URBAN ENVIRONMENTAL GREEN INFRASTRUCTURE DESIGN PLAN

City of Jersey City

Hudson County, New Jersey

Adopted June 13, 2017

Prepared by:

MASER CONSULTING P.A.

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Executive Summary

The City of Jersey City is experiencing unprecedented growth in population and development with a trajectory toward soon becoming the largest city in the state. However, at the same time the City is facing the unique geographic challenge of being located between two rivers, the Hudson and Hackensack, with a significant amount of the growth and development along these two waterfronts.

Jersey City's existing Combined Sewer Operating (CSO) system was originally designed to convey both sanitary sewerage and stormwater, with outfalls into these two watercourses which, over time, has become problematic due to increased flows and numerous outfalls. The existing CSO also presents particular challenges due to tidal flows, large areas within flood zones and development near sea levels.

A substantial downtown office district is threatened by proximity to the waterfront as sea levels rise and the threat of storm surges grows. Also located within flood zones are four historic districts and thousands of new residential units serviced by aging infrastructure. Major tourist destinations and the mass transit that visitors and residents rely on are in a compromised position unless and until recommendations of the Resiliency and Adaptation Master Plans, as well as those contained herein, are effectively put in place.

Jersey City has four main drainage areas and 23 main outfalls connected to the present system, and two First Flush[1] basins are currently being planned. The 18th Street basin will have the capacity to handle 70-75% of the initial combined storm and sewer flows in the Northeast area, and the Mill Creek Basin will have a 10-12 million gallon capacity capable of handling 80-85% of the initial flows in the Southeast CSO area. Within the four drainage areas, there are ten drainage systems on the eastern side and eight on the western side of the city (see Appendix Map #1 for CSOs and Pump Stations). Attempts have been made over the years to formulate green design applications to guide future development and redevelopment related to Jersey City's CSOs and outfalls. As is common in many older cities along waterways, the volume of rainwater falling on exposed impervious surfaces and running into gutters and eventually storm inlets overwhelms the piping system in the short term, with water flushing directly into adjacent waterways. As a result, some of this stormwater gets built up in the streets, leading to localized flooding which is then exacerbated by tidal influences on the water levels.

These local nuances in Jersey City are part of the analysis contained in this report, and the efforts already underway or previously discussed were considered when determining the recommendations herein.

[1] First Flush is defined as the initial surface runoff of a rainstorm. During this phase, water pollution entering storm drains in areas with high proportions of impervious surfaces is typically more concentrated compared to the remainder of the storm. Consequently, these high concentrations of urban runoff result in high levels of pollutants discharged from storm sewers to surface waters. Alex Maestre and Robert Pitt; Center for Watershed Protection (2005)."The National Stormwater Quality Database, Version 1.1: A Compilation and Analysis of NPDES Stormwater Monitoring Information." Report prepared for U.S. Environmental Protection Agency, Washington, DC. September 4, 2005.

The Urban Environmental Green Infrastructure Design Plan will evaluate the present condition of these systems in the city, the expected impact of proposed improvements such as first flush storage areas, the separation of combined flows in areas of recent development, and potential locations for green stormwater management practices going forward. The recommendations made in this Plan are intended to reduce localized flood conditions through green infrastructure site modifications, including within rights-of-way, and open spaces, as well as supplemental measures such as rooftop gardens, and green roofs and walls.

A methodology for determining the appropriateness of various green measures is provided in this report, along with examples of treatments with quantifiable goals and a Green Infrastructure Map identifying locations where the recommended green infrastructure application would be most effective and appropriate.

The green infrastructure recommendations outlined in this document are in keeping with the understanding that Jersey City wishes to create a consistent and comprehensive strategy for improving the City's capacity to reduce, withstand, and recover from the effects of future incidents of stormwater inundation and sea level rise. The recommendations made herein advance the City's Resiliency Goals and Objectives as identified in the Resiliency and Adaptation Master Plans.

What is Green Infrastructure?

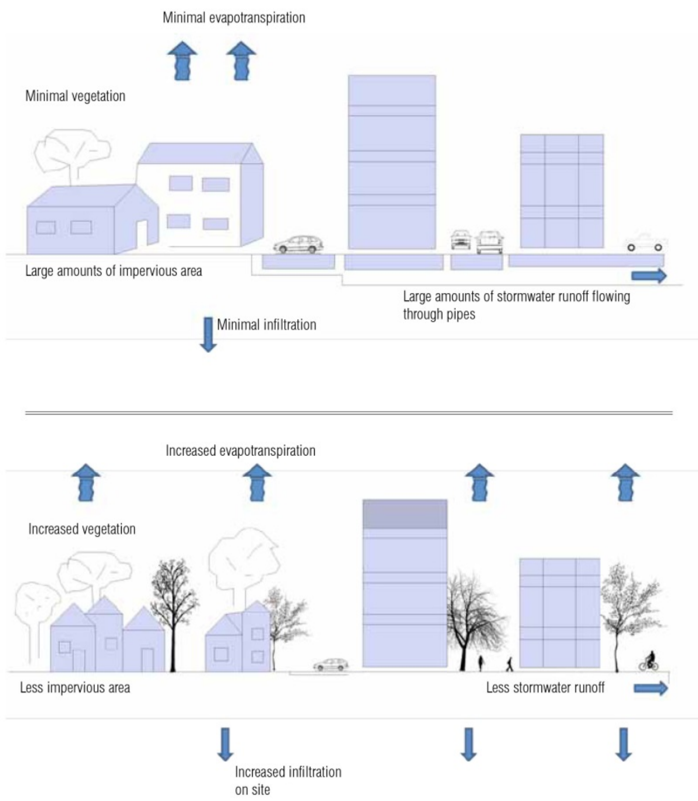
"Green infrastructure refers to the natural and constructed stormwater controls that mimic the natural hydrologic cycle by capturing, treating, and/or using stormwater runoff from public and private properties. These practices are incorporated into the planning, site design and construction phases of development projects."[2] Said another way, "green infrastructure is an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife."[3]

Green infrastructure can be simple or complex, ranging from gardens to man-made wetlands, from green roofs to living shorelines. Green infrastructure can be employed by governments, as is often the case when significant infrastructure is required, or undertaken by the average resident who wishes to capture rain in a barrel or sponsor a street tree.

As a nearly built-out environment, Jersey City has limited pervious surface – pavement and rooftops abound and there is little vegetated cover. Contamination from past industry and land disturbance from development also "mobilizes sediment and releases nutrients to lakes, streams and wetlands - fundamentally changing aquatic habitats and their potential uses. This change in the landscape

[2] City of Camden Green Infrastructure Design Handbook, 2013.
[3] Benedict, M. A., & E.T. McMahon, *Green Infrastructure: Linking Landscapes and Communities*. Island Press, 2006.

decreases groundwater recharge and increases the pollutant load, frequency and volume of surface stormwater runoff. "[4] It is important not to encourage the spread of contaminants through the effort to increase permeability. Increasing pervious coverage or reducing surface runoff in other ways will help water follow its normal course of infiltration or delay infiltration such that the water table can handle the volume which is otherwise limited by the impervious coverage.



Traditional (top image) versus green (bottom) design. Greener approaches serve to treat a greater amount of stormwater on-site, providing multiple benefits along the way.

Figure 1: Stormwater behavior with and without Green Infrastructure (Source: City of Camden Green Infrastructure Handbook, 2003)

[4] Missouri Department of Natural Resources, *Missouri Guide to Green Infrastructure*, 2012.

Jersey City Priorities and Guides

There are two primary statements which shall guide Jersey City's decisions as it relates to green infrastructure and flood resiliency: the Resiliency Goals and Objectives, and the Vision Statement. These two sets of guidelines were introduced in the Resiliency Master Plan.

Goals and Objectives

Goal: *Create a Jersey City that is resilient against flooding*
Objectives:

- To protect vulnerable areas from coastal and pluvial flooding.
- To preserve and protect historic neighborhoods and structures.
- To mitigate the impacts of known sources of hazardous sediment and combined sewer outflows.
- To develop gray and green infrastructure solutions to reduce the impact of flooding events.
- Identify points of necessary infrastructure coordination with the neighboring communities.
- Minimize the impact of flood control infrastructure on existing and planned neighborhoods.

Goal: *Protect Jersey City's critical infrastructure*
Objectives:

- Plan for operational continuity of critical infrastructure networks (energy, water, sewage, mobility, medical, communications, etc.) in the case of an emergency event.

Goal: *Improve emergency preparedness citywide*
Objectives:

- Identify "resilience centers" accessible to and capable of serving residents citywide.
- Provide usable, accessible, and up-to-date online emergency resources.
- Identify City agencies and positions therein who will be responsible for providing leadership during emergencies.
- Provide emergency response training for City departments and positions therein who will be held responsible during emergencies.
- Facilitate mobility and connectivity for ease of emergency evacuation.

Goal: *Create a socially resilient community*

Objectives:

- Maintain and expand access to the Jersey City waterfronts.
- Leverage proposed flood protection infrastructure and landscape projects to benefit all citizens of Jersey City with an emphasis on the most vulnerable communities.
- Ensure that flood protection infrastructure protects the connections between communities and the services, necessities (food, water, medical needs), and critical support needed during flood emergencies, and that no measures isolate neighborhoods or limit points of access.
- Provide equity in protection measures along both the Hackensack and Hudson River waterfronts.
- Retain and expand waterfront access for the enjoyment of the residents of and visitors to Jersey City wherever possible.

Goal: *Ensure economic stability against the threat of flooding*

Objectives:

- Reduce the economic losses due to interruption and insurance expenses for all businesses and employees within Jersey City.
- Coordinate between the proposed flood protection infrastructure and landscape projects and the ongoing and foreseen development projects in the city.

Vision Statement

Jersey City seeks to protect its valuable social, historic, and economic assets against the changing environment and increased risk of storm events through innovative design and infrastructure solutions. By identifying vulnerable populations, neighborhoods, and gaps in the City's preparedness, Jersey City resolves to implement strategies that will ensure that it remains a desirable and dependable place to live, work, and invest for generations to come.

Overview of Previous Studies

The goal of the Urban Environmental Green Infrastructure Design Plan is to evaluate the potential for incorporating Best Practices for stormwater management and green infrastructure into future development in Jersey City, and to create recommendations for implementation going forward to meet storm resiliency standards, including the introduction of green solutions into streets, parks, and future development.

In order to determine what steps are best going forward, we must first look backward and see what previous studies were undertaken by Jersey City in earlier efforts to implement green infrastructure practices or incentives. Numerous studies and reports have been conducted over the years, some pre-dating Hurricane Sandy, which have investigated and made recommendations for a variety of Stormwater Management approaches, including Tree Canopy Assessment and the introduction of green infrastructure. Each of these studies approached resiliency and green development from a differing vantage point, resulting in an abundance of information and recommendations.

Below are chosen excerpts from a number of reports that relate to the Urban Environmental Green Infrastructure Design Plan, to help provide context and understanding of the challenges that Jersey City Faces.

Rebuild By Design Hudson River Scoping Document[5] and Rebuild by Design (RBD) competition[6]

The United States Department of Housing and Urban Development (HUD) launched the Rebuild by Design (RBD) competition in the summer of 2013 to develop ideas to improve physical, ecological, economic, and social resilience in regions affected by Hurricane Sandy. The competition sought to promote innovation by developing flexible solutions that would increase regional resilience. The proposed project for Hoboken, which affects and extends into Jersey City, was one of the competition's six winning concepts; it was developed with the goal of reducing frequent flooding due to storm surge, high tide, and heavy rainfall. HUD awarded $230 million to the State of New Jersey for the project in the municipalities of Hoboken, Weehawken, and Jersey City.

The proposed project takes a multi-faceted approach intended to address flooding from both major storm surges and high tides as well as from heavy rainfall events. The proposed project is based in the City of Hoboken, but extends into Weehawken and Jersey City with the following approximate boundaries: the Hudson River to the east; Baldwin Avenue (in Weehawken) to the north; the Palisades to the west; and 18th Street, Washington Boulevard and 14th Street (in Jersey City) to the south.

[5] Rebuild by Design Hudson River Scoping Document: Resist, Delay, Store, Discharge, Hoboken, Weehawken and Jersey City, New Jersey (November 2015)
[6] Rebuild by Design (RBD) competition , 2013, United States Department of Housing and Urban Development (HUD), and subsequent recommendations.

The project's comprehensive approach to resilience consists of four integrated components:

1. **Resist:** a combination of hard infrastructure (such as bulkheads, floodwalls and seawalls) and soft landscaping features (such as berms and/or levees which could be used as parks) that act as barriers along the coast during exceptionally high tide and/or storm surge events;
2. **Delay**: policy recommendations, guidelines and urban green infrastructure to slow stormwater runoff;
3. **Store**: green and grey infrastructure improvements, such as bioretention basins, swales, and green roofs, that slow down and capture stormwater, and which will complement the efforts of the City of Hoboken's existing Green Infrastructure Strategic Plan; and
4. **Discharge**: enhancements to Hoboken's existing stormwater management system, including the identification and upgrading of existing stormwater/sewer lines, outfalls and pumping stations

The Green Guide, Increasing Sustainable Development on Jersey City's Redevelopment Areas[7]

Because of significant growth over the past decades, both in Jersey City (12% growth between 1990 and 2014) and Hudson County (18% growth during the same period), the *Green Guide* analyzed the City's development trends in order to understand the impact that sustainable development could have on the City's redevelopment progress.

Jersey City's redevelopment areas are diverse in many respects; their sizes range from the Columbus Corner Redevelopment Area at 0.43 acres to the Liberty Harbor Redevelopment Area at 1,161 acres. The vision for the type of redevelopment, as set forth in the plans, is equally varied. For instance, the Greenville Industrial Redevelopment Plan calls for a low-rise industrial and retail development, while a few miles north the Exchange Place North Redevelopment Area is envisioned as an urban mixed-use downtown with buildings up to 50 stories tall. All of the redevelopment plans supersede the zoning ordinance, although many plans include development options and references to the City's zoning code.

The goals developed for the *Green Guide* reflect input from stakeholders as well as from the Jersey City Redevelopment Agency (JCRA). The Goals are presented in two parts. First, Program Design Goals reflect the JCRA's intentions in creating the Green Guide, as well as

[7] Clarke, Canton and Hintz and The Land Use Law Center, The Green Guide, Increasing Sustainable Development on Jersey City's Redevelopment Areas, March 2013.

provide a framework to address the challenges to sustainable development identified by the stakeholders. Next, the Sustainable Development Goals set forth sustainability principles that can be integrated into projects and redevelopment plans.

Program Design Goals:

A. Increase sustainable development in Jersey City's Redevelopment Areas using cost-effective strategies;
B. Increase Jersey City's prominence and reputation as a sustainable community;
C. Employ best practices in program implementation;
D. Employ best practices in program enforcement.

Sustainable Development Goals:

1. Ensure that strategies are sensitive to the context of the City's redevelopment areas, including but not limited to, affordable housing components, historic fabric, neighborhood character and density;
2. Increase energy efficiency of buildings;
3. Increase the use of renewable energy;
4. Reduce the rate of water consumption;
5. Reduce stormwater runoff and combined sewer overflow events;
6. Reduce the rate of consumption and generation of construction materials;
7. Encourage reuse of previously developed sites and structures;
8. Encourage a mix of uses and housing types when appropriate;
9. Encourage access to on-site and off-site community amenities;
10. Encourage healthy and equitable neighborhoods;
11. Improve mobility and the use of alternative forms of transportation, including mass transit.

The *Green Guide* identifies a broad range of incentive strategies available for green development. Potential financial incentives include: tax credits or abatements/exemptions (such as property tax exemptions and sales tax exemptions); loans; grants; and fee rebates, reductions or waivers. Process incentives include: providing for expedited review/streamlined permitting processes, floor area ratio and height bonuses, flexibility in setback requirements, and counting green roofs toward open space requirements. Finally, many programs provide incentives related to assistance, education and publicizing, such as: workshops, educational programs and communication networks; monitoring and direct assistance (technical or non-technical), information dissemination (e.g.: indirect assistance such as free resource lists or green building product information available on the municipal website), award programs, and publicizing assistance (site signage, website/directory listing, etc.). These alternatives are particularly valuable to Jersey City since the development community already looks favorably upon the permitted zoning and approval process that the City offers.

The most careful and well-orchestrated green building programs, whether mandatory or incentive-based, typically take two approaches to implementation. They start with a phased approach involving either a minimal green building standard or a limited scope of applicability, which gradually increases over time. Second, they establish a schedule for periodic reevaluation of the program, to note successes and make necessary adjustments.

Additional Sustainable Development Goals include but are not limited to: ensure that strategies are sensitive to the context of the City's redevelopment areas; increase energy efficiency of buildings; reduce the rate of water consumption; reduce stormwater runoff and combined sewer overflow events; encourage reuse of previously developed sites and structures.

Collaborative Design and Dynamic Modeling for Urban Coastal Flood Adaptation[8]

Collaborative Design and Dynamic Modeling for Urban Coastal Flood Adaptation is a set of adaptation measures developed in workshops, meetings with government officials, and a community charrette. The adaptation recommendations identified in this document are specifically designed to reduce or prevent storm surge flooding. (The scope of this document did not address pluvial (rainfall) flooding, though that is also an important issue for Jersey City.)

Of the many adaptation options for reducing flooding, this document focuses only on local **vertical** solutions (e.g. berms, levees). The report, however, acknowledges that additional options should be studied for a layered approach, including policies and zoning laws promoting retreat, consolidation or structure/infrastructure elevation; regional solutions (e.g. harbor-wide barriers); and green infrastructure for reducing rainfall flooding.

Due to the limits of the report, the recommendations would successfully protect most areas of the city from all storm events tested up to and including Hurricane Sandy plus 31" of sea level rise (a high-end projection for 2055). Hurricanes of a higher flood level than Sandy would not be covered and additional layers of flood adaptation would need to be implemented to address this residual risk.

Jersey City Tree Canopy Assessment[9]

Jersey City's tree canopy was mapped and analyzed as part of the Jersey City Environmental Commission's role of inventorying environmental resources and promoting long-range planning. The document states that "Trees provide the city with many benefits from

[8] Orton, Philip, et al, Collaborative Design and Dynamic Modeling for Urban Coastal Flood Adaptation, May 1, 2015.
[9] Jersey City Tree Canopy Assessment, A Report on Current Tree Canopy and Strategies for the Future, June 2015

clean air, stormwater management, cooling, natural beauty, and improved walkability and safety. For example, between 95 million and 155 million gallons of rainwater are currently intercepted annually by Jersey City's tree canopy and prevented from entering the stormwater system. This means less flooding and less sewer overflows. Furthermore, this is a conservative estimate, since Jersey City's trees are most likely more mature than the ages used for modeling and the model does not account for water absorption by tree roots or evapotranspiration."[10]

The Assessment reports that the city's trees also help to clean the air by filtering particulate matter, ozone, nitrogen and sulfur dioxide, resulting in improved public health. The city's trees reduce costs to the city and add real economic value. Just three trees placed strategically around a house can reduce its utility bills by 50 percent, and trees can also increase property values by up to 37 percent. In tree-lined retail districts, shoppers spend nine to twelve percent more per item and shop longer. Rental rates for commercial spaces are also seven percent higher in high-quality, green landscapes. And, crime decreases by up to 52 percent in neighborhoods with trees.

The report identifies a number of management and funding problems that make it difficult for the city to realize the benefits provided by its urban trees. For example, tree wells are too small, agencies are more response-based than management-focused, tree management is underfunded and understaffed, and private and public sectors are under-tapped as partners. As a result, trees cost the city more to maintain, investments are not fully realized, and needs, such as better stormwater management and reduced flooding, are unmet.

