Massachusetts Stormwater BMP Manual includes a robust list of recommended plant species suitable for use in bioretention.

Bioretention Planting Soil
The bioretention planting soil mix is an engineered soil mix consisting of sand, topsoil, and compost. The mix should conform to the "Engineered Soil Mix for Bioretention Systems Designed to Exfiltrate" found in the Massachusetts Stormwater BMP Manual. The depth of the bioretention soil media should be between 2 and 4 feet. This range reflects the fact that most of the pollutant removal occurs within the first 2 feet of soil, but thicker soils may be required if deeper rooted plants, shrubs, and trees will be considered. The in-situ permeability rate of bioretention planting soil within the bioretention areas after installation should be between 4 inches/hour and 10 inches/hour.

70 BOSTON WATER AND SEWER COMMISSION — BOSTON GREEN INFRASTRUCTURE HANDBOOK — BOSTON GREEN INFRASTRUCTURE HANDBOOK

CHAPTER 4: TOOLKIT

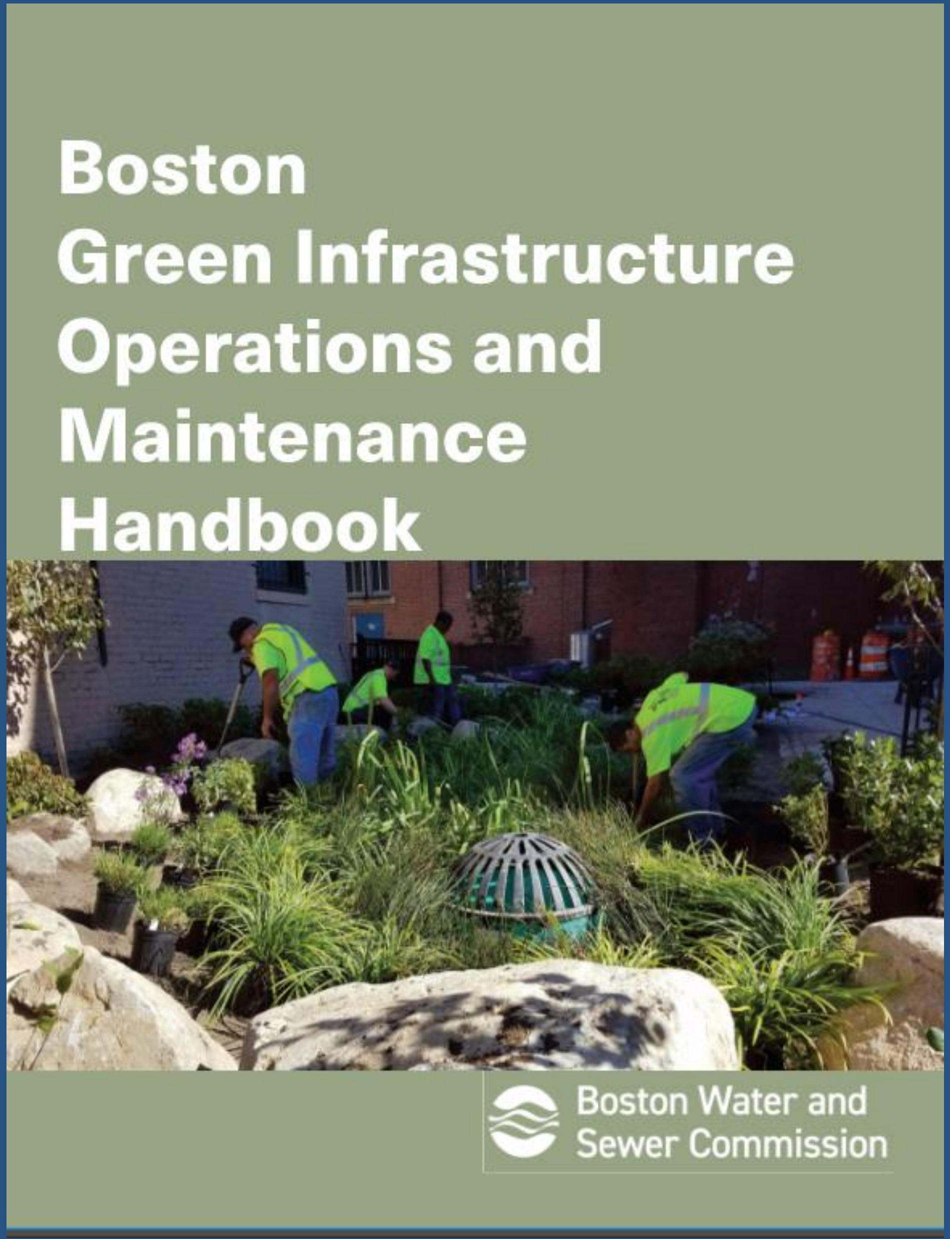
BIORETENTION Basin

BIORETENTION Planter

74 BOSTON WATER AND SEWER COMMISSION — BOSTON GREEN INFRASTRUCTURE HANDBOOK — BOSTON GREEN INFRASTRUCTURE HANDBOOK — BOSTON WATER AND SEWER COMMISSION 75

