THE LONG-TERM SUSTAINABILITY OF THE TWO BRIDGES WATERFRONT COMMUNITY

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Forward

This report is an overview of a 12-week effort stemming from literature review, interviews, intensive neighborhood analysis, and identification of pilot projects. These pilot projects are intended to be useful demonstration cases both to the community and future investors as to the real benefits of green infrastructure. All projects discussed in this report are feasible, fundable, and replicable, and at scale, will yield tremendous benefits for the Two Bridges Neighborhood Council community.

The team would like to thank the Two Bridges Neighborhood Council for their participation in, and support of this research. We would also like to thank our advisor Thomas Abdallah for his guidance and encouragement throughout this project.

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List of Acronyms

BP – Manhattan Borough President
CDBG – Community Development Block Grant
CDBG-DR – Community Development Block Grant Disaster Recovery
CDFI – Community Development Financial Institution
CSO – Combined Sewer Overflow
CSS – Combined Sewer System
DEP – Department of Environmental Protection
DOE – Department of Education
EPA – U.S. Environmental Protection Agency
EPC – Energy Performance Contracting
ESS – Experimental Sewer System
FDR Drive – Franklin D. Roosevelt Drive
FEMA – Federal Emergency Management Agency
FEMA MOTF – Federal Emergency Management Agency Modeling Task Force
GIS – Geographic Information Systems
HUD – U.S. Department of Housing and Urban Development
HVAC – Heating Ventilation and Air Conditioning
LIHEAP - Low Income Home Energy Assistance Program
LIHTC – Low Income Housing Tax Credit
MPP – Multifamily Performance Program
NPDES - National Pollution Discharge Elimination System
NYC – New York City
NYCDOT – New York City Department of Transportation
NYCDPR – New York City Department of Parks and Recreation
NYCEEC – New York City Energy Efficiency Corporation
NYCHA – New York City Housing Authority
NYSERDA – New York State Energy Research and Development Authority
P.S. – Public School
SCA – School Construction Authority
TBNC – Two Bridges Neighborhood Council
TPL – The Trust for Public Land
USGS – U.S. Geological Survey

Introduction

The Two Bridges Neighborhood Council

The Two Bridges Neighborhood Council (TBNC) serves “the residential, commercial, and cultural life of Manhattan’s Lower East Side through community-based programs and strategic partnerships” (Two Bridges Neighborhood Council, 2014). Specific community services include creating affordable housing, advocating for improvements related to quality of life, providing access to social services, technology, education, and recreation programs, and engaging residents in the public, political, and planning processes that impact the community in which they live and work (Two Bridges Neighborhood Council, 2014).

Originally founded in 1955 to resolve racial conflicts and improve communication between settlement houses, churches, and community leaders, TBNC serviced the working-class neighborhood of Manhattan bordered by the Brooklyn and Manhattan Bridges and the East River. In 2003, this geographic area became officially listed as the Two Bridges Historic District in the National Register (Two Bridges Neighborhood Council, 2014).

Although the neighborhood now known as the Two Bridges Historic District was the primary impetus for the formation of TBNC, the communities that they currently serve have expanded to include the diverse neighborhoods of Chinatown, Little Italy, Nolita, the East Village, and the Bowery Corridor. This roughly corresponds to the boundaries of Community Board Three, and the eastern sections of Community Board Two (Two Bridges Neighborhood Council, 2014).

(K. Culhane, Presentation, September 25, 2014).

In addition to the geographic expansion that TBNC’s jurisdiction has experienced over the past 60 years, they have also expanded their scope of advocacy programs to include community planning, neighborhood preservation, and access to affordable housing. Community planning became a focus in the 1960s, when TBNC successfully advocated to prevent the demolition of a large block of residential houses to build an AT&T telephone switching station.

TBNC’s focus on neighborhood preservation and affordable housing began in the early 1970s through a partnership with the Settlement Housing Fund. TBNC co-sponsored the redevelopment of the Two Bridges Urban Renewal Area, formerly a district of tenements and dilapidated commercial buildings along the East River waterfront between the Manhattan Bridge and

Corlear's Hook. From 1972 to 1997, TBNC succeeded in creating nearly 1,500 units of low- and moderate-income housing, much of which will remain permanently affordable (Two Bridges Neighborhood Council, 2014).

Long-Term Sustainability of Two Bridges Neighborhood Council Service Area

Hurricanes Irene (2011) and Sandy (2012) brought to light several vulnerabilities in the TBNC service area that need to be addressed in order to maintain the region's livability and its rich cultural and economic diversity. The threat of climate change-associated temperature rise and the increase in frequency and strength of coastal storms has caused TBNC to become concerned with the long-term sustainability of the region.

TBNC has recently become interested in implementing green infrastructure in their service area in order to mitigate the adverse effects of long-term climate change affecting their often underserved neighborhood. Some such climate change effects include temperature rise, air pollution, frequent flooding, and harsh storms.

As a result of this interest, TBNC applied for and received funding from the Department of Environmental Protection (DEP) to construct a rain garden at its Two Bridges Tower building located at 82 Rutgers Slip (Two Bridges Neighborhood Council, 2014). They have also developed educational programs for neighborhood children, a healthy food-shopping guide, and collaborated on two energy resiliency projects (Two Bridges Neighborhood Council, 2014). Despite these efforts, there is still a need for TBNC to pursue additional sustainability and green infrastructure initiatives.