Jersey City Stormwater Management Plan[11]

Jersey City's Stormwater Management Plan (SWMP) is a comprehensive and dynamic directive for the City to reduce nonpoint sources of water pollution. The City's SWMP is a series of strategies, designed in accordance with governmental agencies and laws, intended to reduce the amount of stormwater pollutants which enter local waterways.

The goals of the City and SWMP, along with how they will be met, are as follows:

- Reduce Flood Damage: this goal is met by implementing the measures addressed in Section 4 through either non-structural or structural Best Management Practices (i.e. stormwater management measures) for achieving stormwater runoff quantity control.
- Minimize stormwater runoff from new developments: this goal is met by implementing the measures addressed in Section 4 through either nonstructural or structural Best Management Practices (i.e. stormwater management measures) for achieving stormwater runoff quantity control.

[10] Jersey City Tree Canopy Assessment, A Report on Current Tree Canopy and Strategies for the Future, June 2015.
[11] Malcolm Pirine, Inc., Jersey City Stormwater Management Plan, August 2008.

- Reduce soil erosion from any developments or construction projects: this goal is met by requiring implementation of stormwater management measures described in Section 4.2 and 4.4 such that they satisfy the requirements of the Soil Erosion and Sediment Control Act, N.J.S.A 4:24-39 et seq. and implementing rules.
- Assure adequately designed culverts, bridges, and other in-stream structures: this goal is met by adhering to the design and performance standards for Structural Best Management Practices presented in Section 4.4 of the SWMP.
- Maintain groundwater recharge: this goal is met by implementing the measures addressed in Section 4 through either non-structural or structural Best Management Practices (i.e. stormwater management measures) for meeting groundwater recharge requirements.
- Preventing increases of Non-Point Source (NPS) pollution: this goal is met by addressing the goal related to minimizing stormwater runoff pollutants described in Chapters 3 and 4.
- Maintain the biological integrity of streams and drainage channels: this goal is met by selecting the BMP"s that are allocated a "high" to "medium" rating in Table 4.2: BMP"s Applicable to Various Land Uses, Stormwater Management Goals, and Other Factors for meeting the groundwater recharge enhancement and runoff quality improvement goals.
- Minimizing stormwater runoff pollutants from new and existing developments: this goal is met by implementing the measures addressed in Section 4.2 through either non-structural or structural Best Management Practices (i.e. stormwater management measures) for achieving stormwater runoff quality control.
- Protecting public safety through proper design and operation of stormwater management facilities: this goal is met by requiring adherence to the design and performance standards discussed in Section 4.2 and requiring adoption of comprehensive safety measures, described in Section 3.3.3 and an operation and maintenance plan that meets the requirements described in Section 3.3.2. To achieve these goals, this SWMP outlines specific stormwater design and performance standards for new development and preventive maintenance strategies to ensure the effectiveness of the stormwater management facilities. Safety standards for the stormwater infrastructure will be implemented to protect public safety.

Green Infrastructure Feasibility Study – Jersey City[12]

The purpose of the Green Infrastructure Feasibility Study was to evaluate feasibility for green infrastructure in order to "identify cost effective ways to help mitigate water quality and local flooding issues." The study is intended to be used as a guide to "begin implementing green infrastructure practices while demonstrating to residents and local leaders the benefits of and opportunities for better managing stormwater runoff."

[12] Rutgers University Agricultural Experiment Station/Rutgers Cooperative Extension Water Resources Program, *Green Infrastructure Feasibility Study*, 2017.

The study identifies 31 potential project sites citywide for green infrastructure implementation. Projects fall into three categories: *Vegetative systems* which can manage smaller storms and primarily focus on reducing water quality impacts and less on reducing flooding through treatment mechanisms of infiltration, filtration, and evapotranspiration; *Rainwater Harvesting systems* which focus on the conservation, capture, storage and reuse of rainwater through methods such as rain barrels and cisterns; and, *Storage, Quantity, & Infiltration systems* which primarily focus on storage and seek to reduce peak flows of stormwater by storing it before it becomes runoff through means such as permeable surfaces

The plan goes on to discuss maintenance issues on each and identifies which measures would be best suited for specific sites.

Standards for Green Design

It has been the intent of most green stormwater systems to evaluate the possibility of intercepting the initial one inch to one and a half inches of rainfall, and divert it to an alternative drain system that can infiltrate and/or store the potential runoff. One of the major goals of the developing stormwater management concepts throughout the City, therefore, is to do just that, and retain and/or infiltrate the first one inch of rainfall in the immediate area where this water falls or, if possible, to divert water at higher elevations prior to it entering the combined sewer. This goal of capturing at least one inch is applied to all analyses and recommendations herein.

Eighty percent of all rain events in the northeast is the “1-inch storm,” which has become the standard used by urban areas throughout the region. As such, our goal of capturing the first one inch could have a significant impact not only on major storms, but on “typical” rain events throughout the year. There are numerous methods by which to achieve this goal, such as integrating green streets concepts into the redesign of urban corridors and spaces, improving infrastructure sustainability, and assisting the regional utility authority in their efforts to reduce peak stormwater flows into the system. Also, green roof systems, combined with porous and pervious surface systems including rain garden areas, shade trees and landscaping to mitigate stormwater prior to it reaching the existing inlets and storm systems are common approaches.

In fact, even an approach as simple as green inlets or tree trenches, which capture water for distribution into a trench stone or other manufactured drain system upstream of existing city inlets and divert or intercept runoff, can capture this first inch.

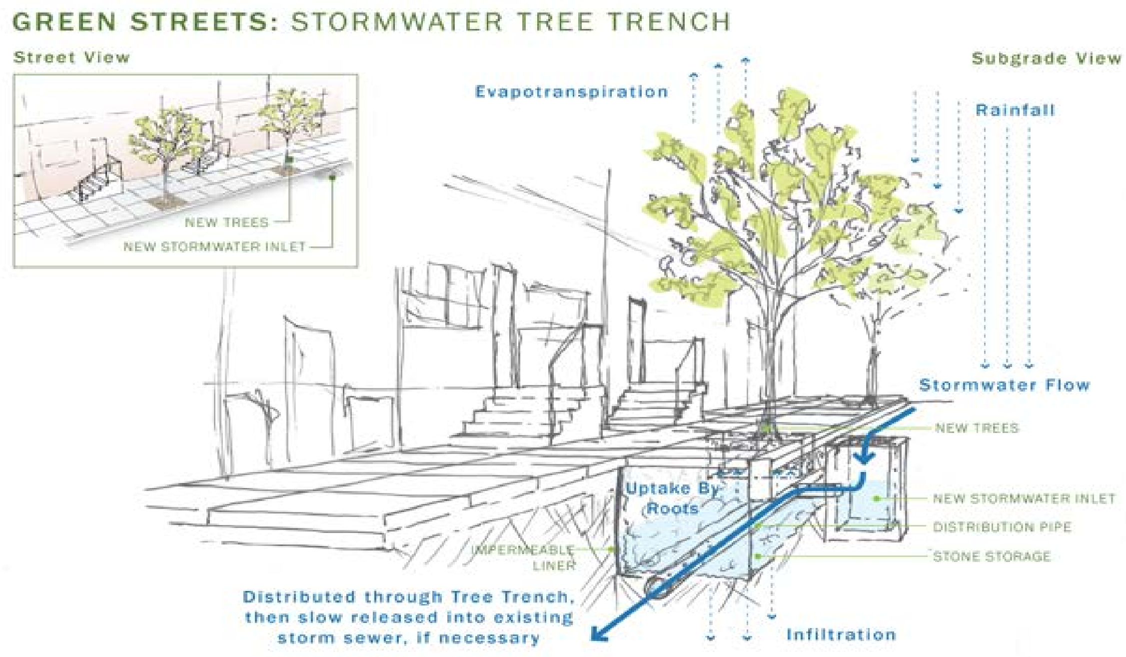


Figure 2: Green Inlet/Tree Trench solution (Source: Philadelphia Complete Streets Handbook)

As illustrated above, the general idea is to intercept rainfall and to develop sufficient systems for storage and potential reuse of the stormwater.

Methodology

The generally used approach for the introduction of green infrastructure in urban areas involves analysis, building relationships with implementation partners, and evaluating a strategic queue of projects. The first element, analysis, is conducted in order to identify immediate opportunities that can be implemented in the short term as well as plan for longer implementation strategies to ensure the targets of Greening programs are, and will continue to be, addressed.

General Considerations

The following general considerations and guidelines were followed in the process of deciding what green infrastructure implementations would be appropriate in any given location.

- Coordination with other planning initiatives to create holistic approaches and projects.
- Communication with partners (Regional and neighboring sewer Authorities, other potential Green Infrastructure partners, such as local educational institutions, Steven's Institute of Technology, Rutgers University, etc.) to align goals.
- Consideration of current and future uses of the identified spaces and their relationship to the surrounding area.
- Seek to maximize Proposed Drainage Area Capture and Water Quality Benefits.
- Locate green infrastructure where maximum volume capture can occur (top of drainage systems and adjacent to open space).
- Consolidation and coordination of the number of stormwater management practices where possible.
- Consider the timing of implementation, balancing short-term opportunities with long-term strategies.
- Respect community needs.

Site Analysis

The first step in analyzing green infrastructure solutions is to investigate the ability of a given area to support stormwater management initiatives and techniques in conjunction with any anticipated development improvements. This approach incorporates best management practices Green Street design standards that can also be integrated into the municipal Land Development Ordinance and design standards.

An evaluation of the existing sewer utilities throughout the designated area and the ground's ability to store or ultimately infiltrate runoff within the existing rights of ways and adjacent properties is necessary in order to understand the best approach for employing green infrastructure. Test Borings and percolation testing also help determine both the current conditions of the subgrade material and the potential for the ground to provide storage and infiltration.

The existing conditions in many areas may have little to no subgrade ability to provide significant storage volumes or infiltration. In those cases, storage volumes will need to be provided through methods such as green roofs and surface or subsurface storage systems in cisterns or stone trenches which are capable of slow release of stormwater.

These issues, as well as many others, can be determined by evaluating the site constraints.

Evaluation of Common Constraints for Street and Parcel Green Infrastructure Projects

The following general considerations and guidelines were followed in the process of deciding what green infrastructure implementations would be appropriate in any given location.

1. Does the drainage area meet the minimum cost effective size for the introduction of green infrastructure? This has been defined in other CSO areas as 5,000-8,000 sf of surface drainage area, though this may vary by location. Drainage areas can be combined to meet these guidelines.[13]

2. Is there sufficient space for the design and installation of a stormwater management system footprint?

3. Does the location of water or sewer infrastructure pose a challenge? (e.g. multiple residential water service lines, utilities near the curbline running parallel to the sidewalk, water service line connecting to a restroom on a park site.)

4. Have other potentially affected agencies, such as electric and gas utilities, highway departments, public works, and telecommunications companies been contacted and referenced to confirm there are no additional utilities present in these locations?

5. Are there mature trees or other constraints (utility poles, lights, etc.) present where the proposed footprint of the green infrastructure application is being planned?

6. Are steep slopes or challenging topography present? (Most green infrastructure applications require a relatively level stone area to allow for storage, infiltration, and/or slow release, and should generally fit between a two-foot topographic contour line.)

7. Are there any potential programming conflicts that should be researched and verified in the field, such as nearby parks and playgrounds, gardens, plazas, building entrances, etc.

8. Professional judgment – Does any proposed location not make sense from both a cost and difficulty standpoint?

Design Criteria and Applications

The two main design criteria for green infrastructure are area and volume. The outline that follows provides an idea as to how these factors are related. Additionally, drainage requirements affect green infrastructure implementation.

[13] 5,000-8,000 sf of surface drainage area as recommended by Philadelphia Water, "Green Stormwater Infrastructure Planning & Design Manual." Version 1.0, September 2016, p. 28.

Area Requirements

When determining if a green infrastructure project is practical and feasible, a key consideration is if there is adequate space to accommodate the physical infrastructure itself. Here, the concept of "loading ratio" must first be evaluated. Loading ratio means the ratio of the area being managed (a lot, a block, etc.) to the area occupied by the green infrastructure itself. Typically, a maximum loading ratio of 10:1 for infiltration systems is recommended.[14,15] This number is calculated by dividing the total drainage area being collected by ten in order to determine the recommended footprint of the infrastructure proposed, whether this is on the surface or below the ground. (For example, if the drainage area to be collected is 8,000 square feet, the proposed green application should be approximately 800 square feet, or one-tenth of the overall area.) This ratio is considered a well-balanced compromise between gathering too much water volume to be effectively controlled, and requiring sufficient area and infrastructure to distribute the loading.

It should be noted that this ratio can be adjusted, and higher numbers may be appropriate if the runoff drains through a surface system such as a rain garden wherein the footprint will be calculated differently to take both the horizontal surface of the system and the base footprint of the green infrastructure application into account.

Volume Requirements

Most green infrastructure systems must be sized to capture and manage the required storage volume (V) equal to a minimum of one inch of runoff from the contributing impervious drainage area. Therefore, the calculation of that potential volume is the drainage area in square feet multiplied by the amount of precipitation. In a standard example, the amount of precipitation desired to be captured is the first inch of rainfall (roughly 0.08 of a foot). The calculation for a drainage area of 8,000 square feet would therefore be 0.08 * 8,000, or 640 cubic feet of storage volume.

$$V = A \times (P/12)$$

V = required storage volume (cu. ft.)

A = impervious drainage area (sq. ft.)

P = desired precipitation capture (inches)

[14] Philadelphia Water Department, "Green Stormwater Infrastructure Design Requirements and Guidelines." Pg. 66-67.

[15] Philadelphia Water Department, "Green Stormwater Infrastructure Design Requirements and Guidelines Packet." May 15, 2015. Pg. 11.

Once the area of capture has been determined and the volume of storage calculated based upon that area, the evaluation of potential sites and various green infrastructure applications can begin.

Other water capture calculations, such as those shown earlier in this report for green inlets, are calculated as follows (note that for planning purposes both 1” and 2” events should be considered):

sq. ft. impervious x rainfall = cu. ft. to be mitigated

Amount of square footage of impervious area (sq. ft.) to be mitigated × rainfall amount (1” = 0.083, 1 ½” = 0.125, 2” = 0.166) equals cubic feet (cu. ft.) of stormwater to be retained and handled by the green infrastructure.

Drainage Requirements

Green stormwater infrastructure systems should be designed to completely drain within a 72-hour period from the end of the storm event, with the majority of the drain down occurring within the initial 24 hours.

Prior to design, soil infiltration testing must be completed, and underdrains must be placed in all systems with subsurface storage components to collect and transport subsurface water. Wherever possible, green infrastructure systems should be designed to infiltrate stormwater. Adjacency to other existing buildings or structures must always be taken into account, and adequate separation maintained to avoid potential basement flooding structural damage. (As a general rule, at least ten (10) feet of separation between infiltrating systems and buildings or structures should be maintained.)

Within most subsurface Green Infrastructure there is some form of overflow or orifice for slow release. In most cases there is minimal storage provided below the overflow control device elevation, and therefore it cannot be counted toward the required storage volume.

The bottom elevation of the Green Infrastructure system located below the surface is recommended to be a minimum of two feet above any infiltration-limiting layer, such as bedrock or seasonal high ground water.

Applications

Stormwater Management systems usually include different applications providing infiltration, evapotranspiration, and storage and slow release. Several applications will be discussed in further detail in the Recommendations section of this report. However, briefly, some examples of successfully completed applications include:

Raingardens: diverting water, usually from a paved corridor, to a planted low area that allows for a volume of storage and infiltration.

Bio swales: directing water through a graded and planted swale usually adjacent to a roadway as a method to attenuate runoff and promote infiltration. The plantings are designed to promote evapotranspiration and are usually native species that require less long term maintenance and can withstand wet conditions.

Stormwater Trenches: capturing an initial one inch concentration of stormwater prior to entrance to a combined sewer system. This involves the introduction of green inlets upstream to redirect stormwater to a series of underground stone or structured storage trenches. The trenches are either for infiltration if possible or storage with slow release if not possible. This application can be used in conjunction with planters and street trees.

Pervious surfacing: Porous concrete and pervious asphalt have been used in a range of applications, notably for surfacing of basketball courts and walking trails within recreation sites, which evolved to the development of pervious streets with stepped and terraced underground storage and slotted inlets. The idea is now being developed in gutter collection systems and for crosswalk areas that can infiltrate and redirect surface runoff.

Individual Infiltration Units: created to provide point diversion of curb line runoff and to provide a means of collection and infiltration of rainwater. Each unit is placed along the curb in relation to an adjacent street tree and planting area, and the runoff is captured and fed to the root system below.

Native Basin Plantings: intended to capture runoff and provide an effective means of infiltration. In most cases this involves the use of native wetland seeding and plantings that are particularly adapted to promoting infiltration.

Evaluation of Existing Geologic Conditions

The general concept for the evaluation for green infrastructure is to look at the drainage areas created by surface runoff and to investigate the existing conditions to identify places where the introduction of greening would be most effective, both with regard to an area's ability to accommodate green infrastructure (e.g. Parks, Open Space, generally level areas), and an area's ability to remove stormwater at the highest points of any given drainage shed. The intent is to remove as much volume of rainwater from the system as possible prior to the release points, which in Jersey City's case are the 23 outfalls into the Hudson and Hackensack Rivers as discussed earlier in this report.

The physical characteristics of the topography, soils, slopes, surface and subsurface geology will determine the ability and potential locations for green infrastructure, guiding the recommendations made in this report both in terms of location and approaches selected to infiltrate, divert, capture and release stormwater within various parts of the city.

Topographic/Geologic Analysis

The City of Jersey City is composed of a ridgeline running mostly north and south through the entire city, flanked on either side by lower lying areas along the water frontage of the two rivers (Hudson and Hackensack). The transitional areas between the lower waterfront and the ridge on either side are steep banded areas with slopes ranging from 5% to 20+%.

Because of these two very different topography and geologic conditions, there should be two sets of recommendations for green infrastructure: one set of recommendations for the upland ridge areas where it is hoped that stormwater can be captured prior to entering the gravity storm drain system, which will also be generally applicable to steep sloped areas, and one set for the lower river edge areas on both sides, where shallow depths to river and ground water elevations will dictate what types of approaches can be used effectively.

As part of a forthcoming Environmental Resources Inventory (ERI) for Jersey City, a series of maps developed by Rutgers University students pertaining to the physical and geologic characteristics of Jersey City provide the base of information relating to many categories from soils and slopes to subsurface conditions which serve as base data for the analysis and evaluation within this report, along with our own internal verification.[16]

Upland

The first area, identified as the Upland, comprise the highest elevations in Jersey City, running as a spine down the center of the city and with elevations ranging from 40 to 170 feet above sea level. Most of this upper area is relatively level with slopes ranging from 0% to 5%.

Bedrock Geology:

Jurassic Diabase: medium to coarse grained material
Lockatong Formation: Dolomitic or silty argillite, mudstone, siltstone, and a minor silty limestone

[16] Hartman, J.M., D. Smith, Z. Tech-Czarny, J. Quispe. DRAFT Jersey City Environmental Inventor, 2017.

Surface Geology:

Rahway Till: "Reddish-brown to light-reddish-brown silty sand to sandy clayey silt containing some to many sub rounded to sub angular pebbles and cobbles and few sub rounded boulders. Generally compact below the soil zone. May show a coarse sub horizontal fissile structure. Gravel clasts include chiefly red sandstone and siltstone, some gray sandstone and mudstone, and minor white-to-yellow quartz, gray-to-purple quartzite-conglomerate and gray gneiss. Dark-gray basalt is common on and west of First Mountain. Boulders are chiefly gneiss and gray quartzite; basalt boulders are common on and west of First Mountain."

