
Title: Greenways as Resilient Infrastructure: The Brooklyn Greenway Case Study

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Introduction:

Greenways as Resilient infrastructure illuminates the recent global progress in redefining and reimagining the possibilities for greenway planning and design. New greenways are highly ambitious as they are planned and designed to address a multiplicity of environmental and social challenges (Searns, R. M, 1995). Urban areas all over the world are experiencing temperature increases, severe rain events (and longer droughts), and sea-level rise while simultaneously impacted by population growth in cities (Cheng, Chingwen, et. Al, 2013). These environmental and social forces add strain to our urban areas and city leaders are looking for multi-objective strategies that can mitigate these strains and risks. *The Brooklyn Greenway: An Agent for Green Infrastructure and Resiliency* is presented as a case study for a 14-mile multi-objective resiliency corridor where greenways can be the first line of defense against big storms, the backbone for network-wide, neighborhood green infrastructure systems, viable habitat for native plants and wildlife, and lush, native landscapes keeping our cities cool (Martin, T. M., 2013). (Figure 1.0)

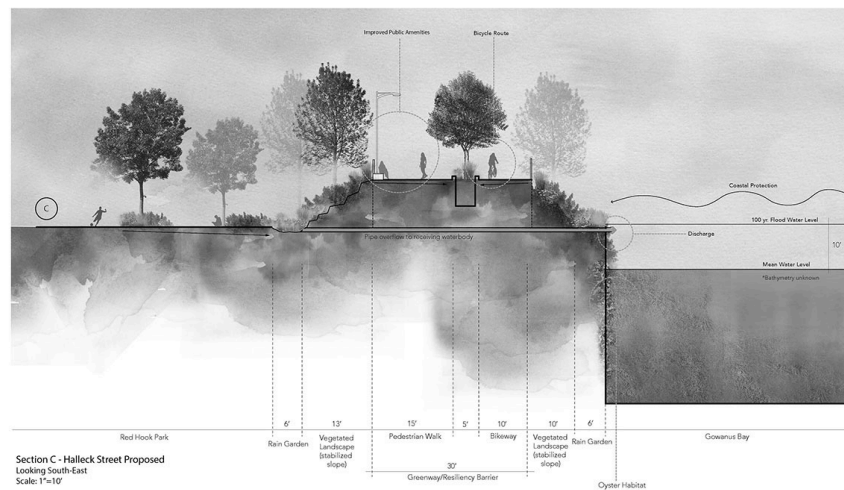


Figure 1.0: The Brooklyn Greenway as resilient infrastructure – Red Hook

Background and Literature Review:

While greenways can contribute to resilience in any city, the role they play in coastal and delta cities is particularly significant. Historically, cities were located along waterways and coastlines for ease of trade, access, transportation, and connectivity (The World Bank, 2010). Now, these geographically advantaged cities are vulnerable to rising sea levels and destruction due to larger waves and stronger winds. Cities such as New York City (Figure 2.0), Rotterdam, and Tokyo are less than 10 meters above sea level. Cities in developing countries are particularly vulnerable as they have fewer resources for resisting the impacts of climate change. China has over 70 million people living in low-lying elevations and this number is increasing yearly (McGranahan, G., D. Balk, et al, 2007).



The linear characteristics of the greenway present an opportunity to develop a continuous line of defense against both coastal and inland floods. Yet at the same time, adjacent conditions change from neighborhood to neighborhood, from block to block. A well-integrated continuous storm surge barrier requires a catalogue of cross-sectional solutions to account for these different conditions. In some areas, the simplest and most cost-effective cross-section might be to lift the greenway on top of a dike, in other areas, such as along commercial corridors, more transparent design solutions might be more appropriate. In the Hague, the waterfront Scheveningen Promenade integrates sand dune reconstruction, hardened amphitheater stairs and restored dune habitat into a dike for coastal flood protection. And, in Singapore, a network of greenways and ecological corridors connect communities to wildlife, provide ecological and infrastructural improvements to address rising climate change indicators.