Report Overview

This report will examine examples of green infrastructure that can be used to mitigate climate change effects, will provide case studies of similar regions throughout the United States and across the world using green infrastructure, discuss possible integration or expansion of existing or proposed projects for the region, perform a neighborhood analysis of the geographic, environmental, and demographic features that influence the area, and include recommendations for green infrastructure implementation and site selection.

Green Infrastructure

Green infrastructure is a network of practices that utilizes natural features to provide a host of environmental and community benefits. The system transforms impervious areas into vibrant and pervious green space. Green infrastructure can be used as part of a hybrid green and gray approach to manage stormwater runoff, reduce combined sewer overflows, reduce urban heat island effect, generate access to green space, and reduce noise, water, and air pollution.

In recent years, green infrastructure has been an increasingly popular strategy due to its ability to deliver multiple ecological, economic, and social benefits. Moreover, its ability to work in many places and to perform multiple functions on the same piece of land makes it even more popular. It differs from conventional approaches to open space planning in that it incorporates conservation values and actions in concert with land development, growth management, and built infrastructure planning (Benedict, 2002).

Types of Green Infrastructure

There are several types of green infrastructure techniques which solve a wide range of problems. Each project should choose the necessary types of green infrastructure to suit the specific situation depending on site specifications and the goals of the project. Below is a review of several types of green infrastructure techniques. All definitions are taken from the Environmental Protection Agency (EPA) (*What is Green Infrastructure?*, 2014).

<u>Downspout Disconnection</u>

Downspout disconnection refers to the rerouting of rooftop drainage pipes to drain rainwater into rain barrels, cisterns, or permeable areas instead of the sewer system.

<u>Rainwater Harvesting</u>

A rainwater harvesting system collects and stores rainfall for later use. If it is designed appropriately, rainwater systems slow and reduce runoff and can serve as a supply of water for other uses. Cisterns and rain barrels can be used to catch and store stormwater. They can be located underground, at ground level, or on an elevated stand.

<u>Rain Gardens</u>

Rain gardens are shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets. They mimic the area’s natural hydrology by infiltrating the vegetation and soil, and releasing it through plant leaves during evapotranspiration. They can be installed in almost any unpaved space.

<u>Planter Boxes</u>

Planter boxes are urban rain gardens with vertical walls and open or closed bottoms that collect and absorb runoff from sidewalks, parking lots, and streets. They are ideal for space-limited sites in dense urban areas and as a streetscaping element.

Bioswales

Bioswales are sunken channels, similar to ditches, which provide treatment and retention as they move stormwater from one place to another. They filter and slow the recharge rate of stormwater into the sewer system.

Permeable Pavements

Permeable pavements are paved surfaces that treat and store rainwater where it falls, as well as help facilitate slow water filtration into the ground or sewer system. They can be constructed using different materials such as pervious concrete, porous asphalt, permeable interlocking pavers, and several other materials. Permeable pavements can be used instead of traditional impermeable concrete or asphalt.

Green Streets and Alleys

Green streets and alleys integrate green infrastructure elements into street and alley design to capture, store, and release stormwater. Permeable pavement, bioswales, planter boxes, and trees are among the many green infrastructure features that may be woven into street and alley designs.

Green Parking

Green parking lot designs can be implemented with the combination of many other green infrastructure elements. Permeable pavements can be installed in sections of a lot and rain gardens and bioswales can be included in medians and along a parking lot perimeter.

Green Roofs

Green roofs are roofs which are covered with growing media and vegetation that enable rainfall water retention and evapotranspiration of stored water. They are particularly cost effective in dense urban areas where land values are high, and on large industrial or office buildings where stormwater management costs are large. Green roofs can add additional community benefits by cooling the surrounding air, growing local food, and promoting bee pollination.

Blue Roofs

Blue roofs are designed without vegetation for the primary purpose of detaining stormwater. Weirs at the roof drain inlets create temporary ponding and gradual release of stormwater into the sewer system.

Urban Tree Canopy

Trees are planted with the purpose of reducing and slowing stormwater infiltration by intercepting precipitation in their leaves, branches, and roots.

Land Conservation

Protecting open spaces and sensitive natural areas within and adjacent to cities can mitigate the water quality and flooding impacts of urban stormwater, while also providing recreational opportunities for residents.

Subsurface Detention Systems

Subsurface detention systems with infiltration capabilities provide temporary storage of stormwater runoff underground. These systems have an open-bottom and can incorporate perforated piping and stormwater chambers for added detention volume. Systems are primarily designed with a gravel bed that stores water as it infiltrates the ground.

Benefits of Green Infrastructure

Green infrastructure installations not only improve infrastructure, but also provide environmental, social, and economic benefits. Many studies have been conducted to evaluate the benefits of green infrastructure techniques. Some of these benefits include:

- Carbon sequestration
- Urban heat island mitigation
- Reduce energy load in buildings
- Community revitalization and cohesion
- Improve air quality
- Workforce development
- Improve quality of life
- Reduce wastewater treatment needs
- Increase landscape connectivity for wildlife movement and habitat restoration
- Support biodiversity conservation
- Facilitate climate change adaptation
- Assist in stormwater management and flood alleviation
- Increase land and property values
- Attract tourists, industry, and skilled workers
- Support the development of green industry
- Reduce costs associated with the urban heat island effect and stormwater flooding
- Improve health and well-being through culture, sport, and recreational opportunities
- Strengthen the sense of community and place