Soils:

Urban Land Till Substratum: the soil is limited to recreational purposes, watershed and habitat based upon the fact that it is mainly a shallow form of soil that can be stony and drought susceptible.

Based on this geology, it would appear that the Upland areas have capacity for the introduction of green Infrastructure in the upper zones (0'-7'), but that the unconsolidated stone layers of the Rahway Till and the Bedrock Geology of the Jurassic and Lockatong Formations will prohibit deep infiltration of water. Rahway Till "may show a coarse sub-horizontal fissile structure," which would indicate that there may be opportunities, if correctly identified, to introduce deeper injection well type of applications.

The types of applications recommended in this area would be surface and/or stormwater stone trenches with release mechanisms.

Terraces

The Terraces area is defined as the sloped areas between the Uplands in the center portion of Jersey City and the River Frontage areas. This area has varying degrees of slopes.

Bedrock Geology

Lockatong Formation: Dolomitic or silty argillite, mudstone, siltstone, and a minor silty limestone
Lockatong Formation Arkosic Sandstone facies: coarse to fine grained arkosic sandstone

Surface Geology

Eolian Deposits: Wind driven sand and stone sediments
Lake Wisconsinan Glacial Delta Deposits: deposits of a range of material from sand and silt to rock formations

Soils

Green Belt Loam: the least restrictive of the soil types in this area; a coarse-loamy, mixed soil that occurs in fill areas on modified landscapes in and near major urbanized areas of the Northeast

Laguardia Articfactual Coarse Sandy Loam: Loamy-skeletal, mixed, superactive soil that occurs on modified landscapes in and near major urbanized areas of the Northeast; limitations based upon slopes and depths as would be suspected in transition areas

Urban Land Till Substratum: soil is limited to recreational purposes, watershed and habitat based upon the fact that it is mainly a shallow form of soil that can be stony and drought susceptible; limitations based upon slopes and depths as would be suspected in transition areas

Urban Land, Greenbelt Substratum: limitations based upon slopes and depths as would be suspected in transition areas.

Based on this geology, the Terrace areas have specific capacity for the introduction of green infrastructure. While the excessively steep sloped area will be difficult to retrofit with green infrastructure, there are areas within the terraces that indicate pockets of well drained soils and substratum that could be used to infiltrate and/or capture stormwater in place.

The types of applications recommended in this area would be surface and/or stormwater storage trenches with release mechanisms.

River Frontage

The third area, identified as the River Frontage, flanks both sides of the prevailing central ridge line. The River Frontage varies in width with elevations near sea level (elevations 0' to 10') and minimal slopes (0%-5%). A significant portion of these areas exhibit similar characteristics of being labeled as Historic Fill.

Bedrock Geology

Manhattan Schist along the Hudson River edge

Stockton Formation between the Hudson River and the base of the slopes: light-gray to light brown and yellowish medium to coarse grained sandstone and reddish to purplish-brown siltstone and mudstone with shale interbeds; and interbedded argillite. In New Jersey, feldspar pebbly sandstone and conglomerate, and quartz-pebble conglomerate are also mapped.

Passaic Formation along Hackensack River frontage: mudstone facies on the river

Lockatong Formation Arkosic Sandstone Facies between the Hackensack River and the base of the slopes eastward. USGS describes this formation, noting, "cycles in northern Newark basin are thinner and have arkosic sandstone in lower and upper parts. Upper part of formation in northern basin composed mostly of light-gray to light-pinkish-gray or light-brown, coarse- to fine-grained, thick- to massive-bedded arkosic sandstone (Trla). Thermally metamorphosed into hornfels where intruded by diabase (Jd)."

Surface Geology

Salt-Marsh Estuarine Deposits: "salt-marsh peat, organic silt and clay; dark brown to black; sand and minor pebble gravel; very pale brown, white, gray. As much as 60 feet thick. Deposited during the Holocene sea level rise, and commonly underlain by lower terraced deposits, which have a greater sand content with gravel and mica added." (USGS)

Soils

Historic Fill and Urban Land: soil is limited to recreational purposes, watershed and habitat based upon the fact that it is mainly a shallow form of soil that can be stony and drought susceptible

Sandy Loam (Hackensack River side near Lincoln Park, and on the Hudson River side in the Liberty State Park area and south.): very fine loam to very coarse and feels quite sandy or gritty, but contains some silt and a small amount of clay. The amount of silt and clay is sufficient to hold the soil together when moist. Makes a weak ribbon (less than 2.5 cm long). [17]

These bedrock, surface geology, and soil conditions mean that these River Frontage areas have a shallow depth to groundwater and while areas may be adequately drained for agriculture they are generally not suited for storage of stormwater, therefore most recommended applications of green infrastructure in these areas will be surface type of features such as rain gardens and bio swales.

Specific Green Infrastructure Recommendations

The recommendations for green infrastructure in Jersey City will look in more detail at these three specific geographic subcategories identified as the Upland, Terrace, and River Frontage to determine the best applications for green infrastructure, based on their ability to handle green infrastructure due to their soils and geology as well as their location relative to the upward side of gravity fed drainage lines.

The Upland area is a localized high point within the City and, in green infrastructure terms, serves as an ideal location to remove as much stormwater as possible at the highest point in the Stormwater/Sewer (Combined Sewer Operating) System.

[17] Classification reaffirmed in report: U.S. Army Corps of Engineers, Baltimore and New York District, Site Investigation Liberty State Park, Jersey City NJ, Volume 1, Text, Figures and Tables, April 2004.

The Terrace lies between the Upland and the River Frontage, and has been the subject of repeated inundation due to its location at the lower end of a gravity system and attempts to mitigate the stormwater will contribute to alleviating the total effects of storm events.

The River Frontage is the low-lying areas along the banks of the Hudson and Hackensack Rivers with soils that are not conducive to water storage.

A site's location within one of these three areas determines the best course of action to take when implementing stormwater mitigation. Within these areas, public spaces (including rights of way) and municipally owned properties (including parklands and open spaces) will be prioritized for their ability to accommodate stormwater storage and diversion. Other areas that will be identified include large expanses of impervious surfacing such as parking lots, which could potentially be retrofitted to store and release peak stormwater flows.

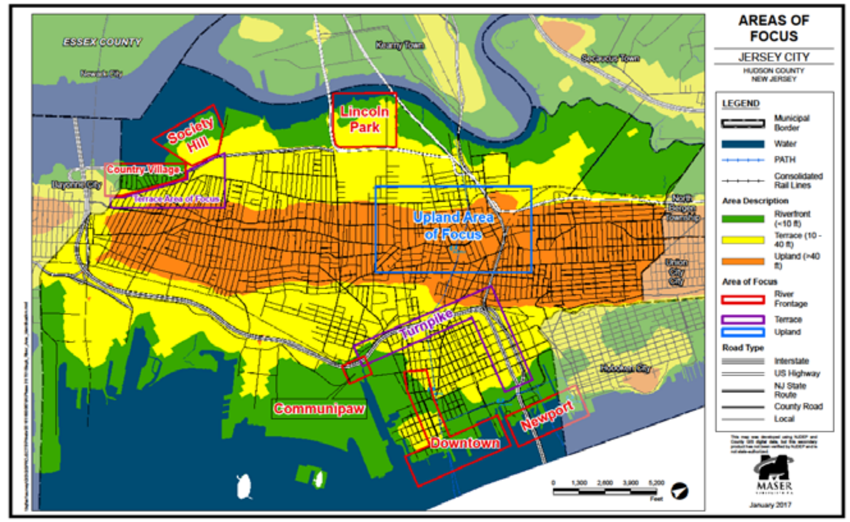


Figure 3: Upland (orange), Terrace (yellow), and River Frontage (green) areas

Upland – Goal: Remove water from system early on

The Upland areas overall can serve the city best by removing water from the system before it flows downhill. The sample Upland area in the following discussion is located around Tonnele Avenue and John F. Kennedy Boulevard; however, the techniques described herein should be applicable to the entire Upland.

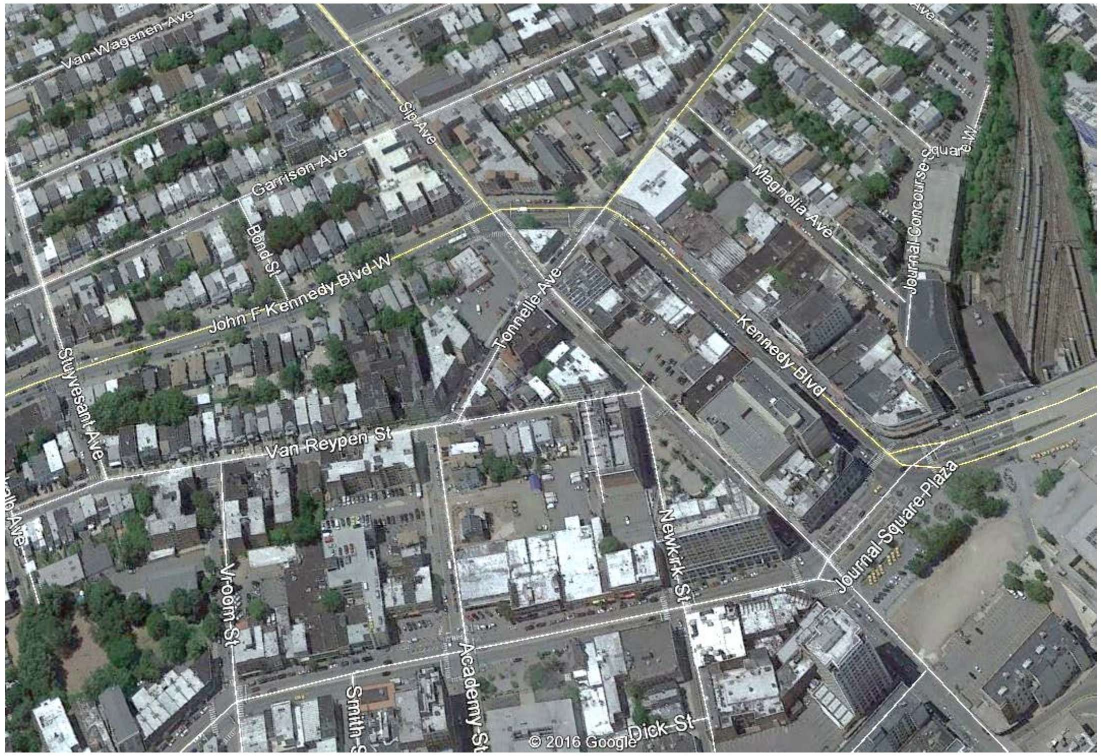


Figure 4: Upland Area (source: Google Earth)

By its elevations, the sample area shown in Figure 4 is one of the higher points in the city and therefore on the upper edges of the Combined Sewers (CSO) collection area. As stated earlier in this report, an important tenet of planning for urban green design is to delay water from entering the stormwater system. Because there is a significant amount of impervious coverage in the Upland areas, particularly with surface parking lots, green infrastructure improvements at these higher elevations can make a substantial impact on the city's overall stormwater capacity by diverting water and lessening the compounding effect further downhill.

This aerial map taken from Google Earth shows that most of this area is developed, with residential areas to the northwest near Garrison and Sip Avenues, and commercial uses dominating along Bergen Avenue and Kennedy Boulevard. There is major redevelopment taking place in the entire area in accordance with the Journal Square 2060 Redevelopment Plan, which may afford the opportunity to introduce green into the planning and design processes.

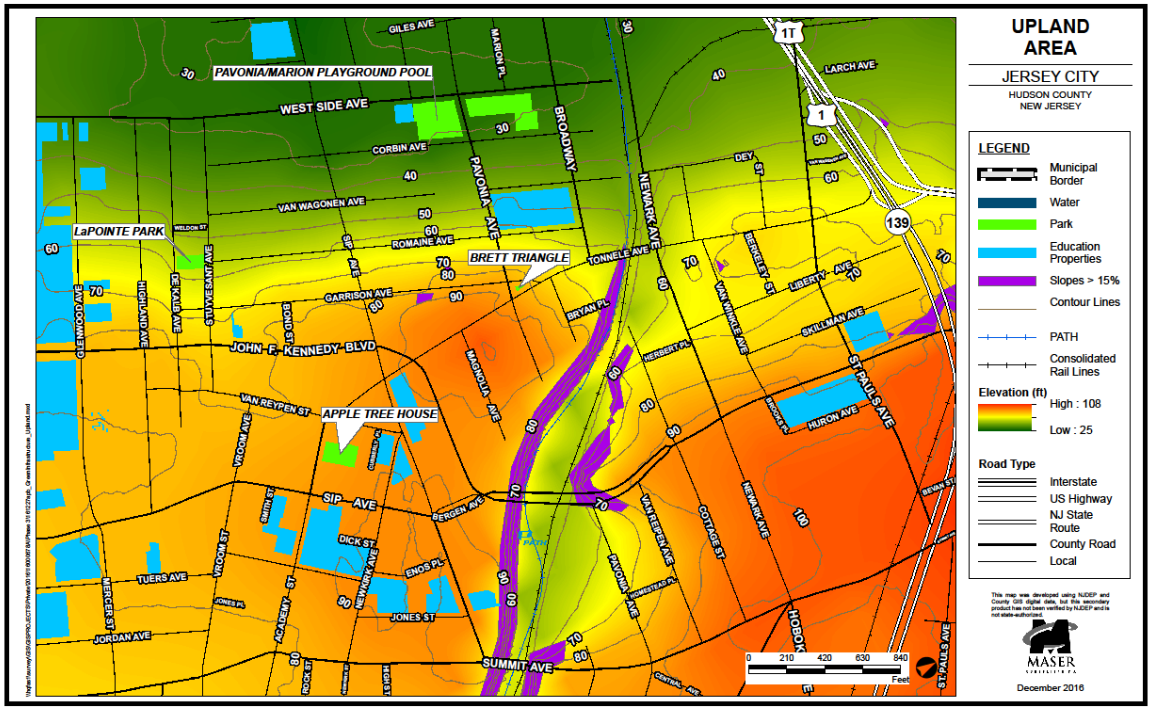


Figure 5: Slopes in Upland Area

Figure 5 shows elevation in the Upland area, with brighter shades of orange reflecting higher elevation, and green the lower elevation areas. One can see, then, that there is a high point in the area of Tonnele Avenue near Magnolia Avenue and Kennedy Boulevard. It is in this area, between Brett Triangle and Apple Tree House, that this plan will look for places to divert stormwater.

In the vicinity of the Apple Tree House and Newkirk Street are many impervious parking areas. With development an almost certain eventuality on these parcels, future improvements should be coupled with a requirement for the introduction of green elements to mitigate stormwater on site. In cases where parking lots remain, requirements for storage facilities beneath such impervious surfaces should be considered, and calculations based on the established methodology discussed above in *Design Criteria and Applications*.

The following specific locations have the potential for significant net improvement in stormwater reduction by introducing green infrastructure. Each analysis is based upon actual volume of stormwater that falls in that corridor, and serves as a guide for the evaluation of potential sites and a methodology for determining volumes and sizing:

- Upland Area No. 1: Bergen Avenue and Vroom Street;
- Upland Area No. 2: John F. Kennedy Commercial Corridor;
- Upland Area No. 3: Sip Avenue at Garrison Avenue;
- Upland Area No. 4: Brett Triangle.

These specific locations were selected to demonstrate a variety of applications which could be easily replicated in different corridors or intersections throughout the Upland Area to illustrate applications within commercial areas, residential areas, and open spaces.

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Upland Area No. 1: Bergen Avenue and Vroom Street

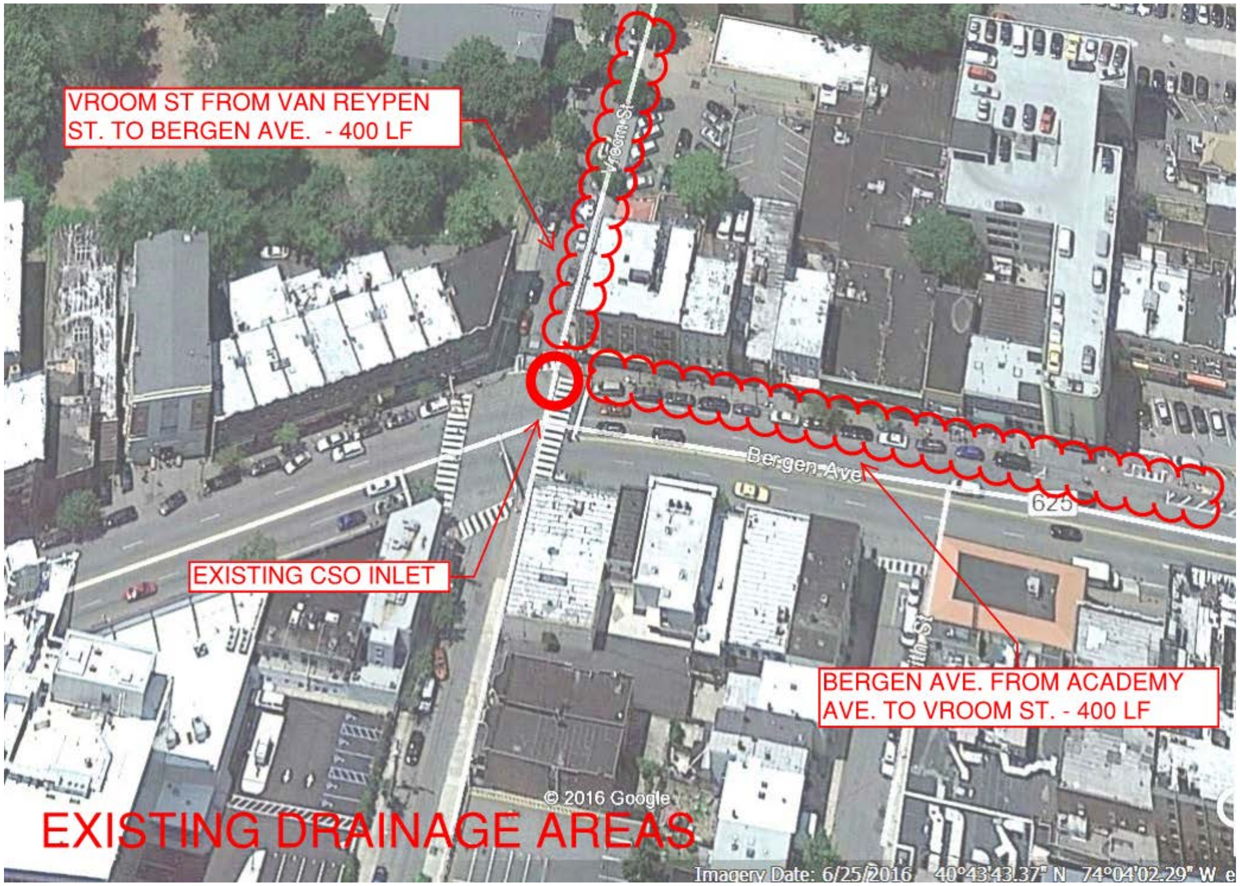

Figure 6: Upland Area 1

The inlet located at the northwest corner of Bergen Avenue and Vroom Street collects stormwater from the northern half of Bergen Avenue between Academy and Vroom Streets, and the western side of Vroom Street from Van Reypen Street to Bergen Avenue. These two drainage areas converge at the corner and enter the storm drain inlet at that point.

The design intent is to calculate the volume of water that flows to the corner under a typical 1-inch storm event as described earlier. Using standard mathematical methodology based on the street width and length, a total of 1,660 cubic feet of rainwater could be captured.[18]

Such a system would be designed to have one green inlet on each upslope from the existing corner catch basin in order to collect the first 1-inch, allowing the stormwater to fill the trench during storm events and slowly release the stored water back into the inlet through an orifice. This would be most effectively combined with the introduction of curb inlets and trees located along the edge of the trench to assist in the mitigation.