Boston Green Infrastructure O&M Handbook (BWSC)

Anticipated to be published in 2023



Six Key Drivers for Green Infrastructure in Boston

Water Quality

The Issue:

Urban stormwater runoff discharges sediments and nutrients to local water bodies, leading to water quality impairment

How GI Can Help:

Green infrastructure practices use filtration and infiltration techniques which are highly effective at removing nutrients and other pollutants from stormwater runoff

Algal Blooms in the Charles River

Bioretention Planters and Educational Signage at New England Avenue, Boston

Six Key Drivers for Green Infrastructure in Boston

Inland Flooding

The Issue:

More extreme precipitation events are leading to more frequent and widespread inland flooding

How GI Can Help:

Green infrastructure practices can be optimized to increase retention and detention capacity to alleviate overtaxed storm drain systems

BWSC Flood Inundation Model

Harvard Business School (Recover Green Roofs)

Six Key Drivers for Green Infrastructure in Boston

Sea Level Rise

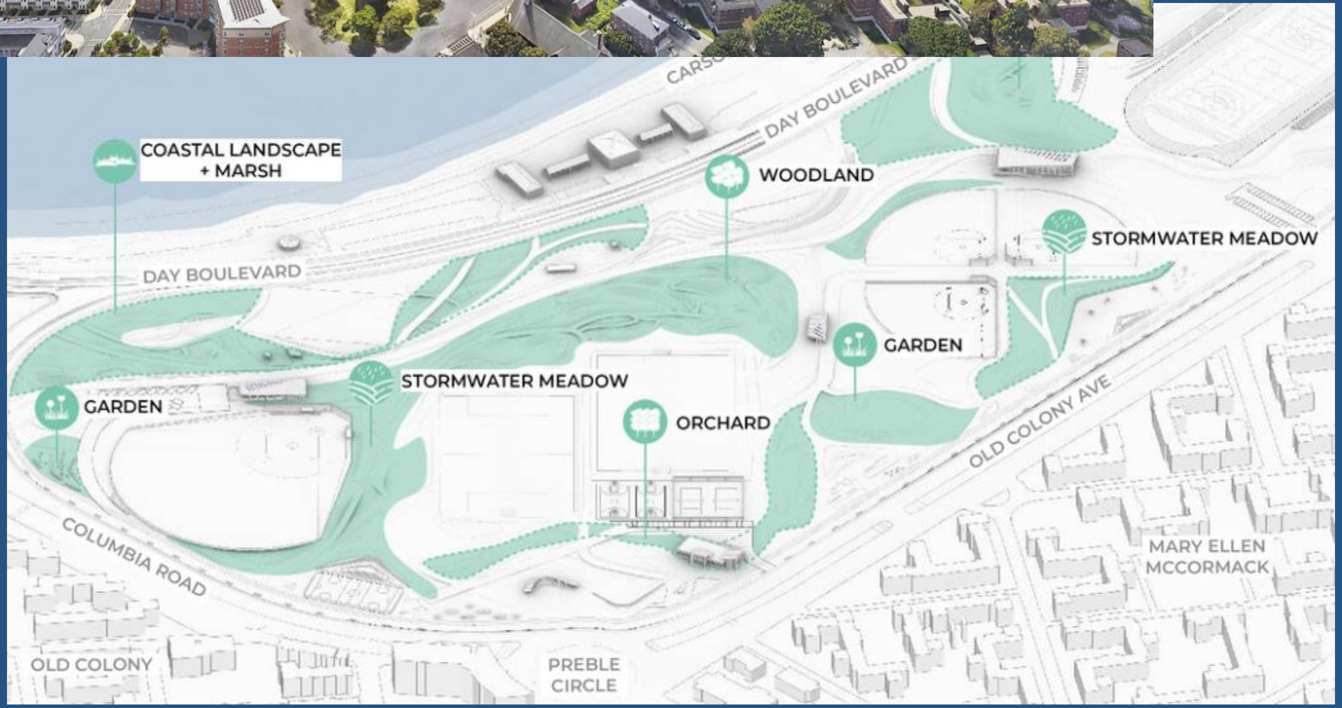
The Issue:

Sea Level Rise will continue to exacerbate coastal and inland flooding conditions

How GI Can Help:

Green infrastructure can be coupled with coastal flood mitigation strategies to support ongoing climate adaptation planning

The Moakley Park Vision Plan



Six Key Drivers for Green Infrastructure in Boston

Groundwater Recharge

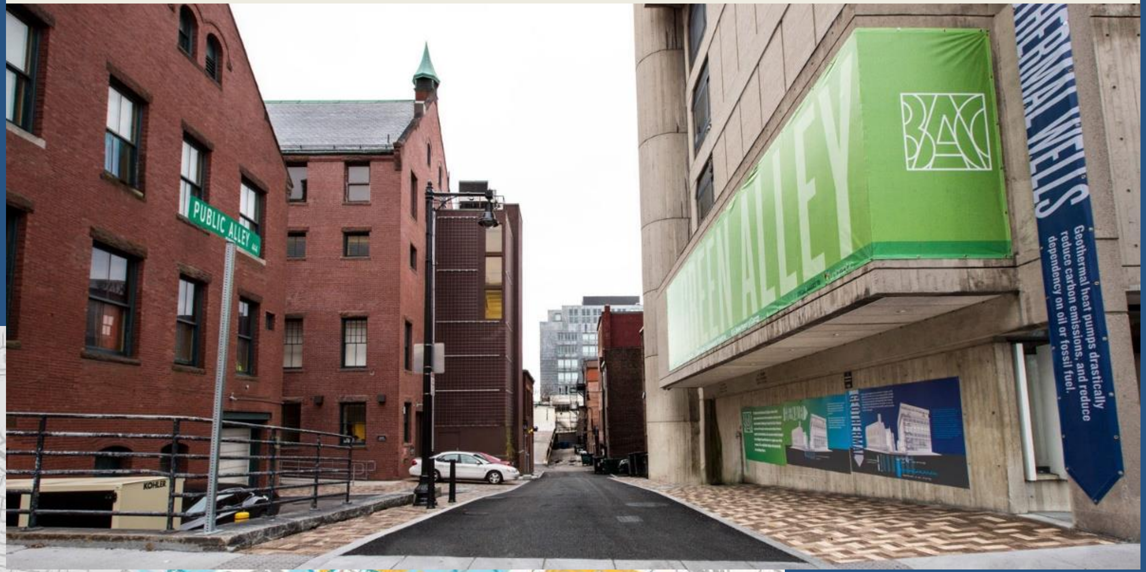
The Issue:

Depleted groundwater levels are impacting the structural integrity of the wood pylons of Boston's historic buildings