Yes / Maybe / No

Water Harvesting	Permeable Pavement	Bioretention & Infiltration	Tree Planting	Green Roofs	Benefit	
Yes	Yes	Yes	Yes	Yes	Reduces Water Treatment Needs	Reduces Stormwater Runoff
Yes	Yes	Yes	Yes	Yes	Improves Water Quality	Reduces Stormwater Runoff
Yes	Yes	Yes	Yes	Yes	Reduces Grey Infrastructure Needs	Reduces Stormwater Runoff
Yes	Yes	Yes	Yes	Yes	Reduces Flooding	Reduces Stormwater Runoff
Yes	No	Maybe	No	No	Increases Available Water Supply	
Maybe	Maybe	Maybe	Maybe	No	Increases Groundwater Recharge	
No	Yes	No	No	No	Reduces Salt Use	
Maybe	Maybe	No	Yes	Yes	Reduces Energy Use	
Maybe	Yes	Yes	Yes	Yes	Improves Air Quality	
Maybe	Yes	Yes	Yes	Yes	Reduces Atmospheric CO_2	
No	Yes	Yes	Yes	Yes	Reduces Urban Heat Island	
No	No	Yes	Yes	Yes	Improves Aesthetics	Improves Community Livability
No	No	Yes	Yes	Maybe	Increases Recreational Opportunity	Improves Community Livability
No	Yes	Maybe	Yes	Yes	Reduces Noise Pollution	Improves Community Livability
No	No	Maybe	Yes	Maybe	Improves Community Cohesion	Improves Community Livability
No	No	No	Maybe	Maybe	Urban Agriculture	Improves Community Livability
No	No	Yes	Yes	Yes	Improves Habitat	
Yes	Yes	Yes	Yes	Yes	Cultivates Public Education Opportunities	

(Garrison, 2011)

Comparable Cities and Situations

Background

More than half of the world's population currently lives in cities, especially vulnerable delta cities. It is estimated that more than two thirds of the world's largest cities will be vulnerable to rising sea levels and climate change, with millions of people being exposed to the risk of extreme floods and storms (Dircke, Aerts, & Molenaar, 2010). Many cities are gradually taking on the issue of climate adaptation, and there is a growing interest in sharing and exchanging experience and knowledge between cities. Since the choices made today will influence vulnerability to climate risks in the future, it is important to link adaptation measures to ongoing investments in green infrastructure and spatial planning, and to draw up detailed estimates of the benefits of green infrastructure for climate change mitigation. The followings case studies detail green infrastructure progress through adaptation plans and investments in cities leading the green urban agenda.

Rotterdam

Situation and Green Infrastructure

The Rotterdam Water Plan 2030 requires that the city develop an additional 600 million liters of stormwater storage space. This increased storage demand is equivalent to 60 hectare meters of extra lakes and canals (Kerssen, 2010). This plan has been implemented primarily in the city center, where the city is using open water areas to store water, and in city parks where the city is retrofitting ponds to provide better storage capacities. Additionally, the city has encouraged the building of green infrastructure on roofs, and in Water Plazas, underground parking garages, and crowded built areas. These green infrastructure techniques are financially feasible due in large part to government subsidization. Since 2006, nearly 50,000 m^2 of new green roofs have been developed (Kerssen, 2010).

Brooklyn and Rotterdam Waterfront Exchange Project

New York joined forces with Rotterdam and other Dutch partners in the Brooklyn-Rotterdam Waterfront Exchange. The 2010 exchange, co-organized by New York City and Rotterdam, includes the New York and New Jersey Port Authorities, the City and Port of Rotterdam, the Netherlands Water Partnership, and several other parties. The forum was successful in sharing experiences, devising innovative solutions, strategies, and plans, and developing models and best practices for reshaping outdated port areas. Such solutions are necessary in contributing to the economic prosperity and environmental sustainability of the surrounding metropolitan regions. The exchange organized well attended and successful workshops both in New York and Rotterdam (Dircke, Aerts, & Molenaar, 2010).

The Exchange focused on a comparison of plans and best practices for Brooklyn's south-western waterfront, located at the mouth of the New York Harbor, and for Rotterdam's city ports. The objective was to select and apply international best practices in these two locations and help generate support for long-term decisions around key challenges, which include economic development, environmental sustainability, transportation infrastructure, waterfront uses, and climate change. Participants shared expertise about effective public policies, which are instrumental in implementing innovative solutions in both cities (Dircke, Aerts, & Molenaar, 2010).

In proactively redeveloping Brooklyn's waterfront into climate resilient communities, green infrastructure was able to improve the local economy. These climate resilient communities will be able to recover quickly from climate impacts, while maintaining their economic and social viability (Licata, Nauta, & Coh, 2010).

Tokyo

Precipitation is a very large issue in Tokyo; the ratio between normal flow quantity and that during a storm is 1:100. Heavy rainfall, in combination with the city's steeply sloped landscape, gives way to short yet powerful storm surges. The city's current green infrastructure includes infiltration side ditches, planter boxes, bioswales, green streets and alleys, green roofs, and permeable pavement (Kato, 2011).