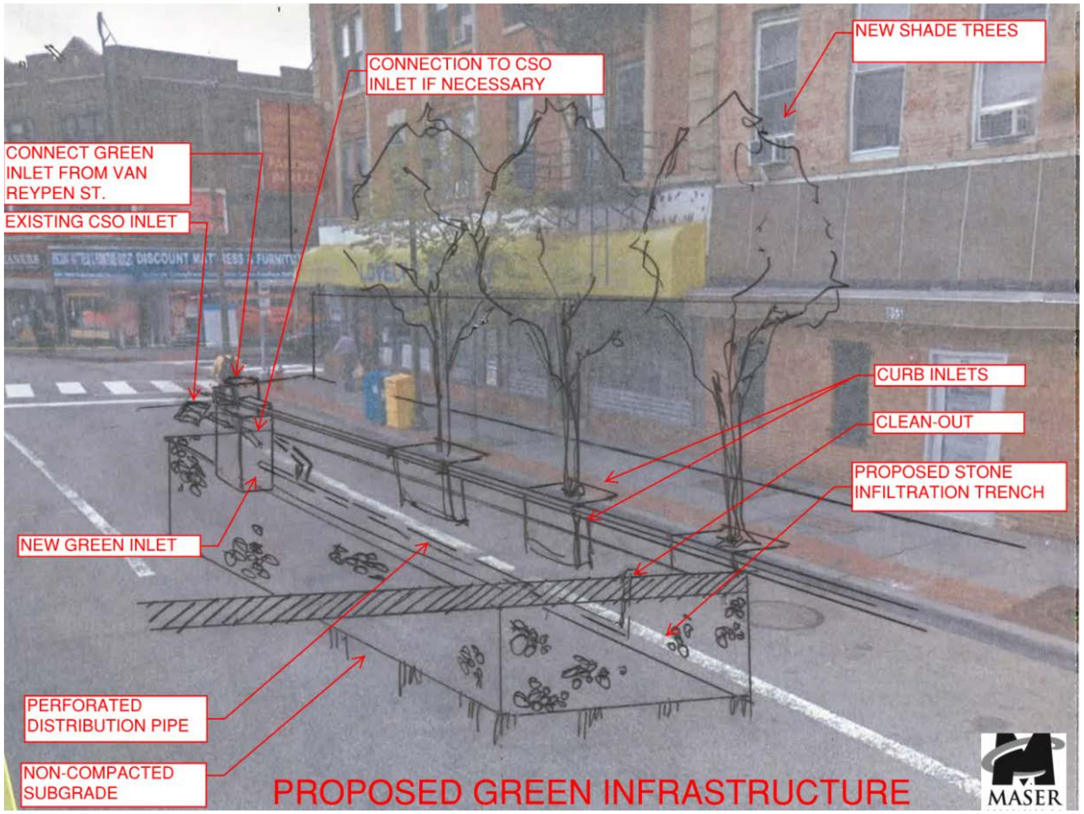

Figure 7: Illustrative view of street improvements

[18] All mathematical calculations can be found in detail in the Appendix of Formulas at the end of this document.

Upland Area No. 2: John F. Kennedy Commercial Corridor

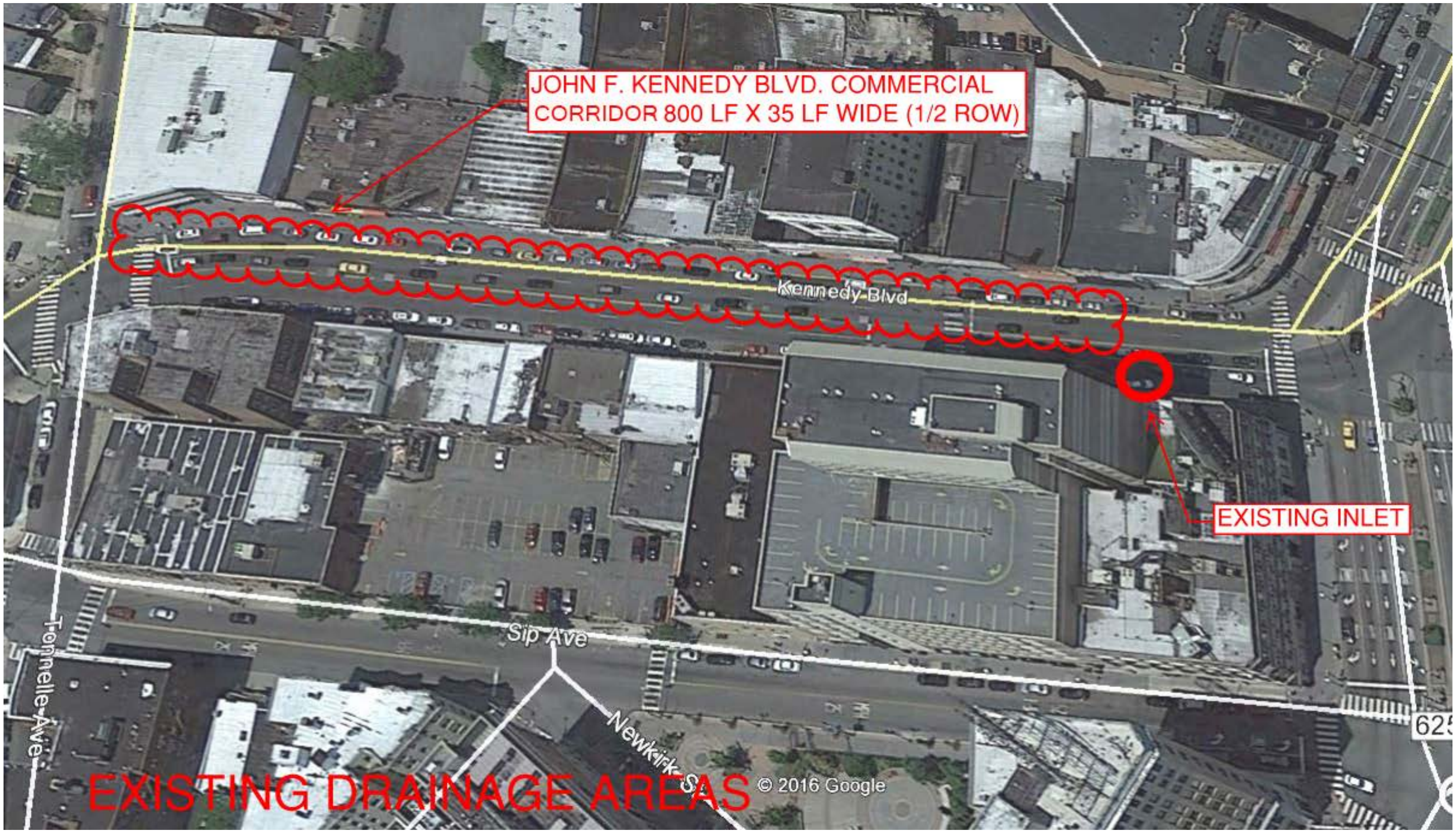

Figure 8: Upland Area 2

The John F. Kennedy Boulevard Commercial Corridor, and in particular the area between Tonnele Avenue and Bergen Avenue on the southern side of the street as shown in Figure 8, is an ideal location to introduce green as part of an overall streetscape improvement project. The mid-block inlet shown in the lower right corner is responsible for collecting one half of the 60' right-of-way from Tonnele

Avenue, which is a distance of approximately 800 linear feet. A number of green infrastructure applications could be used here to provide traffic calming, reduce heat island effects by introducing shade trees and planting areas, and generally provide a more pleasant and pedestrian friendly streetscape. Using standard mathematical methodology based on the street width and length, a total of 2,000 cubic feet of rainwater could be captured.

In this case, the stormwater would be handled both on the surface by diverting rainwater into a green bed system and beneath the street in drainage bedding.

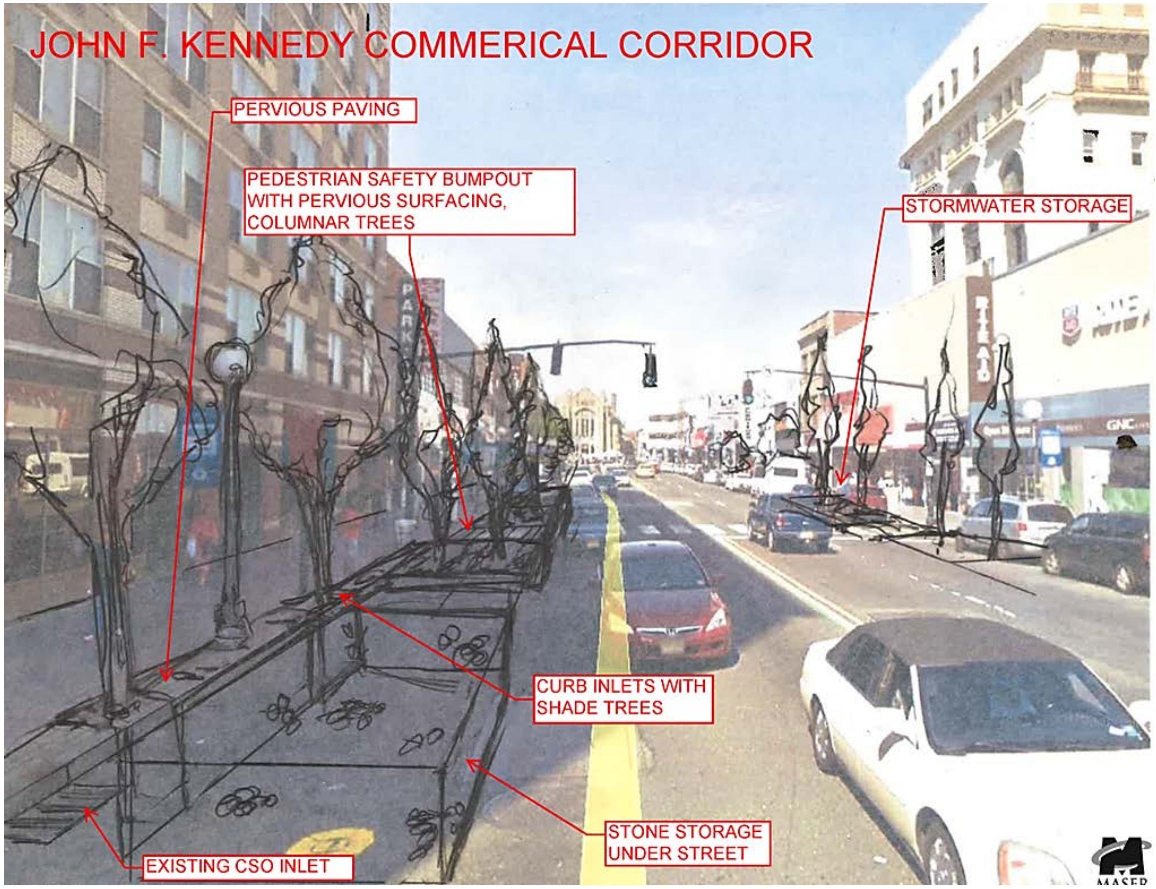

Figure 9: Illustrative view of street improvements

Figure 9 above illustrates how a bump out area at the mid-block pedestrian crossing light combined with various applications of green infrastructure, such as pervious surfaces, curb inlets and portions of stone storage beneath the street with columnar trees in the bump out and shade trees along the edges could transform the look and feel of this commercial corridor.

Upland Area No. 3: Sip Avenue at Garrison Avenue

Figure 10: Upland Area 3

The intersection of Sip and Garrison Avenues was chosen because it has drainage from three (3) directions converging on the area before proceeding down Sip Avenue to the west. This means that the green infrastructure could be maximized by connecting one or more of the drainage areas, thereby providing excellent options for the most cost effective installation.

Using standard mathematical methodology based on the street width and length, a total of 3,165 cubic feet of rainwater could be captured.

Figure 11: Illustrative view of street improvements

Upland Area No. 4: Brett Triangle

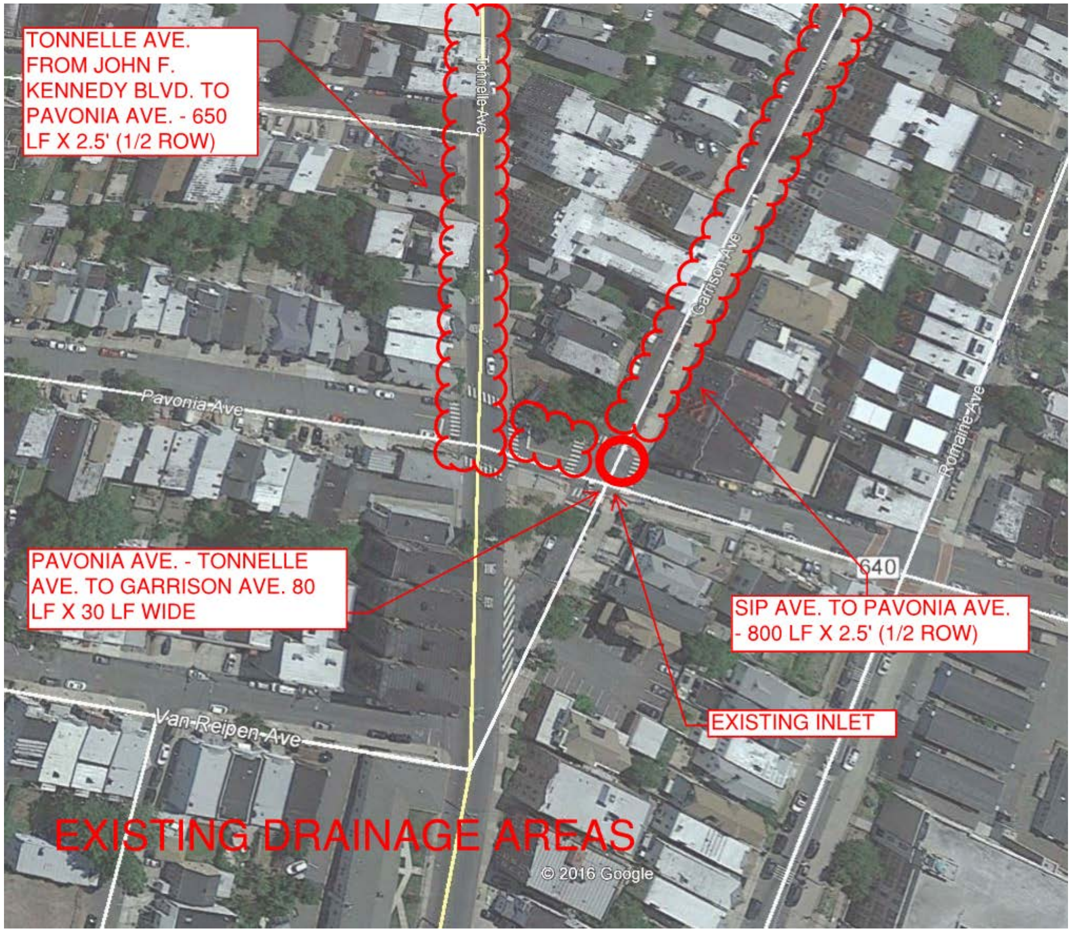

Figure 12: Upland Area 4

The Brett Triangle area is recommended for green infrastructure improvements as well because both of the side streets, Tonnele and Garrison Avenues, meet Pavonia Avenue at this location with only one inlet located at the lowest spot at the corner of Pavonia and Garrison. Therefore, stormwater converges at this location.

Using standard mathematical methodology based on the street width and length, a total of 2,988 cubic feet of rainwater could be captured.

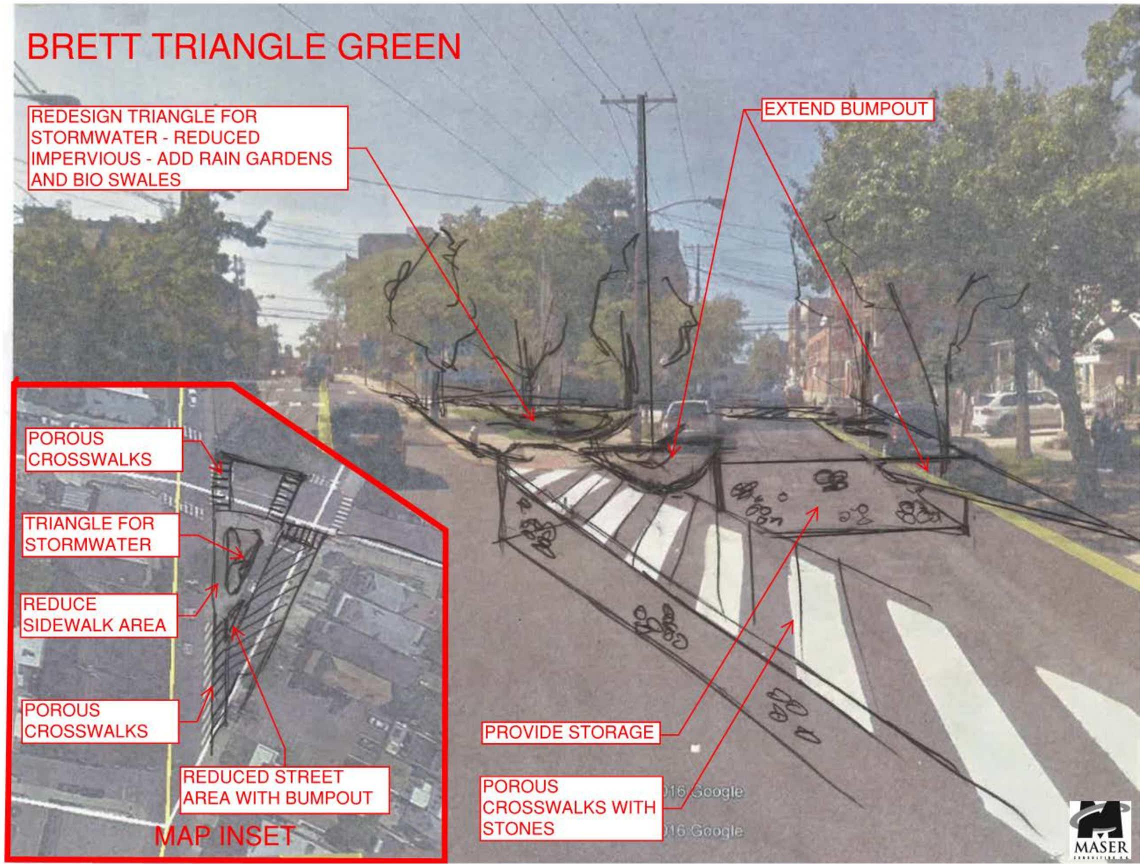

Figure 13: Illustrative view of street improvements

Figure 13 shows both an aerial view and a street view of what could be a green application, including the opportunity for open space in the Triangle. A combination of pervious crosswalks, extended bumpouts, and storage could be easily retrofitted within the existing ROW corridor.

The Terraces – Goal: Slow release using open spaces

The Terraces area overall can serve the city best capturing water and slowly releasing it into open spaces in the area. The sample Terraces area in the following discussion is located in the western side of the city proximate to the Hackensack River and Route 440, however the techniques described herein should be applicable to the entire Terraces.