How GI Can Help:

Green infrastructure practices re-direct stormwater runoff from impervious surfaces and into the ground, thereby helping to replenish shallow aquifers

The Boston Architectural College (BAC) Green Alley



Boston's Groundwater Conservation Overlay District (GCOD)

Six Key Drivers for Green Infrastructure in Boston

Urban Heat Island

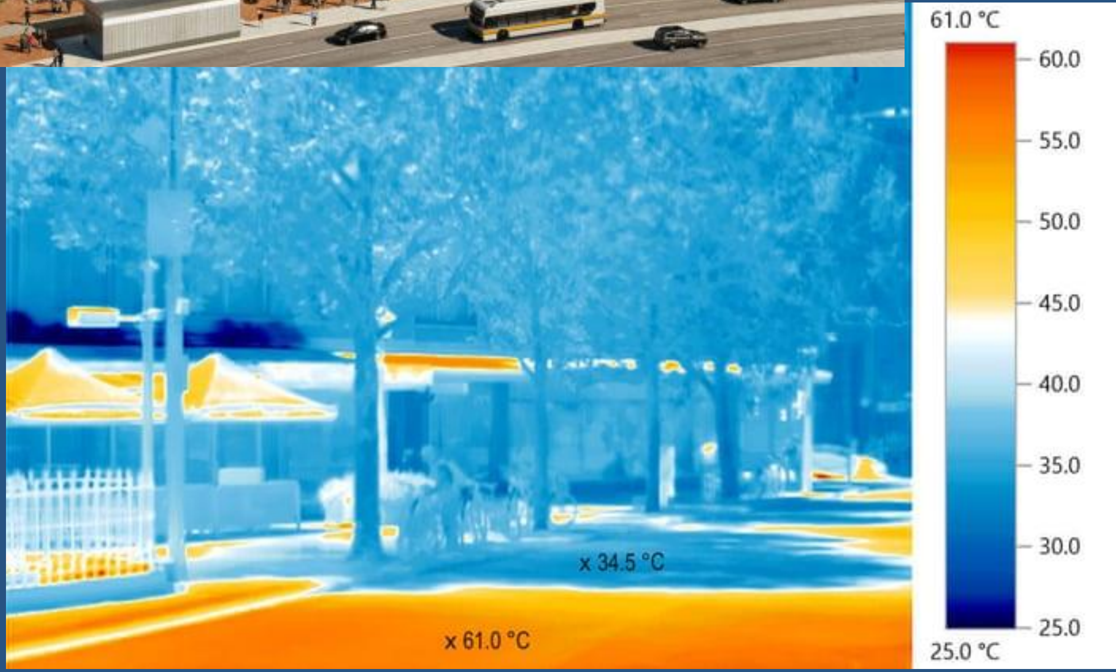
The Issue:

Impervious surfaces absorb energy from the sun and radiate heat back out at night

How GI Can Help:

Green Infrastructure increases pervious surfaces and provides shade that helps to cool impervious surfaces

Boston City Hall Plaza Restoration



Six Key Drivers for Green Infrastructure in Boston

Habitat and Transportation Connectivity

The Issue:

Urbanization and has fragmented critical habitat corridors and prioritization of the automobile has limited safe and sustainable transportation modes

How GI Can Help:

Green Infrastructure supports critical habitat networks that can be integrated into greenways and transportation corridors

The Fens, Olmstead's Emerald Necklace

New England Avenue Streetscape Project

Discussion: Widespread Implementation of Green Infrastructure

How can Green Infrastructure support other Resilience and Sustainability Initiatives in Boston?

- Climate Ready Boston
- Imagine Boston 2030
- Boston Harbor Resilience Plan
- Coastal Resilience Neighborhood Plans
- Flood Hazard Mitigation Plans
- Urban Forest Plan
- Heat Resilience Plan
- Open Space and Recreation Plan
- Green Links Plan

Discussion: Widespread Implementation of Green Infrastructure

What are the opportunities and hurdles?