According to research by Dircke, Aerts, & Molenaar (2010), permeable pavement is the most innovative measure in protecting against storm surges in Tokyo. Urbanization has resulted in an expansion of impermeable areas, such as roofs and pavement. In Tokyo, runoff increased from approximately 30% in the beginning of the twentieth century to 80% in 1994. Permeable pavement enables further urbanization and is a suitable measure for coping with climate change related flooding. Japan is currently using permeable pavement in its Experimental Sewer System (ESS). ESS is a new sewer system which is capable of controlling stormwater runoff by adding infiltration and storage facilities to the conventional combined sewer system. This system reduces runoff, lessening the threat of river flooding. Additionally, it reduces the frequency and quantity of overflow from the combined sewer system (Dircke, Aerts, & Molenaar, 2010).

Since 1992, the Tokyo Metropolitan Government has built around 494,000 m^2 of permeable pavement, accounting for about 2.3% of the city's total street area. Permeable pavement is cleaned using high pressured water. This method restores the pavement to its original infiltration capacity (Dircke, Aerts, & Molenaar, 2010).

Seattle

In Seattle, heavy precipitation causes a river or stream to overflow its banks into the adjoining floodplain. This happens suddenly when intense rain overwhelms the capacity of the drainage system.

Where green infrastructure solutions have been widely adopted, communities in Seattle have found that the resulting enhanced aesthetic experience of local residents has improved their quality of life as well as property values. For example, Seattle's Bullitt Center won the Sustainable Building award in 2013. The project's aesthetic design was an important element in its overall finish. Like a forest concept, the Bullitt Center uses only the water it can collect onsite. Below the structure's solar panels, a parapet roof captures rainwater and brings it to downspouts which carry the water to a 56,000 gallon concrete cistern in the basement. On its way down, the water is funneled through a vortex filter, which removes large particulates. Next to the cistern is a "day-use tank" which holds 500 gallons of clean, potable water. To create the potable water, the rainwater is "ultra-filtered" through three ceramic filters. The rainwater is also passed under ultraviolet light and through activated charcoal, and a small amount of chlorine is added. Local regulation currently prohibits the use of harvested rainwater in the Bullet Center. This hurdle prohibits the project from being officially net-zero in terms of water use. Until these regulatory hurdles are overcome by the city, the center will receive its water from the municipal supply (Bullitt Foundation, 2013).

Policy Considerations for Green Infrastructure in New York City

History of Green Infrastructure Policy in New York City

New York City's policy framework for green infrastructure planning is central to the City's strategy for reducing combined sewer overflows (CSO) impairing the waterways surrounding the City.

With the passage of the Clean Water Act in 1972, New York City was forced to bring its waterways into compliance with federal standards. The EPA regulates the control of CSOs through the National Pollution Discharge Elimination System (NPDES) permitting system. The EPA's CSO Control Policy contains four fundamental principles to ensure CSO controls are both cost-effective and meet the environmental objectives of local governments:

- Clear levels of control to meet health and environmental objectives
- Flexibility to consider the site-specific nature of CSOs and find the most cost-effective way to control them
- Phased implementation of CSO controls to accommodate a community's financial ability
- Review and revision of water quality standards during the development of CSO control plans to reflect the site-specific wet weather impacts of CSOs

(*CSO Control Policy*, 2014)

Together with the New York State Department of Environmental Conservation (DEC), the EPA works to achieve its CSO Control Policy through implementation of enforcement mechanisms such as administrative and judicial orders (*CSO Control Policy*, 2014). Since 2005, New York City has been required to reduce CSOs and improve quality through an Order on Consent. The 2005 Order required New York City to complete a series of enforceable Long-Term Control Plans, detailing how each impaired water body will be restored after CSO events (New York State Department of Environmental Conservation, 2014).

This policy increases public awareness of CSO issues in New York City and promotes the quality of the City's waterways as a key environmental issue. This increased public awareness and regulatory enforcement makes the ongoing recovery of New York City's waterways a core focus of the City's long-term sustainability planning strategy.

PlaNYC A Greener, Greater New York

First released in 2007, New York City's *PlaNYC* was an unprecedented and ambitious program to develop and implement sustainability policy within the City. In this plan, the use of green infrastructure is widely discussed as an opportunity to reduce CSOs and improve the quality of the City's surrounding waterways. The plan identifies several initiatives to reduce stormwater pollution with the overall goal of opening up 90% of accessible waterways to recreation. The plan intends to accomplish this by preserving natural areas and reducing pollution (New York City Mayor's Office of Long Term Planning and Sustainability, 2011).

In order to improve water quality through the introduction of green infrastructure strategies in New York City, PlaNYC calls for an analysis and pilot project implementation of best management practices. In its 2011 update, PlaNYC expanded the use of green infrastructure to help improve stormwater management through initiatives such as spearheading public green infrastructure projects, modifying codes to improve the capture of stormwater, and enhancing the protection of the City's natural systems for reducing stormwater pollution.

New York City Sustainable Stormwater Management Plan

The City's first comprehensive strategy to include green infrastructure as a method to reduce CSO events is the Sustainable Stormwater Management Plan introduced in 2008. This strategy relies on a combination of gray (conventional) and green (natural) technologies to reduce the incidence of CSOs. This plan was the result of an interagency task force discussion, and was the City's first comprehensive analysis of the costs and benefits of alternative methods for controlling stormwater (New York City Mayor's Office of Long Term Planning and Sustainability, 2008). The Sustainable Stormwater Management Plan establishes a series of policy initiatives to implement the most cost effective and feasible CSO controls. Among these initiatives are new design guidelines for public projects and complete ongoing demonstration projects to test a number of newly proposed source control technologies. Source control technologies aim to answer unresolved questions about feasibility, costs, maintenance, and performance of green infrastructure projects (New York City Mayor's Office of Long Term Planning and Sustainability, 2008).