The sample area shown in Figure 14 is located on the hill sloping down to the west from Kennedy Boulevard toward the river. The elevations noted on the map indicate slope by the tonal gradation from orange to yellow to green. With the general slope and the stormwater sewer (CSO) flowing down to a collector pipe on the Hackensack, this is an ideal location to introduce green infrastructure and seek opportunities to keep stormwater out of the system. As noted earlier in this report, mitigating water at the higher elevations lessens the compounding effect further downhill. However, in this case lower areas will also be studied for their ability to assist in the mitigation of stormwater by storing and slowly releasing stored water after rain events.

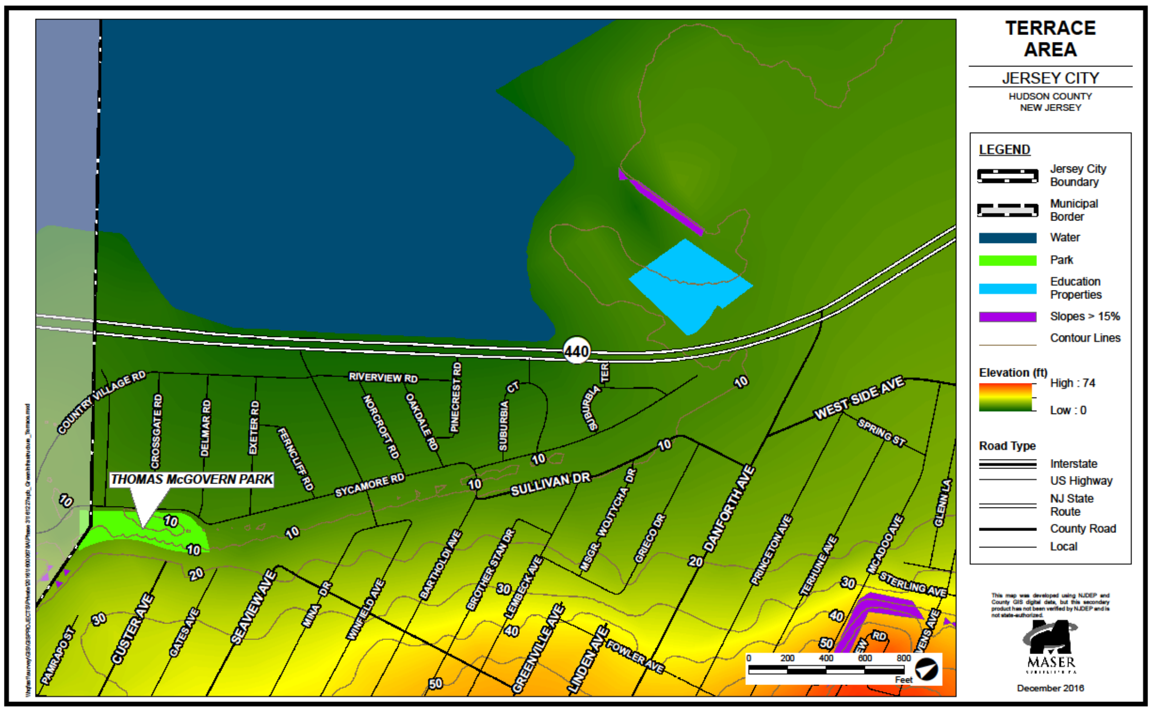

Figure 14: Terraces slope map

Combining the topography with the existing public open spaces is the basis for the recommendations for locations of potential green infrastructure within The Terraces Area.

The logical locations that will be investigated are:

- Terraces Area No. 1: Bartholdi Avenue at Sullivan Drive;
- Terraces Area No. 2: Mina Drive at Sayles Street;
- Terraces No. 3: McGovern Park at Sycamore Road.

Terraces Area No. 1: Bartholdi Avenue at Sullivan Drive

The intersection of Bartholdi Avenue at Sullivan Drive shown in Figure 15 slopes down along both Bartholdi and Sycamore toward Sullivan Drive. There is sufficient space to provide a combination of greening elements, including porous paving, storage trenches, and bio swales.

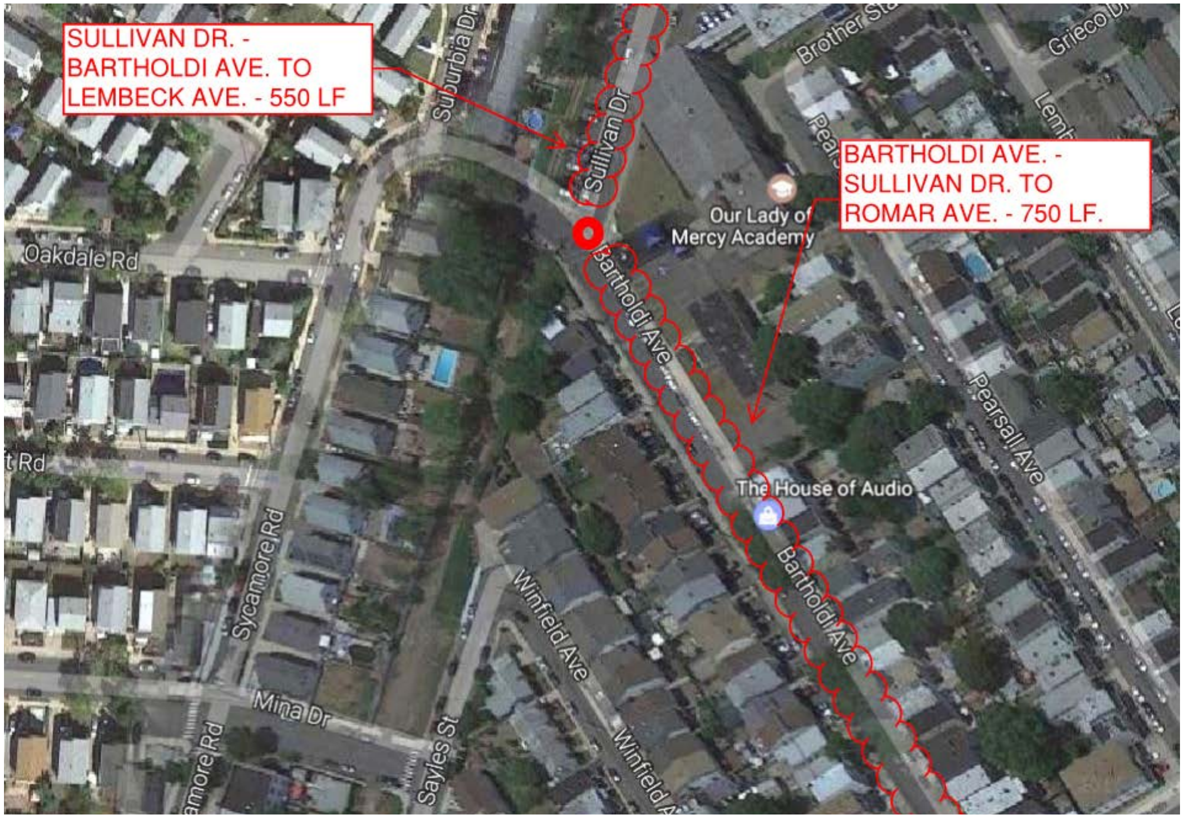

Figure 15: Terraces Area 1

Using standard mathematical methodology based on the street width and length, a total of 2,698 cubic feet of rainwater could be captured. The system would be designed to have one green inlet put on each upslope from the present corner catch basin to collect the first one inch, allowing the stormwater to fill the trench during storm events and slowly release the stored water back into the inlet through an orifice. This would be combined with the introduction of curb inlets, bump outs, bio swales and trees along the edge of the trench to assist in the mitigation.

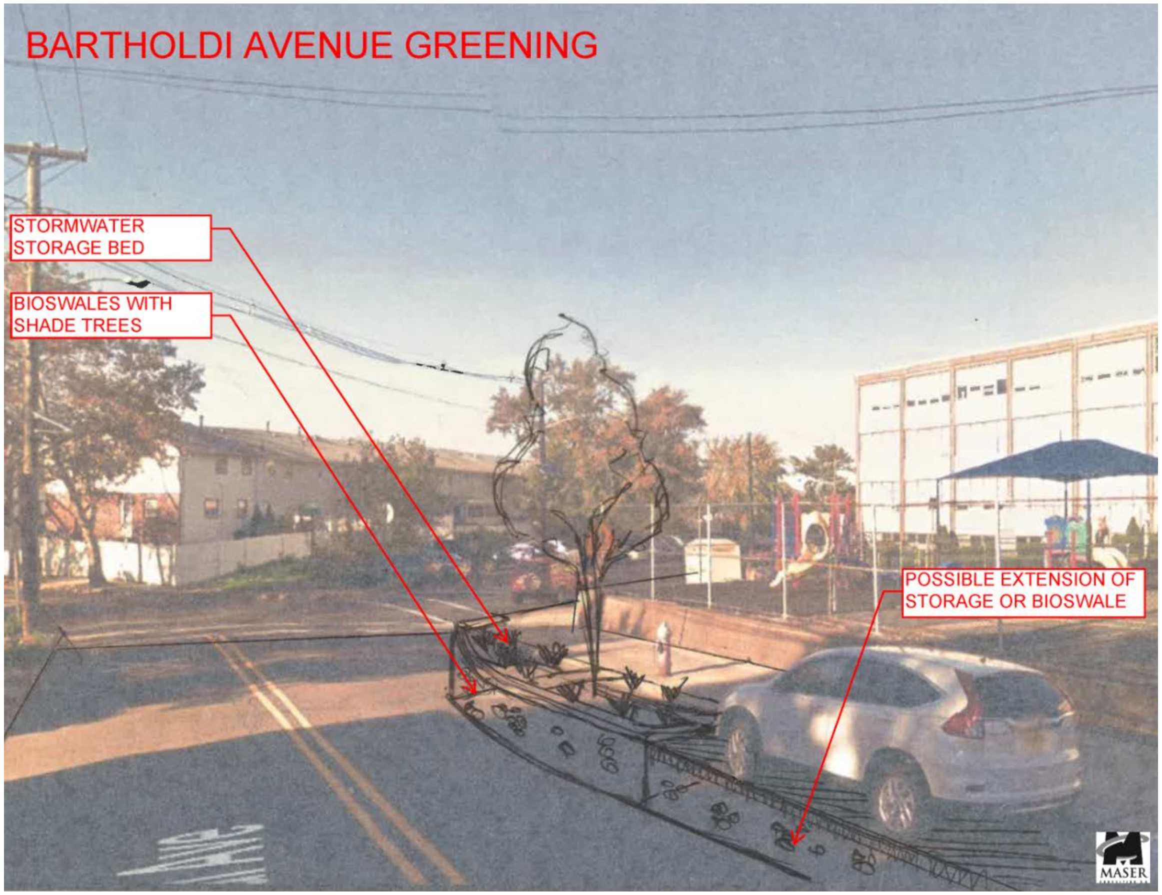

Figure 16: Illustrative view of street improvements

Our Lady of Mercy Academy is also located near Bartholdi Avenue at Sullivan Drive, an ideal location to demonstrate the greening of a schoolyard. There has been movement in recent years to add green elements to school play areas, acting as both an environmental education tool and a means by which to help cool schoolyards that are often devoid of shade. This, combined with green infrastructure elements, works to develop an understanding from an early age of our environment and the impacts we have on it.

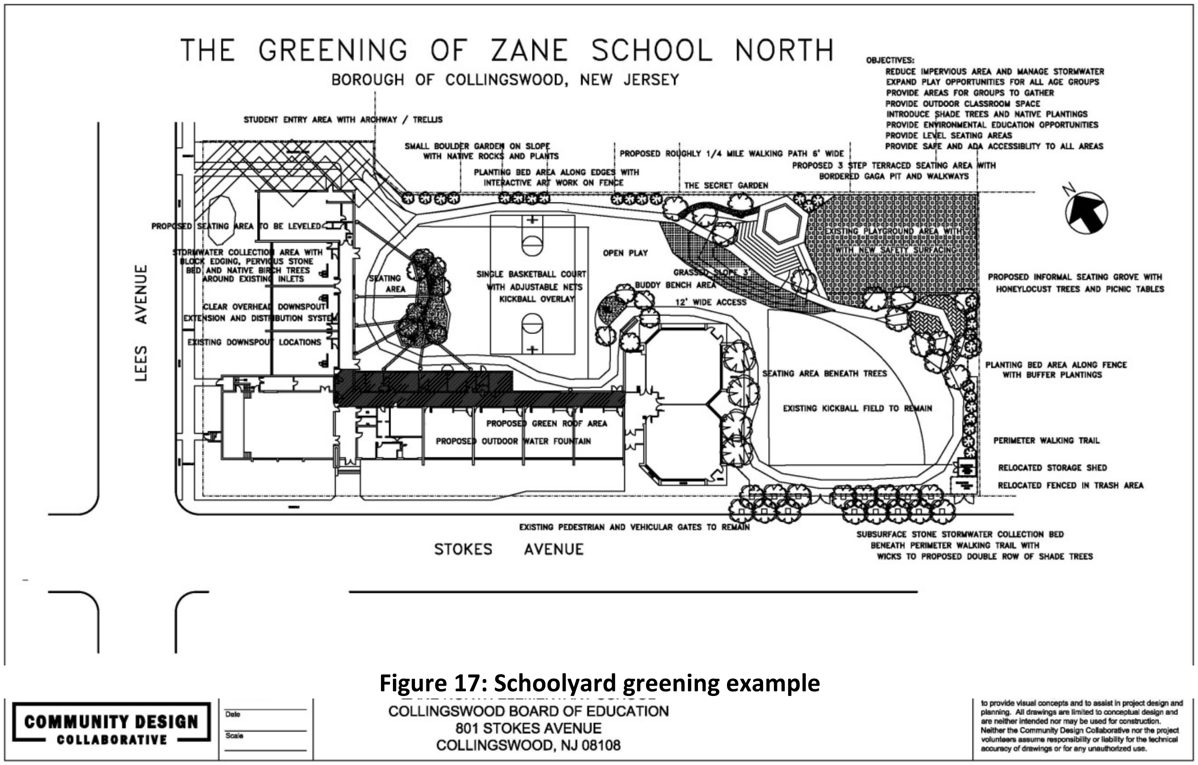

Figure 17: Schoolyard greening example

Terraces Area No. 2: Mina Drive at Sayles Street

The intersection of Mina Drive with Sayles Street and Neptune Avenue is another possible location for green infrastructure improvements. Here, Sayles Street runs adjacent and parallel to a utility ROW, allowing significant space on the west side of the street for creative green infrastructure.

Figure 18: Terrace Area 2

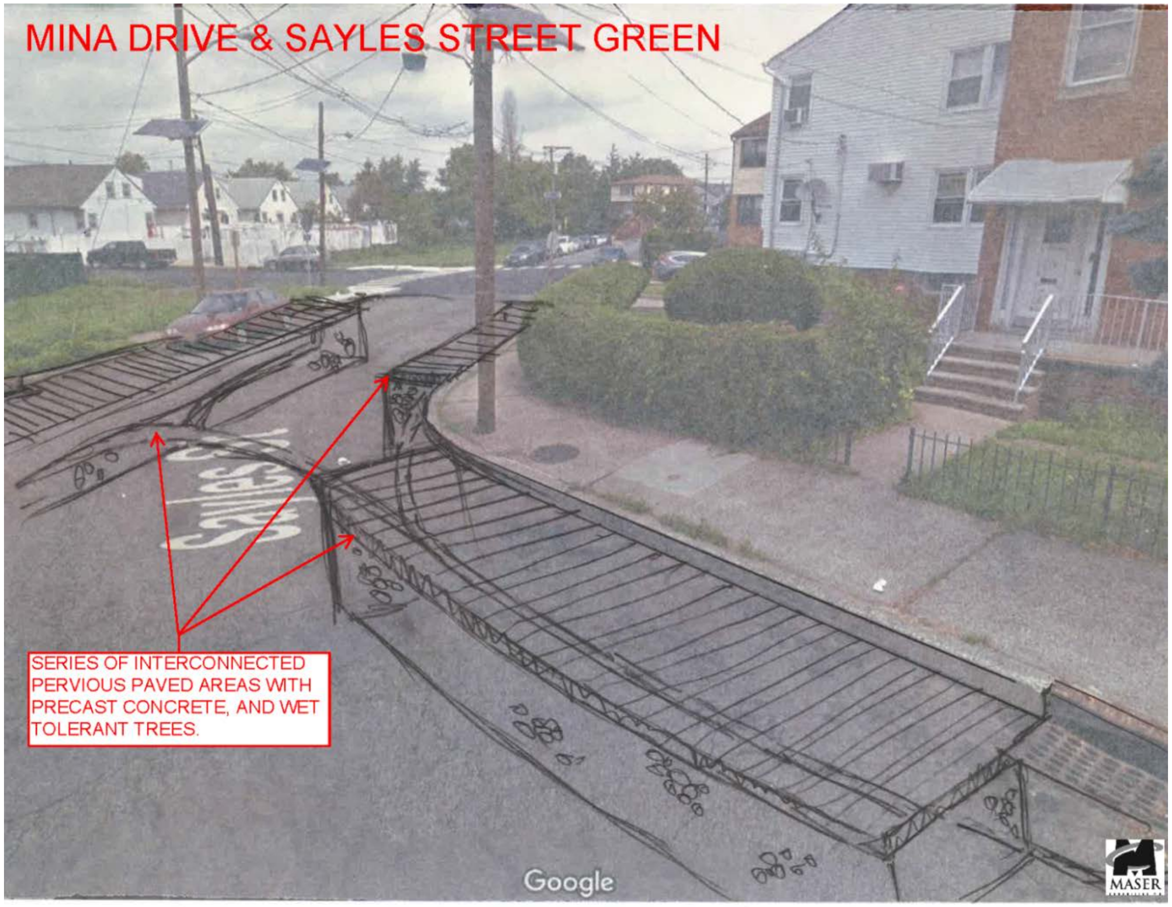

Figure 19: Illustrative view of street improvements

Figure 19 shows a flexible green infrastructure application of connected trenches that can be combined with a number of additional green elements within the footprint of the trenches, including curb cuts, green inlets, and shade trees, all designed to mitigate as much stormwater as possible.

Terraces Area No. 3: McGovern Park at Sycamore Road

Figure 20: Terraces Area 3

While the McGovern Park area lies at the bottom of the hill sloping from Kennedy Boulevard toward the Hackensack River, this open space is an ideal location to introduce unique and educational applications of green infrastructure. As shown in Figure 20, there are a number of inlets located along Sycamore Road at Briarwood, Crossgate and Delmar Roads where water could be diverted and the greening of the park could assist in the mitigation of rain events.

Figure 21: Illustrative view of street improvements

Improvements within the park and along the park edges are recommended. This could include repaving the perpendicular parking to provide stone storage beneath porous paving in the parking spaces. The volume of storage would be determined by the depth that the stone can be filled.

Figure 22: recommended Park improvements

The existing baseball field could be excavated to provide stone storage beneath the playing field surface. This has been done previously in urban areas with the playing field surface being replaced with synthetic turf. Additionally, the large roller hockey rink could be retrofitted with green to both reduce the amount of impervious surface runoff and to provide mitigation from redirected stormwater. This rink removal was also recommended in the City's 2008 Recreation and Open Space Master Plan. Paving throughout the park could also be replaced with pervious paving, which is increasingly common in urban parks.

Terraces Area No. 4: Turnpike

Beneath the New Jersey Turnpike overpasses and along parallel streets is a vast amount of pavement that provides an opportunity to improve stormwater recharge and retention. Not only are retention areas more aesthetically pleasing than other detention basins, but they provide high pollutant removal in addition to absorbing rainwater. Designed within a relatively small area, residential rain gardens range from 100 to 300 square feet in area[19] and is typically designed to handle 1.25 inches of rain in a two-hour period.