Goals and Objectives:

The New York City Department of Transportation's Brooklyn Waterfront Greenway Implementation Plan details 23 capital projects stretching from

Newtown Creek to Bay Ridge (Figure 2.0). *The Brooklyn Greenway: An Agent for Green Infrastructure and Resiliency* study, funded through a grant from NYS Department of State Local Waterfront Revitalization Program, builds on this work to develop concepts that can inspire and show how resiliency strategies, including sustainable stormwater management, can be integrated into the capital project. Each of the greenway segments will run along one of the lowest contours of Brooklyn's East River sub-watersheds offering an incredible opportunity to address water impacts from the East River while also mitigating the effect of rainwater runoff from upland sites. The goals for the study were to (1) determine opportunities and challenges for resiliency design, (2) develop a framework for integrating resiliency strategies into greenway design that addresses variations in site and program along greenways and (3) to demonstrate how the framework can be applied, addressing real site conditions, opportunities and challenges.

Methods:

The study was divided into three tasks: Segment analysis, Framework, and Framework applied. Segment analysis included mapping of existing conditions that impact the ability to integrate green infrastructure and resiliency strategies into the greenway. For each segment we identified the limit of the 100-year flood plain, topography including the direction and quantities of existing stormwater runoff, street geometries, and existing land-use. At a finer scale, soil borings were evaluated for water table heights and the probability of positive drainage; and, loading docks and large trees were noted as challenges for green infrastructure.

The framework included the development of a kit of parts for green infrastructure design. The purpose of the kit of parts was: (1) to identify the various conditions that were repeated along the entire 14 miles, (2) to develop a green infrastructure tool-kit, and (3) to generate a list of possible environmental outcomes (Figure 3.0). The framework included two other key elements to address storm surge projection and a subwatershed green infrastructure network that we call our *big moves*.

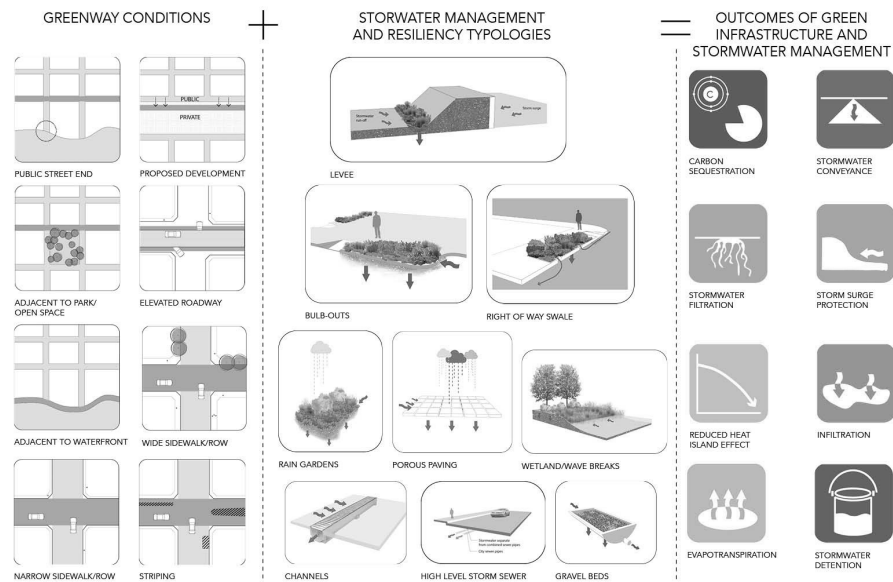


Figure 3.0: Framework Took Kit: Site Conditions + Resiliency Strategies = Environmental Outcomes

Big moves:

One of the primary goals of the study was to understand how greenways could function as a backbone to a larger, subwatershed sustainable stormwater network. Therefore, the framework includes strategies for connecting and linking various green infrastructure strategies so that we can move water (1) across streets, (2) from public to private land (or private to public land) and (3) directly to the receiving water body (even if the greenway corridor was one block upslope). We call these connecting strategies our *big moves*, as strategies one and two are currently not permitted per city code.

Greenway as Levee:

A typology of raised greenway designs were developed to understand the potential of the greenway to directly address coastal flood protection. The typologies address variations in land use and sectional constraints.

Framework applied puts the framework and tool kit to the test in two communities that were greatly impacted by Superstorm Sandy, Red Hook and Sunset Park.

Stormwater Management Calculations Methodology

In order to identify the extent of contributing stormwater run-off within each segment's sub-watershed we have identified four stormwater management "Tiers" as the base criteria to map opportunities for capturing run-off adjacent to the Greenway route (Figure 4.0). While it is not likely that the run-off from these total areas can be entirely managed within the Greenway footprint, the areas provide a target goal and quantified potential for stormwater mitigation. The Tiers are defined as follows:

Tier 1- represents the Greenway footprint itself and the impervious rights-of-way directly adjacent.