The successful completion of these demonstration projects transitioned the City's CSO control policy from a mostly gray strategy, to a more progressive effort to use green infrastructure as the primary tool to reduce CSOs. Moreover, this strategy is enforceable by an Order on Consent.

In 2012, the DEP and DEC announced an agreement to reduce CSOs using green infrastructure in New York City (New York State Department of Environmental Conservation, 2012). This agreement on a revised consent order advanced DEP's green infrastructure efforts by incorporating an investment of $1.5 billion to reduce CSOs. Previous agreements to reduce CSOs were based entirely around the completion of traditional gray infrastructure projects. This agreement was introduced as the official "green light" for the groundbreaking New York City Green Infrastructure Plan (New York State Department of Environmental Conservation, 2012).

New York City Green Infrastructure Plan

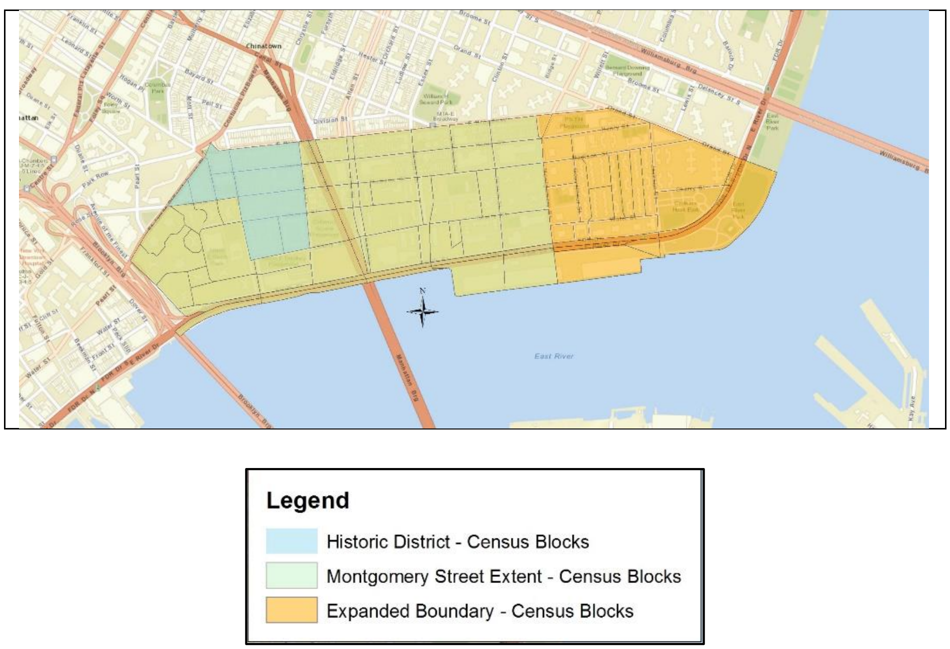
In September of 2010, the DEP released its first Green Infrastructure Plan. The plan establishes a goal to reduce 10% of all impervious surface coverage in CSO areas. The plan identifies that in order to reduce CSOs, traditional approaches must be combined or replaced by green infrastructure projects. Given a similar investment of public funds, gray infrastructure does not provide the public with the same plethora of sustainability benefits as green infrastructure. To reach this 10% reduction goal, the City has identified several opportunities to incorporate green infrastructure into areas with CSO outfalls. After an evaluation of the potential strategies and technologies to meet this goal, the City is focusing its efforts towards implementing green infrastructure on different land uses in CSO areas, such as streets and sidewalks, parking lots, parks, schools, vacant lots, etc. (New York City Department of Environmental Protection, 2012).

Neighborhood Analysis

Methodology

A thorough analysis of the TBNC service area was vital to understanding the geographic features and built environment that contribute to the area's vulnerability to storm-related flooding. The use of geographic information systems (GIS), specifically Esri ArcGIS, was necessary to visualize and interpret the features present in the neighborhood.

The first step was to determine the TBNC boundary area in order to define features in the region. Three different boundaries were selected for analysis including the Two Bridges Historic District, the Montgomery Street extent, and an expanded boundary. The Montgomery Street extent is the second classification of the area that encompasses a larger region, including the area from the Historic District southeast to the East River waterfront and northeast to Montgomery Street. A third expanded boundary was selected that builds upon the Montgomery Street extent, consisting of an additional area northeast beyond Montgomery Street to Grand Street, and including Corlear's Hook. These three boundaries are used in all subsequent analyses.