Figure 23 shows a bioswale in Portland, Oregon, adjacent to an elevated highway. This type of project can have a positive impact on capturing the first inch of rain and reducing stormwater runoff. The challenge of multi-agency buy-in is acknowledged since the property is owned by the Turnpike Authority, but the benefits would be well worth the effort.

Figure 23: Bioswale example[20]

[19] Rutgers Green Infrastructure Planning, Design & Implementation: Training for Design Professionals. November 2010

[20] Rain City Gardens, Portland, OR, website www.raincitygardens.com

Streets parallel to the elevated Turnpike such as Merseles Street on the west side and Center Street and Christopher Columbus Drive on the east side, should implement bioretention features such as bioretention curb extensions and sidewalk planters to permit more stormwater to be recharged into the ground than currently exists.

River Frontage - Goal: small scale surface treatments

The River Frontage, despite being the closest to the waterfront and the lowest in elevation, has the most limited impact in terms of green infrastructure. As discussed in the topographic and geologic analysis, the River Frontage has elevations near sea level (elevations 0’ to 10’) and minimal slopes (0%-5%). The geologic conditions mean that these areas along the Hudson and Hackensack Rivers have a shallow depth to groundwater and are generally not suited to storage of stormwater.

The River Frontage areas overall can serve the city best through levees, revetments, and embankments. A benefit to these approaches is that each offers a dual opportunity of providing open space or walkways along or beside the structure, as well as the potential to allow people the opportunity to approach the water’s edge, connecting them to nature. The sample River Frontage areas in the following discussion are scattered throughout the waterfront along both rivers.

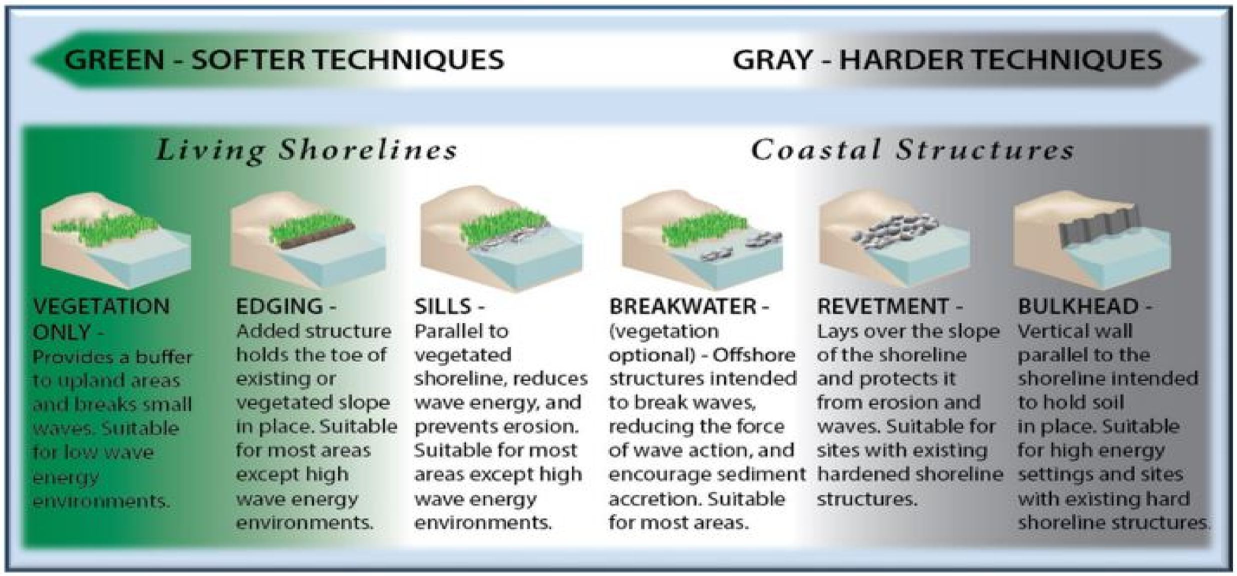

Figure 24: Various shoreline-stabilization methods are shown, ranging from “green” living shorelines to hardened structures, shown in gray. Image: NOAA

River Frontage Area No. 1: Country Village

In stream restoration, river engineering, or coastal engineering, revetments are sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water. This type of structure is what exists along the west side of Route 440 in Country Village. This project would improve and enhance the revetment and the shoreline along the west side of Route 440 between Bayonne City boundary to the south and the Thomas M. Gerrity Athletic Complex at its northern end. Currently, the narrow shoreline primarily consists of a stone revetment, as the aerial below shows.

Figure 25: River Frontage Area 1 (Country Village)

Given that the shoreline is not directly accessible to pedestrians and currently has no walkway, a ***joint planting revetment*** is recommended.

Revetments are sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water and protect the shoreline from erosion. Revetments typically consist of a cladding of stone, concrete, or asphalt to armor sloping natural shoreline profiles. Although a conventional stone revetment is more preferable to a bulkhead, it is less preferable to an ecologically enhanced revetment or natural shoreline, where it is acceptable. A hardened revetment may be the only alternative for certain developed areas or roadways along a coast before a bulkhead or seawall is necessary.

A joint planting revetment involves live stakes tamped into openings between rocks which have been previously installed on a slope. An example of joint planting is included in Figure 26. This option does offer some positive results with regard to storm waves, sea level rise, wave reduction, and flow resistance. It also enhances habitat appearance and access to water, which will be useful when the walkway is developed along this portion of the shoreline. This would work with the street levee proposal outlined in the Adaptation Plan, as the revetment is the first line of defense along the coast line.

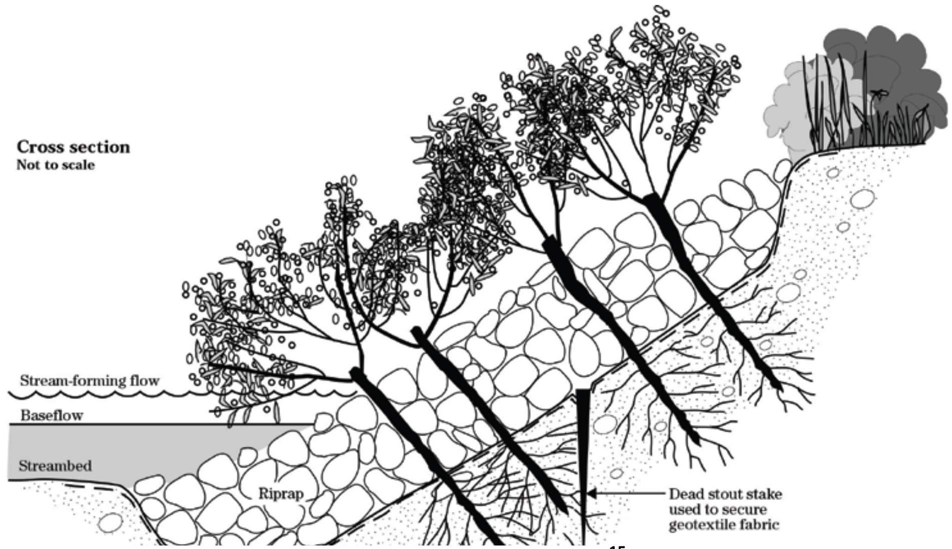

Figure 26: Joint Planting Revetment[15] (source: USDA)

[21] USDA - NRCS Engineering Field Handbook, Chapter-16. 1996.

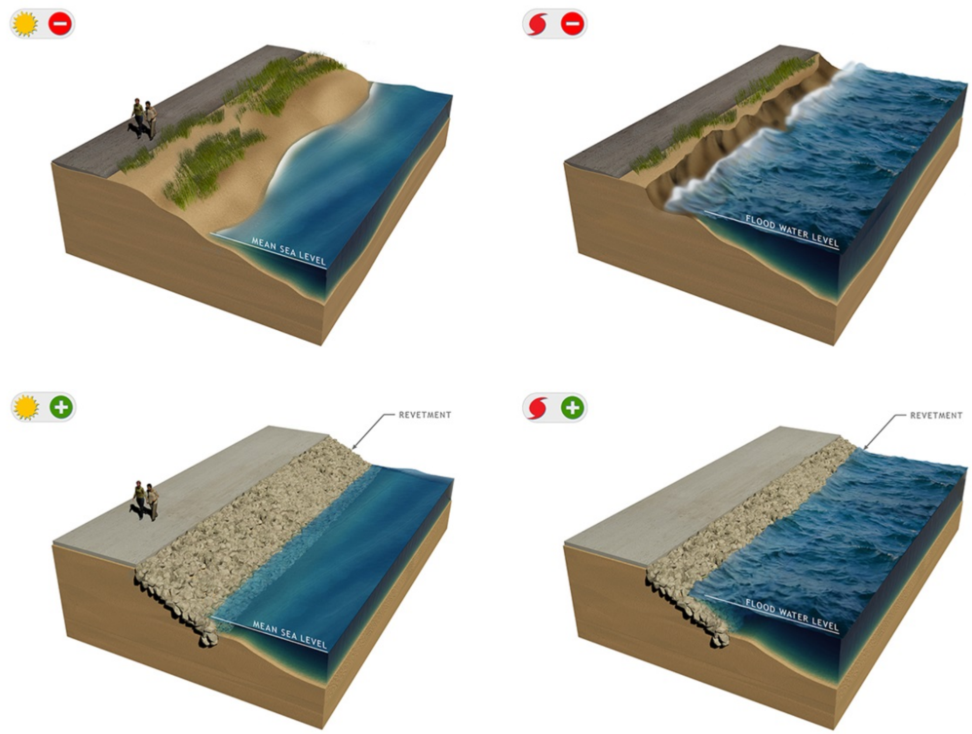

Figure 27: Diagram of expected impact of stone revetments on coastal stabilization (Source: U.S. Army Corps of Engineers)

Also in this area, Route 440 has no green infrastructure features. As part of the long term boulevard redesign of Route 440, a Green Streets Program should be included in the plan to allow for additional stormwater mitigation along the roadway.

River Frontage Area No. 2: Society Hill

Along the riverfront, the shoreline consists of a revetment abutting the Gerrity Athletic Complex then to the north around Society Hill.

Figure 28: River Frontage Area 2 (Society Hill)

A ***joint plantings revetment*** is recommended for the shoreline adjacent to Gerrity Athletic Complex and Society Hill. The shoreline abutting the existing Hackensack River Walk has sufficient width to allow this implementation, which is also in concert with the Adaptation Master Plan's recommendation of constructing a Boardwalk levee.

Additionally, the existing Route 440 Boulevard project will be an effective means by which to allow for additional stormwater mitigation along the roadway.

River Frontage Area No. 3: Lincoln Park

Lincoln Park provides an outstanding opportunity to implement green infrastructure and enhance temporary flood storage. A County park, Lincoln Park has an area of 273 acres. To complement the East Park's ponds and landscaped greenery, Lincoln Park West is an exceptional collection of open space, including preserved natural habitats and areas to engage visitors. The County is currently in the process of a wetland restoration project that will enhance the observation of the natural habitat and local species with a waterfront walkway.

Figure 29: River Frontage Area 3

Jersey City realizes that Lincoln Park is a County park, and therefore all decisions made with regard to upgrades, changes, or improvements are at the sole discretion of Hudson County. However, Jersey City should recommend to the County that as the park upgrades over time, design features such as pervious pavers and other green infrastructure methods incorporated into the park pathway design, berms and terraces to trap stormwater, and flood storage would be an incredible asset. Moreover, living shorelines could be created along the Hackensack riverfront to address erosion control with natural features.

Living shorelines have a breakwater of rocks, a strand of coastal wetlands and beach, then a bankface, and an upland buffer. Wetlands and natural structures are better at absorbing the impact of floodwater, particularly long-term.

Figure 30: Living shoreline example (NOAA)

Living reef breakwaters or ***ecologically enhanced revetments*** may also be appropriate in this location. Living reef breakwaters use a heavily-weighted substrate, such as reef balls, bagged shells, or oyster castles to provide a durable aquatic habitat for reef species to settle and build a "living" reef. The reef structure serves as a breakwater, slowing wave energy from eroding the sensitive shoreline. Generally, a breakwater will be submerged at high tide, but somewhat visible at low tide. A marsh habitat should be able to grow in the protected area. A living reef breakwater will reduce the impact from open water and allow marsh to continue to expand behind it.

Ecologically enhanced revetments are typically constructed of stone, felled trees, or broken up concrete and placed along a shoreline, which may be either open coastal locations or sheltered areas, such as a creek. Unlike most revetments, these are meant to be porous and allow vegetation to grow within and between the stones. The more durable substrate provides a foundation, as well as protecting the upland shoreline vegetation and sediment.

These approaches also offer a great opportunity for people to approach the water, giving children exposure to the nature in their own backyard, nature lovers a sense of attachment, and even recreation for fishermen.

Living Reef Breakwaters

Living reef breakwaters function similarly to constructed breakwaters, but are built to provide habitat for baby oysters, mussels and other reef species to settle upon. Reef balls, oyster castles, bagged shell and other reef structures provide a durable and heavily-weighted substrate. Over time, large reef structures can form that not only serve as a natural breakwater, but also provide critical aquatic habitat.

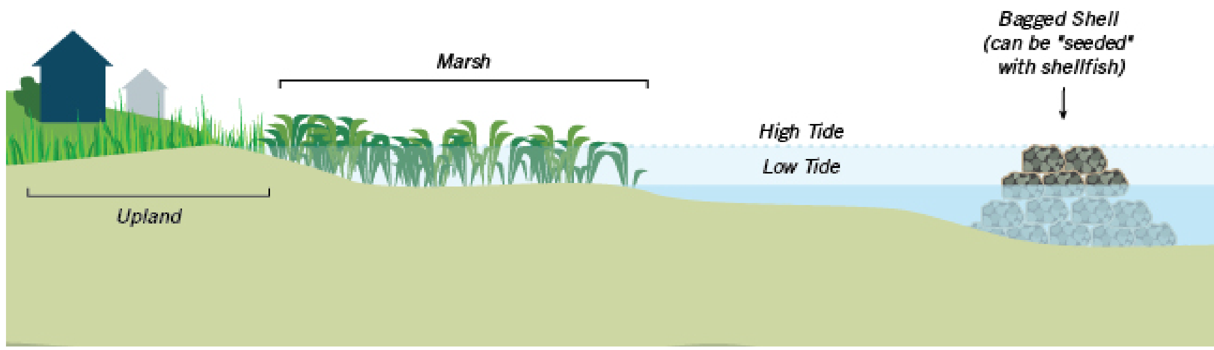

Figure 32: Diagram of a living reef breakwater in a tidal marsh (Source: The Nature Conservancy)

Ecologically Enhanced Revetment

Ecologically-enhanced revetments are porous, vegetated structures attached to the shore. They are typically constructed from rock or broken up concrete, although other materials can be used (e.g., gabion baskets, rubble/debris, and even felled trees). They can be used at both open coastal locations and on lower energy sheltered areas.

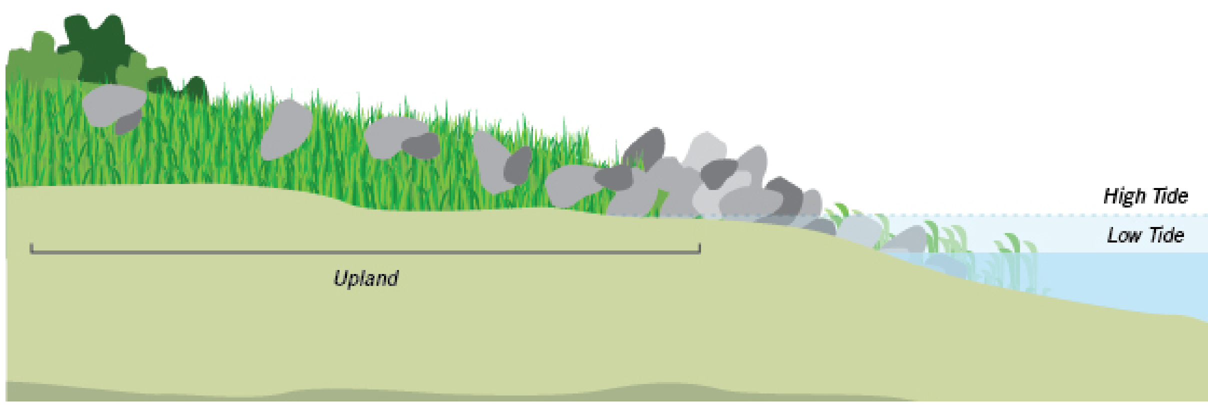

Figure 31: Diagram of an ecologically enhanced revetment (Source: The Nature Conservancy)

River Frontage Area No. 4: Communipaw

The Mill Creek section of the Morris Canal within the Communipaw neighborhood has significant potential for green infrastructure. This area is located within the Grand Jersey Redevelopment Area, which designates the land area on the south side of the Canal as a Park District, an ideal location to implement ***artificial stormwater wetlands***. Generally, the area may include protection features to retain soil, mitigate shoreline edge erosion, and can dissipate wave energy, alleviate erosion, retard storm surge intrusion, and buffer tidal flooding.

Artificial or constructed wetlands are new or restored coastal wetlands that lie in sheltered and low-elevation areas from mean tide level to spring high tide level. These areas incorporate wetland plants in shallow pool-like wet ponds, and as stormwater runoff flows through the wetland, pollutant removal is achieved by settling and biological uptake within the practice. Different from natural wetlands, artificial wetlands are designed specifically for treating stormwater runoff, and typically have less biodiversity than natural wetlands both in terms of plant and animal life. There are several design variations of the stormwater wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. Although it is a challenge to use artificial wetlands in an urban watershed because of the land area each wetland consumes, in this location both sides of the Canal provide an opportunity for the development of artificial wetlands. Generally, these systems have lower installation costs and simple hydraulics.

Figure 33: Urban Stormwater Wetlands in China (Source: inhabitat.com)

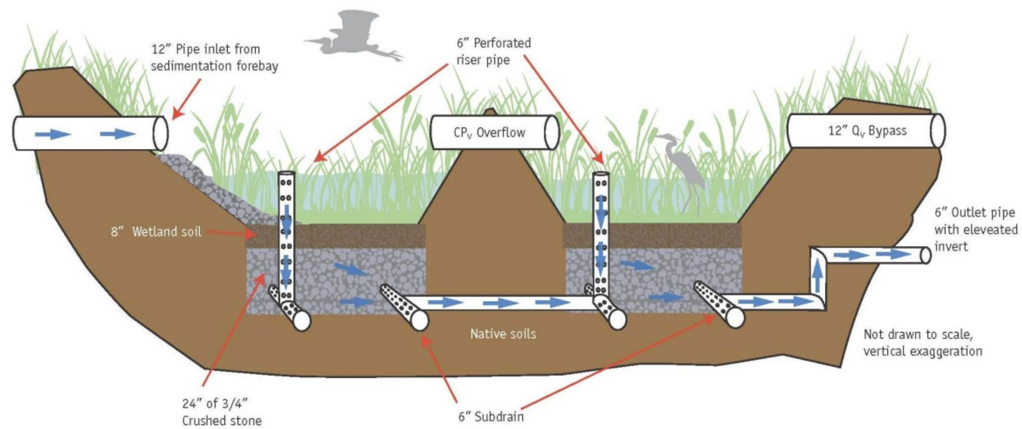

Figure 34: Stormwater wetlands cross section (Source: Water Environment Federation)

River Frontage Area No. 5: Downtown

Along the Liberty Harbor North frontage of the Tidewater Basin, a ***joint plantings revetment*** is recommended for the shoreline adjacent to the Waterfront Walkway. Installing these improvements will provide more resistance to storm waves, sea level rise, wave reduction, and flow resistance than the current situation permits. The habitat appearance and waterfront access will also be improved. Those positive aspects contribute to the aesthetics of the Waterfront Walkway in addition to its primary task of reducing adverse impacts of stormwater and waves.