Tier 2- represents one block upland from the Greenway route and includes right-of-way areas and adjacent impervious areas such as vacant and parking lots.

Tier 3- represents building roof areas within one block upland that could be disconnected for future connection with the GI system.

Tier 4- includes the remaining area and rooftops of the upland contributing sub-watershed adjacent the Greenway route.



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Results:

After developing the framework, we tested our ideas in two communities that were heavily impacted by Sandy, Red Hook and Sunset Park in Brooklyn, New York. Below is a summary of our analysis and design recommendations for Sunset Park.

The Greenway travels mostly through industrial land use in Sunset Park. This stretch is particularly unique in that much of the land ownership is by one or two developers or public land and a long stretch of the Greenway passes along the waterfront. Sunset Park has many opportunities to demonstrate how the

Greenway can be an elevated barrier serving as an integrated flood protection system while also improving the quality of life for those working and commuting to and from Sunset Park.

We identified five different conditions along the Greenway in Sunset Park with the opportunity to integrate four different green infrastructure design typologies, including right-of-way bio-swales along 2nd Avenue and 3rd Avenue, rain gardens down the center of 29th Street, and wetlands along Marginal Street (Figure 5.0). In addition, we have proposed two different design alternatives for an elevated greenway along Marginal Street. One alternative shows the elevated barrier hugging the existing bulkhead. The second alternative is a more ambitious proposal where the Greenway is integrated into a large park-like space, with fingers of constructed wetlands, boardwalks and kayak launches for visitors.

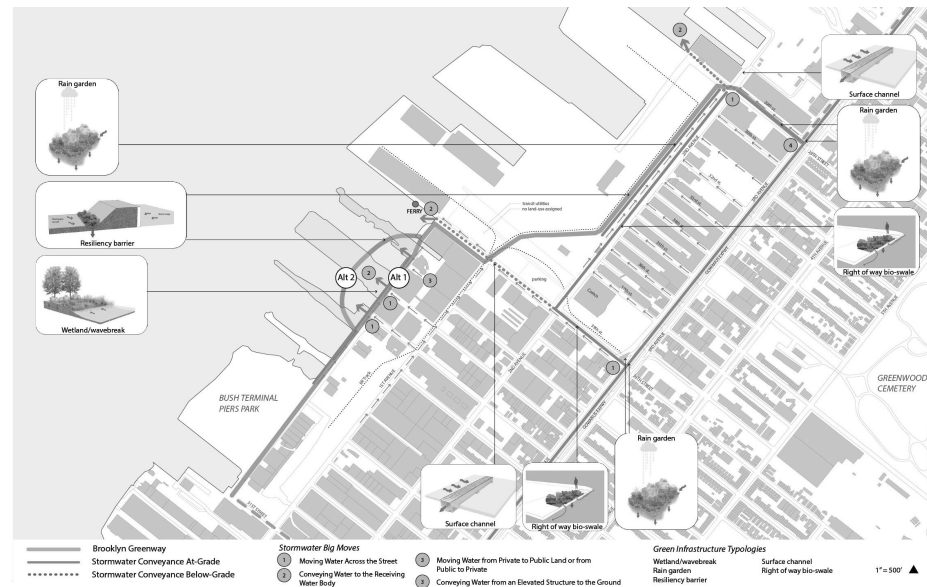


Figure 5.0: Framework Applied: Sunset Park

Stormwater calculations for Sunset Park Segments (Table 1.0). Proposed green infrastructure interventions for the Sunset Park Master Plan Alt. 1 design has the capacity to capture 11,738,000 gallons of stormwater run-off annually with 24,100 square feet of green infrastructure. This matrix is based on our methodology's tier 1 and tier 2 goals to capture and treat 100% of the first one inch of rainfall within the Greenway right of way and upland connector streets.

discharged into our waterways.

4. Additionally, flood protection from storm surge and rising water levels can be addressed through greenway infrastructure. Waterfront edges can be softened with (natural) saltwater marshes to stabilize shorelines and (engineered) floating islands. Barriers – both temporary and permanent – can be created as part of the greenway: levees, gates, and enhanced bulkheads.

References:

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