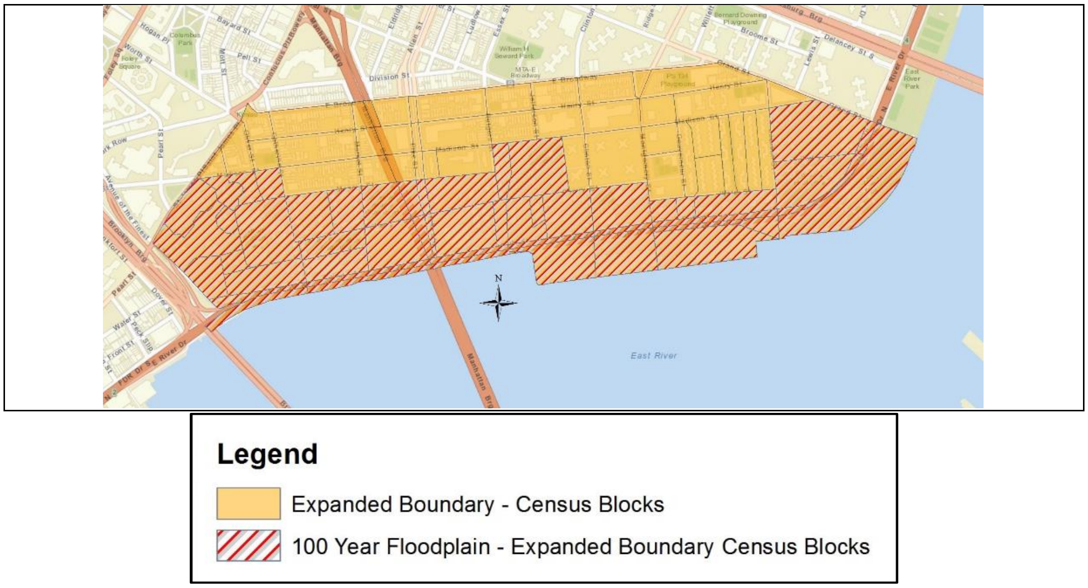
Geographic Analysis

The geographic analysis of TBNC includes the evaluation of total land area, and administrative boundaries including census blocks and tax lots, elevation, impact of Hurricane Sandy storm surge, and projected future storm events.

TBNC's total land area of 283 acres was determined by using the 2010 New York City Census Blocks dataset (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014), and tax lot distribution was determined using the MapPLUTO dataset (New York City Department of Planning, Information Technology Division, 2014). It is important to note that the total area from census blocks is a more accurate representation of the land area, because the tax lot dataset does not include roads.

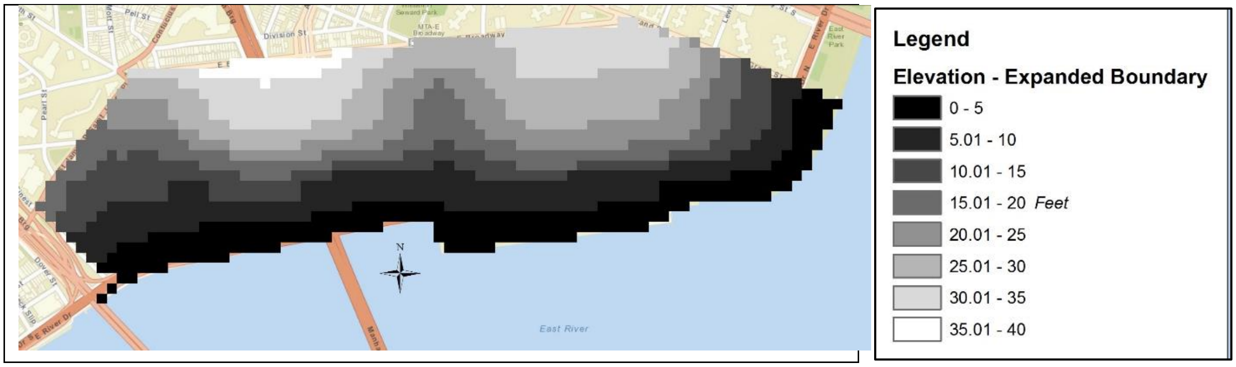
The census blocks and tax lot datasets were then analyzed in conjunction with the Hurricane Sandy floodwater inundation and 100-year Federal Emergency Management Agency (FEMA) floodplain maps (New York City Mayor's Office of Long Term Planning and Sustainability, 2014).

In the expanded boundary, 56.95% of census blocks (135.28 acres) were affected by some amount of flood water during Hurricane Sandy. Based on the projections for the 100-year floodplain, 58.87% of the census blocks (139.86 acres) of the expanded boundary can anticipate some amount of flooding.



During Hurricane Sandy, 64% (127.10 acres) of tax lots in the expanded boundary experienced some type of flooding. Based on the 100-year floodplain projection, 67% (133.29 acres) are vulnerable to flooding. The distribution of tax lots most affected by Hurricane Sandy and projected to experience flooding based on the 100-year floodplain are 31% residential, 22% open space and recreation, and 14% public facilities.

TBNC's elevation was assessed using a raster data file from the U.S. Geological Survey (USGS) (U.S. Geological Survey, 1999). Slightly over one third (34.32%) of the TBNC land elevation is at or below ten feet above sea level. When analyzed in conjunction with the Hurricane Sandy storm tide high water marks measured by the USGS, over one third of the TBNC service area was incredibly vulnerable to the 11.2 foot storm surge (U.S. Geological Survey, 2013).