Also Downtown, ***bulkheads*** are a common bank stabilization measure along the Hudson River. While revetments are meant to absorb the energy of incoming water along sloped surfaces, vertical bulkhead structures are meant to retain or prevent sliding of land into the water, and protect against damage from wave action. Bulkheads are often used in moderate- to high-wave action areas along the Hudson River waterfront that are exposed during storms. Improvements to existing bulkheads can be made such as placing stones at the toe of bulkhead to shelter aquatic life, support marsh plantings along the face of the wall, and encouraging growth of marine flora and fauna on the bulkhead walls.

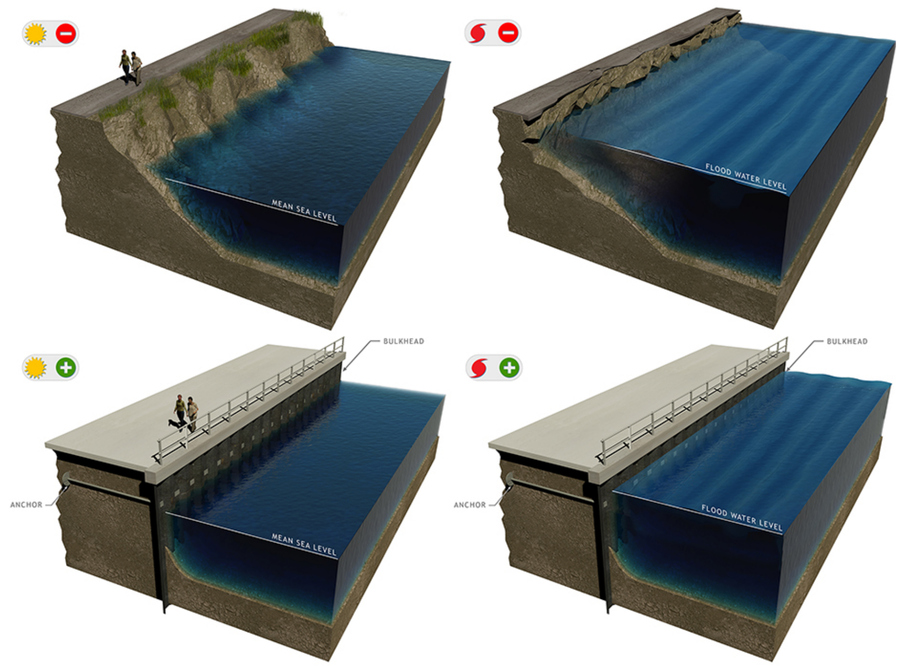

Figure 35: Diagram of expected impact of bulkheads on coastal stabilization (Source: U.S. Army Corps of Engineers)

Away from the shoreline, improvements are recommended to Christopher Columbus Drive which has significant opportunity for narrowing, a road diet, and additional landscaping. This four lane road does not have medians or other green infrastructure to assist in mitigating stormwater, so a ***Green Streets*** program would be an effective improvement. Improvements such as street trees, a boulevard down the centerline bioswales, and possible street narrowing should be implemented along its entire east-west route.

River Frontage Area No. 6: Newport

The Newport area of Downtown faces many of the waterfront challenges that Area No. 6 addresses. Revetments are already present near the Lefrak Point Lighthouse and some of the piers in the northern portion of Newport. A ***joint plantings revetment*** is recommended for the shoreline adjacent to the Waterfront Walkway. This option offers some positive results with regard to storm waves, sea level rise, wave reduction, and flow resistance, while enhancing habitat appearance and access to water.

More prevalent along the Newport waterfront than revetments are ***bulkheads***.

As discussed earlier, bulkheads can incorporate ecologically friendly vegetation and are effective at reducing wave energy and resisting bank erosion. Improvements to existing bulkheads can be made such as placing stones at the toe of bulkhead to shelter aquatic life, support marsh plantings along the face of the wall, and encouraging growth of marine flora and fauna on the bulkhead walls.

Maintenance

For each of the green infrastructure applications recommended herein, it is imperative that the City maintain the projects in order to receive the most benefit and longest life cycle from each. The systems are designed to last 50 years with proper maintenance, although because green infrastructure is a young concept, no demonstration projects have been in longer than eight years in this climate.

An effective and rigorous maintenance program is crucial for the long-term sustainability and function of green infrastructure systems. Because these systems incorporate vegetation, they can change over time as plant communities grow and establish. In urban environments in particular, green infrastructure may be subject to temperature extremes, pollution, heavy sediment and trash accumulation, and an aggressive weed community -- all of which can create a challenging environment for plants. Furthermore, sediment and trash, if allowed to accumulate, can create unsightly conditions. Proper maintenance can ensure that green infrastructure systems remain healthy, attractive, and safe for many years to come.

Typical maintenance tasks include removing competitive species that can hinder the growth of target plant species and removing sediment, trash, and debris from storage areas, piping, and other structures. Maintenance tasks may also include a range of other activities including repairing small erosion problems, pruning trees, removing graffiti, and replanting or reseeding areas. A complete table of maintenance issues can be found in the Appendix of this document.

For plan execution, including evaluation, design and specifications of bid documents, geotechnical, survey, landscape architecture, and civil engineering professionals would be required. Upon completion, personnel familiar with underground piping systems (flushing and jetting) and well monitoring will be required for maintenance, as well as landscape professionals for the planted systems. Many cities have trained and used DPW personnel for this work, although alternatively third party monitoring and maintenance contracts could be considered.

Citywide Recommendations

LEED

In addition to the site-specific green infrastructure recommendations above, part of incorporating green infrastructure into the city should be the encouragement to Leadership in Energy and Environmental Design ("LEED") qualifying development.

LEED is a recognized green building certification rating system which provides third-party verification that the building was designed and built (or rehabilitated, as the case may be) using strategies and materials to lower a building's carbon footprint. LEED was developed by the U.S. Green Building Council and is a "voluntary rating system that encourages buildings to do better, but does not add significant cost".[22] LEED has five rating systems for multiple project types (for example, homes, building design, neighborhood development), and eight main credit categories:

- Location and transportation;
- Sustainable sites;
- Water efficiency;
- Energy and atmosphere;
- Materials and resources;
- Indoor environmental quality;
- Innovation;
- Regional priority.

LEED "provides building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions."[23] Furthermore, LEED has been constantly improving its manuals and guidelines to keep up with the latest technology and trends. Presently, there are four levels of LEED certification: Certified, Silver, Gold and Platinum.

[22] http://www.usgbc.org/articles/leed-facts
[23] USGBC website, http://www.usgbc.org/articles/about-leed

Green Streets

"Green Street" is a term for a street that has limited pervious surfaces, uses native vegetation and substrate to absorb stormwater, recognizes various uses for the space, and that is aesthetically pleasing. It is recommended that Jersey City pursue various ways to make its streets, citywide, as "green" as possible as space permits and as opportunities arise.

Green Streets are designed to:

- Mimic local hydrology prior to development
- Provide an integrated system of stormwater management within the right of way
- Reduce volume in stormwater, thereby reducing the volume of water discharged via pipe into receiving streams, rivers and water bodies
- Link community efforts to develop local green infrastructure networks
- Enhance the right-of-way
- Improve local air quality by providing interception of airborne particulates and shade for cooling
- Enhance economic development along the corridor
- Improve pedestrian experience along the street right-of-way.

Numerous approaches are available for creating Green Streets including:

- Alternative Street Designs (narrower street widths)
- Swales
- Bioretention Curb Extensions and Sidewalk Planters
- Permeable Pavement
- Sidewalk Trees and Tree Boxes[24]

A green street might look very similar to the following image and "anatomy", although any improvements to reduce runoff and to the environment are beneficial.

[24] "Green Streets." Beachapedia. July 11, 2016. Accessed November 10, 2016. http://www.beachapedia.org/Green_Streets

Figure 36: Street Trees and Curb Bulb Outs with Bioretention (Source: Low Impact Development Center)

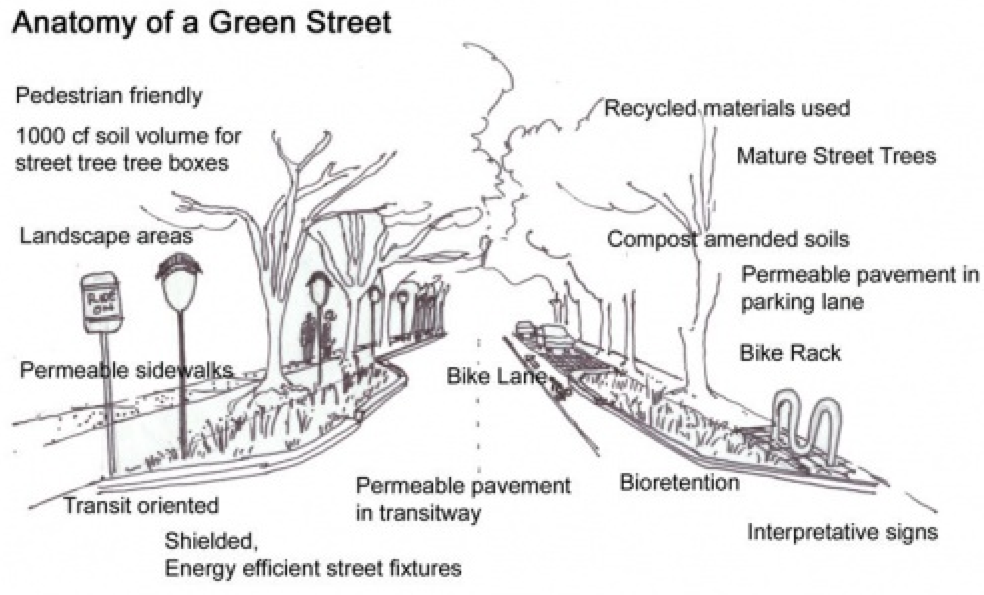

Figure 37 Green Street Concept (Source: Low Impact Development Center)

As briefly described in the "Applications" section above, bioswales and rain gardens may be used to remove excess water from the streets that may otherwise flood adjacent properties or run into nearby waterbodies. Minor curb cuts, as shown in the illustration below, allow water flowing down a street to be diverted into the garden at the higher elevation. Generally, water will only need to enter the garden and can be absorbed without having to exit the garden. However, an additional curb cut may be placed at the lower elevation to do so. Depending on the length of the street, there may be several bioswales in the right-of-way with curb cuts that can remove stormwater. This is a complimentary method to stormwater drainage systems, but is a good alternative on older streets and where water is regularly directed down a street. Bioswales can also project into the right-of-way, doubly serving as traffic calming techniques by narrowing cartways.

Figure 38: Right-of-Way Bioswale (Source: NYC DEP)[25]

Street trees are also an important element of green streets for a variety of reasons. Not only are trees attractive, but they also help to absorb carbon dioxide and emit oxygen, are able to absorb a significant amount of water, and reduce the urban heat island effect of hot asphalt.

More trees should be planted citywide, and consideration should be paid to locating trees in bumpouts *in* the right-of-ways along some of the larger streets to assist in traffic calming. In some areas, narrowing the roads to allow for wider sidewalks and more pedestrian space and trees will benefit the community without causing hardship.

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[25] Zimmer, Lori. "2,000 Stormwater-Absorbing Sidewalk Gardens Planned for Queens, Brooklyn, and the Bronx." November 12, 2014. Accessed November 11, 2016. Image via NYC.gov. New York City Department of Environmental Protection. http://inhabitat.com/nyc/2000-stormwater-absorbing-sidewalk-gardens-planned-for-queens-brooklyn-and-the-bronx/

Figure 40: Example of a streetside bioswale (Source: www.kwalliance.org)

Figure 39: Arlington Park, Jersey City, NJ

An example of how these features combined would look in Downtown Jersey City is illustrated in Figure 41 on the following page. This illustration depicts stormwater detention, levees, green roofs, and bioswales – all elements recommended in this document as well as the Adaptation Master Plan. This illustration also shows tide and flood levels, to best demonstrate the risks.

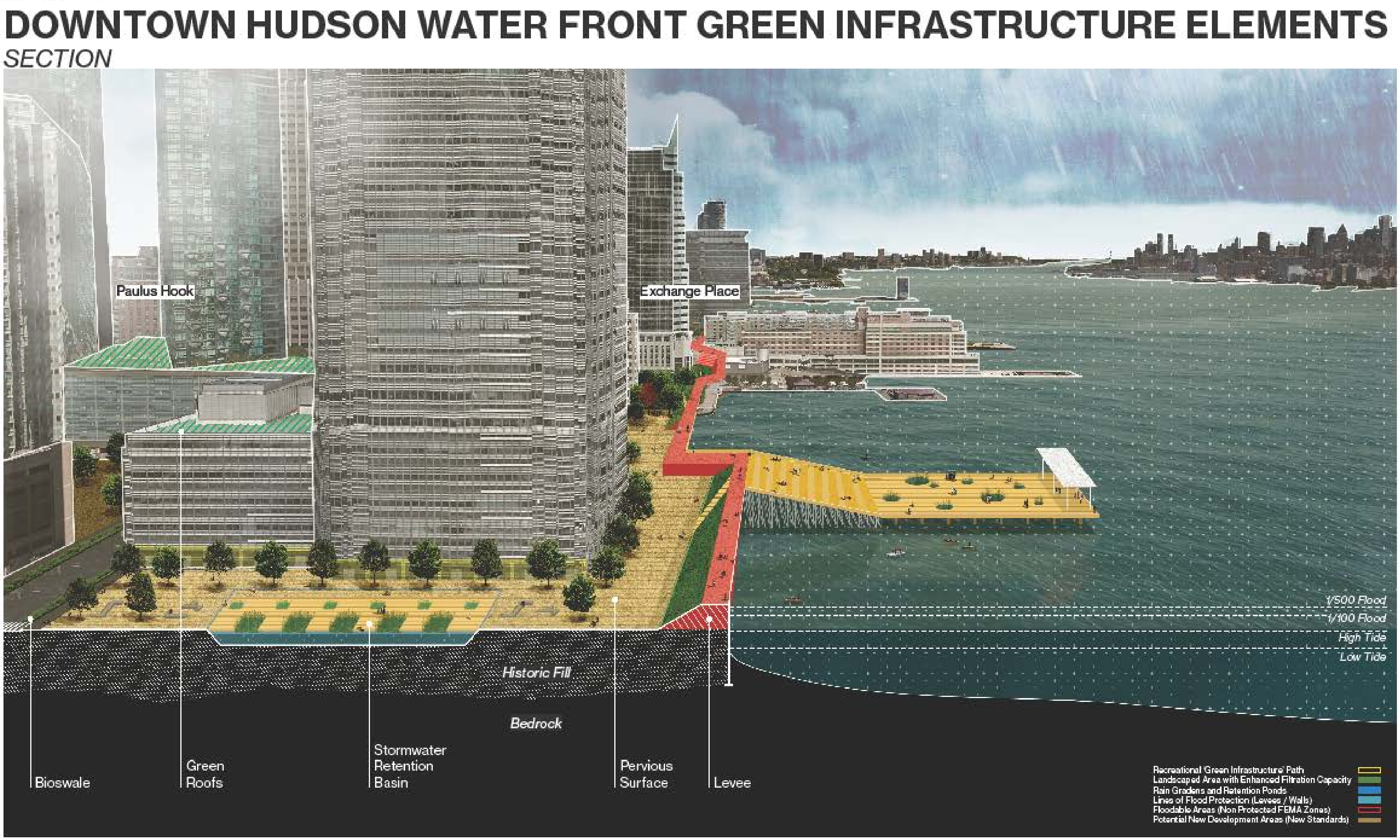


Figure 41: Hypothetical green infrastructure rendering for Downtown Jersey City

Landscaping & Green Roofs

The City should use in its public spaces and encourage residents to use a landscaping technique called xeriscaping. Xeriscaping is defined as "quality landscaping that conserves water and protects the environment."26 This generally means that only plants which are drought-tolerant (require little to no watering) will be used, as well as other non-living materials, such as stone or mulch. Xeriscaping takes into account the regional and microclimatic conditions of the site, as well as topography, existing vegetation, and zoning of plant materials. There are also seven principles associated with xeriscape landscapes, which are:

1. Planning and Design
2. Soil Improvement
3. Appropriate Plant Selection
4. Practical Turf Areas
5. Efficient Irrigation
6. Use of Mulches
7. Appropriate Maintenance[27]

[26] http://xeriscape.sustainablesources.com/#DEFINITION
[27] http://xeriscape.sustainablesources.com/#DEFINITION

Figure 42: Xeriscaping (Source: www.cleanairlandscaping.ca)

In addition to conserving water, landscapes should also balance the need to absorb water so that floodwater may be removed from hard surfaces, such as streets and stored naturally in the ground, and preventing nonpoint source pollution runoff into the rivers. More information about local rain gardens and how to install them may be found through the Rutgers University Water Resources Program in the "Rain Garden Manual of New Jersey."[28]

Green roofs should also be encouraged as another way to remove stormwater that would otherwise be on the streets and become runoff into nearby waterbodies. Green roofs use several layers of substrate that slowly percolate through various layers, but must be able to properly drain from the roofs. Green roofs may be incredibly heavy, especially with soil, vegetation, reinforcement, and the added rainwater and, therefore, must be held on a very structurally sound roof and able to get rid of any excess weight.

Many older homes may not be able to use green roofs due to their age and structure, but green roofs may be used on new construction, or even creatively such as on bus shelters, as shown below (Figure 42). Although the impact that a bus shelter may have would be minute,

[28] "Rain Garden Manual of New Jersey." Rutgers University. New Jersey Agricultural Experiment Station. Water Resources Program. http://www.water.rutgers.edu/Rain_Gardens/RGWebsite/RainGardenManualofNJ.html

it is an additional step towards cleaner streets and waterways, like a rain garden, but also provides an example to residents that is eye-catching. On a larger scale, green roofs can save thousands of gallons of water a year by collecting it and using it as graywater to clean or water lawns, etc. They also provide insulation, create a habitat for wildlife, help to lower air temperatures by mitigating the urban heat island effect, provide a pleasing landscape and possible additional open space, and potentially arable land, if made accessible.