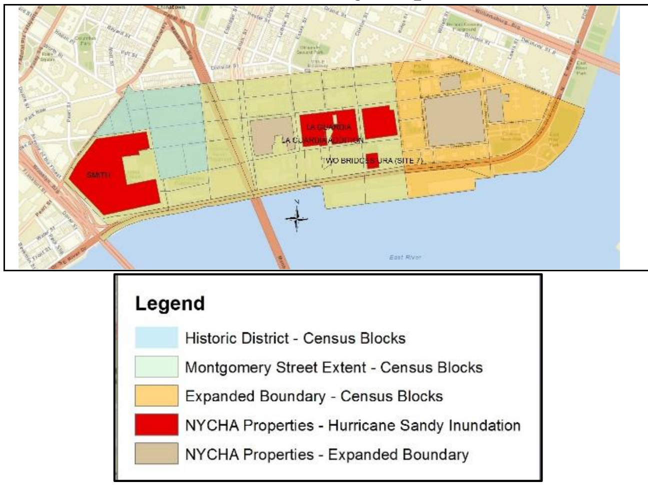
Hurricane Sandy flood inundation was further investigated by analyzing raster digital data files from the Federal Emergency Management Agency Modeling Task Force (FEMA MOTF). Almost 95% of inundation was at or below 7.5 feet, with 37.37% in the 0-2.5 foot range, 43.58% in the 2.5-5.0 foot range, and 13.53% in the 5.0-7.5 foot range. This is corroborated by FEMA determination points dataset (Federal Emergency Management Agency Modeling Task Force, 2013), which contains field data from storm-related damage claims. There are 30 determination points within the expanded TBNC boundary ranging from 0.297 feet to 6.299 feet, with the average depth of flooding reaching 2.4 feet. FEMA defines the depth of the determination points as the feet of inundation at each structure point relative to the ground surface.

Built Environment Analysis

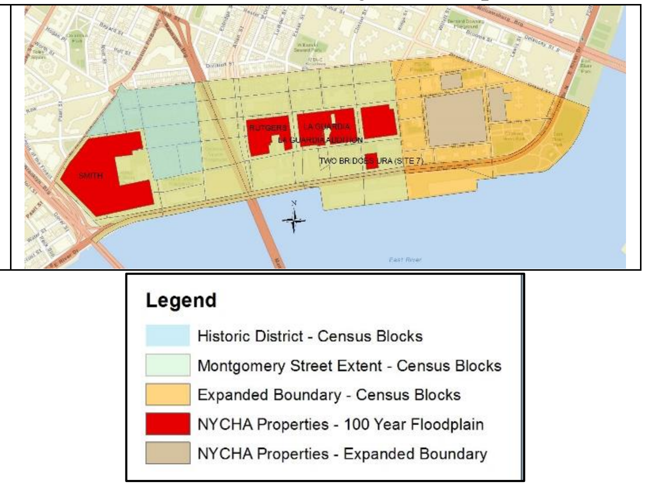
To determine the types and amount of built infrastructure in TBNC's service area and their corresponding vulnerability to flood events, data were analyzed for the New York City Housing Authority (NYCHA) properties, schools, recreational facilities, parks, and land cover.

In the expanded boundary, there are seven NYCHA properties (49.93 acres), accounting for 20.81% of the service area (New York City Housing Authority, 2011). Based on data from Hurricane Sandy flood inundation levels, four NYCHA properties (29.66 acres) experienced some extent of flooding during the storm, representing 60% of the total NYCHA properties in the boundary. Projections based on the 100-year floodplain anticipate that five NYCHA properties (34.74 acres), representing 70.27% of the total NYCHA properties in the expanded boundary, will experience some extent of flooding. Each NYCHA property consists of several low-income housing buildings, each with hundreds of apartment units.

Hurricane Sandy Impact



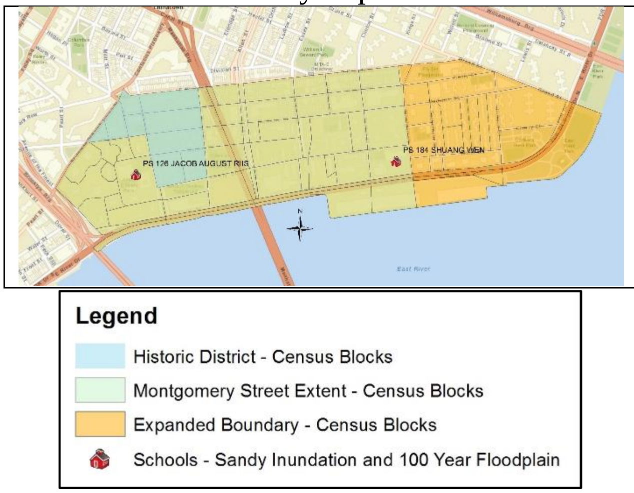
100-Year Flood Projected Impact



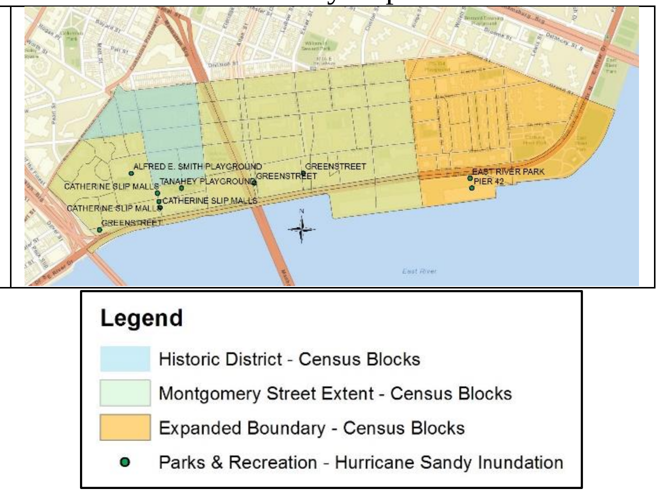
The New York City facilities schools dataset shows that there are 13 schools on nine tax lots in the expanded boundary (11.44 acres tax lot, 5.27 acres building footprint, 6.17 acres open space). Only two schools, P.S. 126 Jacob Riis (2.69 acres tax lot, 0.83 acres building footprint, 1.86 acres open space) and P.S. 184 Shuang Wen (1.95 acres, 0.82 acres building footprint, 1.13 acres open space), are in both the Sandy inundation zone and the 100-year floodplain zone (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014). As a result, these two schools were selected for case study analysis.