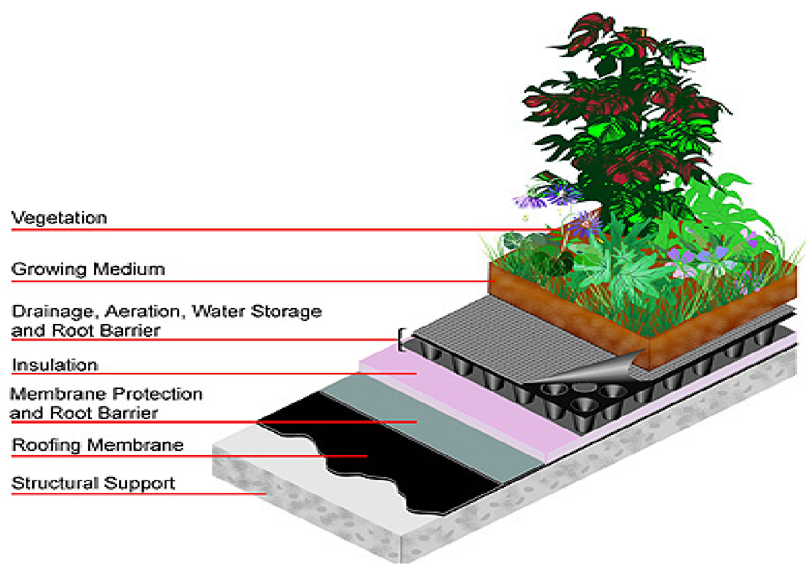


Figure 43: Illustrative cross-section with typical layers of green roofs

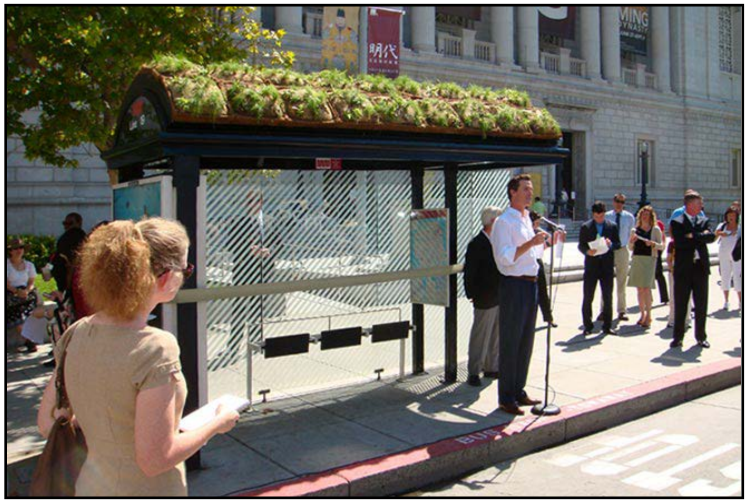


Figure 44: Green Roof Bus Shelter, Philadelphia[26]

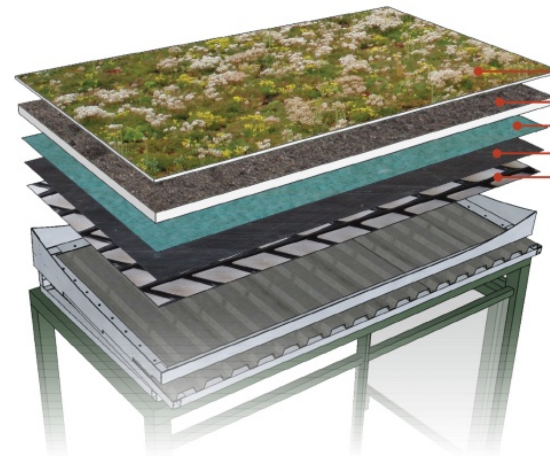


Figure 45: Green Roof Bus Shelter[27]

Zoning and Design Standards

Zoning and design standards for stormwater retention and detention, and pervious coverage, as well as design recommendations for open spaces, streetscapes, and public places should be considered.

It is recommended that the city institute a green building/green infrastructure requirement for parcels located in V and AE FEMA flood zones. This approach has been undertaken in other cities around the world, and it assigns a point value to various stormwater mitigation and green infrastructure elements of a project. A required number of points in any given zone must be achieved in order to have a compliant development, allowing the City to target areas that are particularly susceptible to flooding or which have the potential to significantly reduce stormwater runoff, ensuring that resiliency measures are part of all new development. Should the implementation of this approach be successful, it could easily be broadened to other areas of the City.

[29] 450 Architects. San Francisco, California, 2008. Accessed November 11, 2016. http://450architects.com/advocacy/green_roof_bus_shelter#/images/advocacy/02/1-green-roof-bus-shelter.jpg
[30] "Green Roof Bus Shelter". Philadelphia Water. 2016. http://www.phillywatersheds.org/green-roof-bus-shelter

Many of these regulations can facilitate the capture the first one inch of rain, alone or as part of a larger development plan, adding additional improvements to the more substantial undertakings recommended above for the Upland, Terraces, and River Frontage Areas.

Conclusion

The use of green infrastructure in Jersey City's efforts to mitigate stormwater, tidal flooding, and sea level rise could have a profound effect. Simply by capturing the first one inch of rain in a typical storm, significant improvements will be seen in the system.

Site specific examples and recommendations for the Upland, Terraces, and River Frontage Areas of Jersey City were chosen based on the specific geology and topography of each Area. The green improvements discussed have resulted in improved stormwater management in other cities throughout the region, and are expected to provide equally beneficial results in Jersey City.

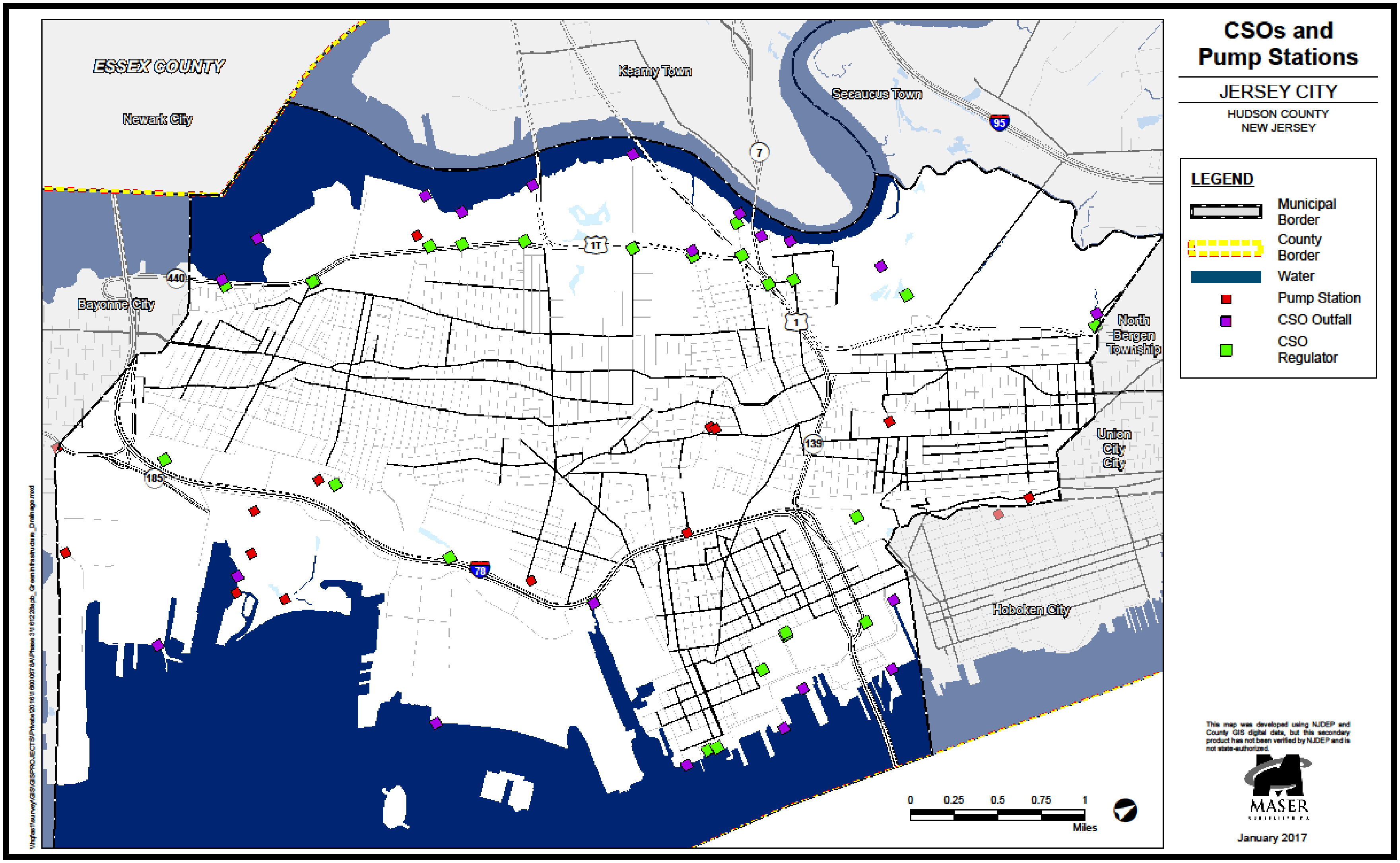
Prior to implementation, selected sites will require additional investigation as to its specific infiltration rates and potentials for infiltration as opposed to storage and release, but the basic methods delineated in these examples remain the same and in fact can be applied to locations throughout the City of Jersey City, even those yet unidentified.

On a citywide scale, the encouragement of LEED and LEED-ND development will help developers focus on environmentally sensitive development. Green streets, landscaping, green roofs, and modifications to the zoning and design standards can, collectively, improve the stormwater capture even more.

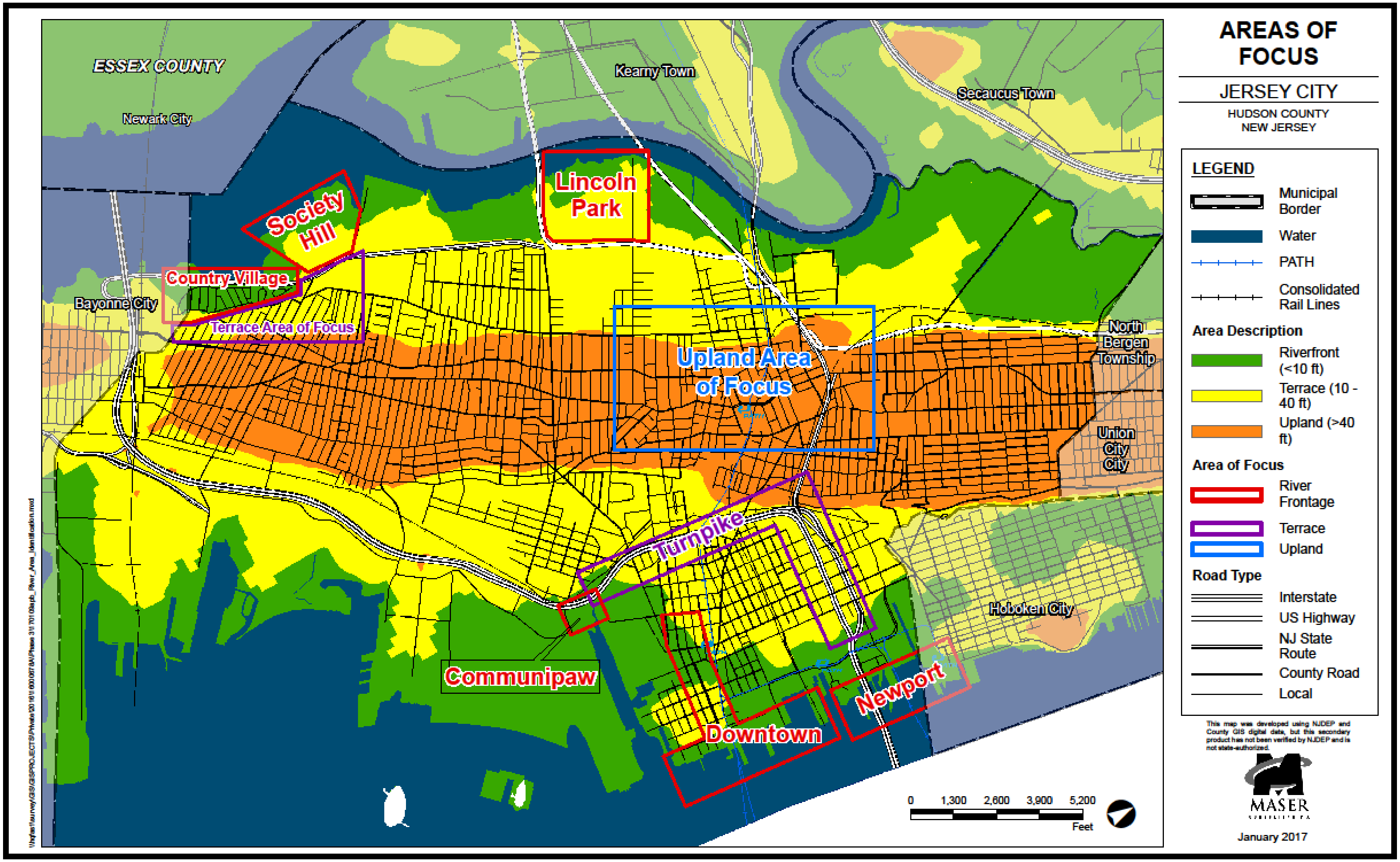
Together, all of these efforts can not only contribute to the resiliency of Jersey City, but will make it a safe, protected, and beautiful place.

Appendix

Appendix Map 1: Existing CSOs and Pump Stations



Appendix Map 2: Proposed Locations of Green Infrastructure



Formulas

Mathematical calculations for recommended green infrastructure.

Upland Area No. 1: Bergen Avenue and Vroom Street

Area 1A: Bergen Avenue between Academy and Vroom Streets

Right of Way on Bergen Avenue 60' +/- (use ½ of this for calculations 30')
Distance between corners: 400' linear feet
Total area = 30' x 400' = 12,000 square feet
Total square feet x 1" of rainfall (.083 of a foot) is

12,000 x 0.083 = 996 cubic feet of rainwater

Area 1B: Vroom Street between Bergen Avenue and Van Reypen Street

Right of Way on Vroom Avenue 40' +/- (use ½ of this for calculations 20')
Distance between corners: 400' linear feet
Total area = 20' x 400' = 8,000 square feet
Total square feet x 1" of rainfall (.083 of a foot) is

8,000 x 0.083 = 665 cubic feet of rainwater

Combining both areas = 665 + 996 cu ft = 1,660 cubic feet of rainwater

1,660 Cu Ft x .40 = 4,150 cu ft of stone bed storage area is necessary.

Upland Area No. 2: John F. Kennedy Commercial Corridor

Area 2: John F Kennedy Boulevard between Tonnele Avenue and mid-block inlet

Right of Way on Bergen Avenue 60' +/- (use ½ of this for calculations 30')
Distance between corners: 800' linear feet
Total area = 30' x 800' = 24,000 square feet
Total square feet x 1" of rainfall (.083 of a foot) is

24,000 x 0.083 = 2,000 cubic feet of rainwater

2,000 Cu Ft x .40 = 5,000 cu ft of stone bed storage area is necessary.

Upland Area No. 3: Sip Avenue at Garrison Avenue

Area 3A: Sip Avenue between Garrison Avenue and Kennedy Boulevard

Right of Way on Sip Avenue 50' +/- (use ½ of this for calculations 25')
Distance between corners: 275' linear feet
Total area = 25' x 275' = 6,875 square feet
Total square feet x 1" of rainfall (.083 of a foot) is

6,875 x 0.083 = 570 cubic feet of rainwater

Area 3B: Garrison Avenue between Sip Avenue and Bond Street

Right of Way on Bergen Avenue 50' +/- (use ½ of this for calculations 25')
Distance between corners: 450' linear feet
Total area = 25' x 450' = 11,250 square feet
Total square feet x 1" of rainfall (.083 of a foot) is

11,250 x 0.083 = 935 cubic feet of rainwater

Area 3C: Garrison Avenue between Sip Avenue and mid-block grade change

Right of Way on Garrison Avenue 50' +/- (use ½ of this for calculations 25')
Distance between corners: 800' linear feet
Total area = 25' x 800' = 20,000 square feet
Total square feet x 1" of rainfall (.083 of a foot) is

20,000 x 0.083 = 1,660 cubic feet of rainwater

Combining all areas = 570 + 935 + 1660 = 3,165 cubic feet of rainwater

Upland Area No. 4: Brett Triangle

Area 4A: Tonnele Avenue between Pavonia Avenue and Kennedy Boulevard

Right-of-Way on Tonnele Avenue 50' +/- (use ½ of this for calculations 25')
Distance between corners: 400' linear feet
Total area = 30' x 400' = 12,000 square feet
Total square feet x 1" of rainfall (.083 of a foot) is

12,000 x 0.083 = 996 cubic feet of rainwater

Area 4B: Garrison Avenue between Sip and Pavonia Avenues

Right-of-Way on Garrison Avenue 50’ +/- (use ½ of this for calculations 25’)
Distance between corners: 800’ linear feet
Total area = 25’ x 800’ = 20,000 square feet
Total square feet x 1” of rainfall (.083 of a foot) is

<u>*20,000 x 0.083 = 1,660 cubic feet of rainwater*</u>

Area 4C: Pavonia Avenue between Tonnele and Garrison Avenues

Right-of-Way on Pavonia Avenue 50’ +/-
Distance between corners: 80’ linear feet
Total area = 50’ x 80’ = 4,000 square feet
Total square feet x 1” of rainfall (.083 of a foot) is

<u>*4,000 x 0.083 = 332 cubic feet of rainwater*</u>

<u>*Combining all areas = 996 + 1,660 + 332 = 2,988 cubic feet of rainwater*</u>

Terraces Area No. 1: Bartholdi Avenue at Sullivan Drive

Area 1: Sullivan Drive & Bartholdi Avenue

Right-of-Way on Sullivan Drive 25’ +/- , 550 linear feet
Right-of-Way on Bartholdi Avenue 25’ +/- , 750 linear feet
Total area = 25’ × 1300’ = 32,500 square feet
Total square feet × 1” of rainfall (.083 of a foot) is

<u>*32,500 × 0.083 = 2,698 cubic feet of rainwater*</u>

2,698 Cu Ft x .40 = 4,150 cu ft of stone bed storage area is necessary.

Green Infrastructure Maintenance

TASK	DESCRIPTION	FREQUENCY
SURFACE MAINTENANCE		
Remove trash, sediment, and organic debris	Remove trash, sediment, and organic debris from all	Monthly
	Clean pretreatment devices	Monthly
	Wipe down signage	Monthly
	Dredge large volumes of trash, sediment, and organic debris from basin and forebay areas using approved equipment	When sediment occupies greater than 50% of the forebay volume or as per site specific maintenance plan
Winterize SMP	Clean and grease appurtenances	Annually in November
Apply mulch	Apply mulch to landscaped beds as needed	Annually in March
Remove non-target/invasive vegetation	Remove non-target/invasive plants using one or more of the mechanical or chemical methods	Monthly from March to November
Cut back target perennials	Manually cut detrital herbaceous vegetation from the previous growing season to 4-6 in. above the ground	Annually in March
Mow turf and meadow areas	Mow turf areas to a height of 2-4 in.	Monthly from May to October
	Mow naturalized meadow areas to a height of 8 in.	Two (2) times per year in June and October
Prune trees and shrubs	Elevate lower limbs and remove dead, rubbing, or crossing limbs	Annually, when trees are dormant between September and the end of December
Water trees	Place water bag(s) on tree(s)	Annually in March for first 12 months after planting
	Fill water bag(s)	Weekly, April - October for first 12 months after planting during any period of seven (7) or more days without rain
	Remove water bag(s) from tree(s)	Annually in November
Water herbaceous vegetation and shrubs	Water evenly and thoroughly at the base of vegetation so that the top of soil is saturated	Ever four (4) days during any period of four (4) or more days without rain, June-August for the first 24 months after planting
Subsurface Maintenance		
Vacuum clean structures	Remove trash/sediment/organic debris from subsurface access and flow control/conveyance structures	Annually
Jet-rodding pipes	Jet-rod conveyance and underdrain	Annually

Routine Green Infrastructure and Pervious Paving Routine Maintenance Tasks

TASK	DESCRIPTION	FREQUENCY
SURFACE MAINTENANCE		
Remove trash, sediment, and organic debris	Remove trash, sediment, and organic debris from all SMP surfaces	Three (3) times per year
	Wipe down signage	Three (3) times per year
Winterize SMP	Clean and grease appurtenances	Annually in November
SUBSURFACE MAINTENANCE		
Vacuum clean structures	Remove trash/sediment/organic debris from access and flow control/conveyance structures	Annually
Remove fine sediment and debris	Vacuum or air sweep fine sediment and debris from surface pore space	Two (2) times per year
Jet-rodding pipes	Jet-rod underdrain pipes	Annually

Source: Philadelphia Water Department, “Green Infrastructure Maintenance Manual,” June 1, 2014.