The recreational facilities and parks dataset shows 35 parks and facilities in the expanded boundary. Ten of these parks were within the Sandy inundation zone (7.724 acres open space) and 11 are within the 100-year floodplain zone (7.747 acres open space) (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014).

Hurricane Sandy Impact - Schools

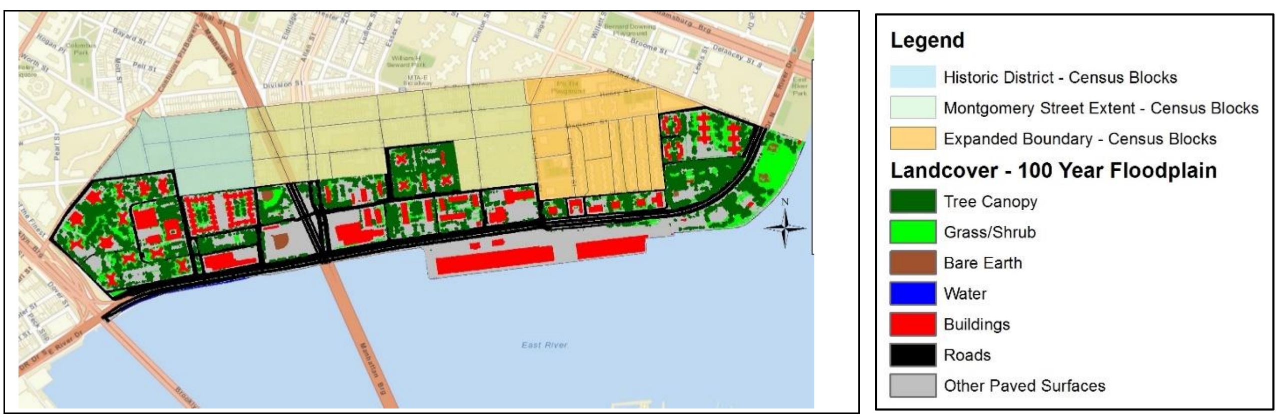


Hurricane Sandy Impact - Parks



To better assess the types of land surface coverings in TBNC's service area, and to determine any possible contribution that the built environment may have on storm-related flooding, land cover raster digital data from the New York City Department of Parks and Recreation was assessed. In the expanded boundary, 68.73% of land surface which is covered by artificial surfaces (buildings, roads, and other paved surfaces) and 31.28% which is covered by natural surfaces (tree canopy, grass/shrubs, and bare earth) contribute to storm-related flooding (New York City Department of Parks and Recreation, 2014).

The census blocks impacted by Hurricane Sandy flooding and projected to experience flooding based on the 100-year floodplain are covered by 65% artificial surfaces and 35% natural surfaces.

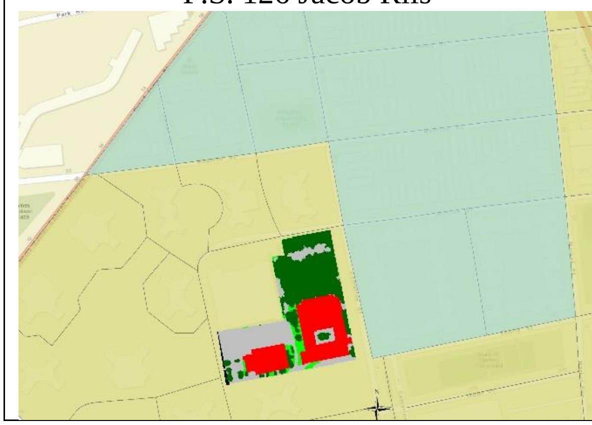


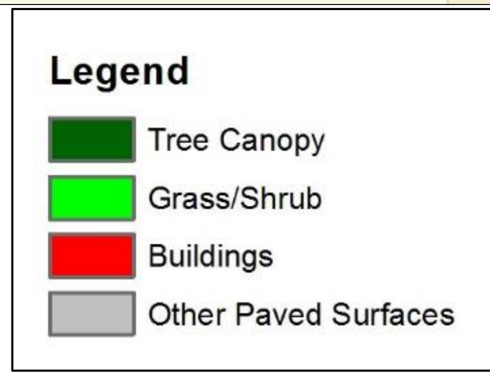
Similar land cover analyses were performed on three specific areas of interest, including P.S. 126 Jacob Riis, P.S. 184 Shuang Wen, and 80 Rutgers Slip - a building managed by TBNC. The land cover for P.S. 126 Jacob Riis is 58% artificial surfaces and 42% natural surfaces. P.S. 184 Shuang Wen is 89% artificial surfaces and 11% natural surfaces. TBNC's building at 80 Rutgers Slip is 74% artificial surfaces and 23% natural surfaces.

80 Rutgers Slip

P.S. 184 Shuang Wen

P.S. 126 Jacob Riis





One major limitation of the land cover raster dataset is that certain features like tree canopy may obscure paved impermeable surfaces below the canopy's extent. This may result in an underrepresentation of impermeable surfaces in the boundary.

Additional GIS analysis information can be found in Appendix A.

Vulnerabilities of the Two Bridges Community

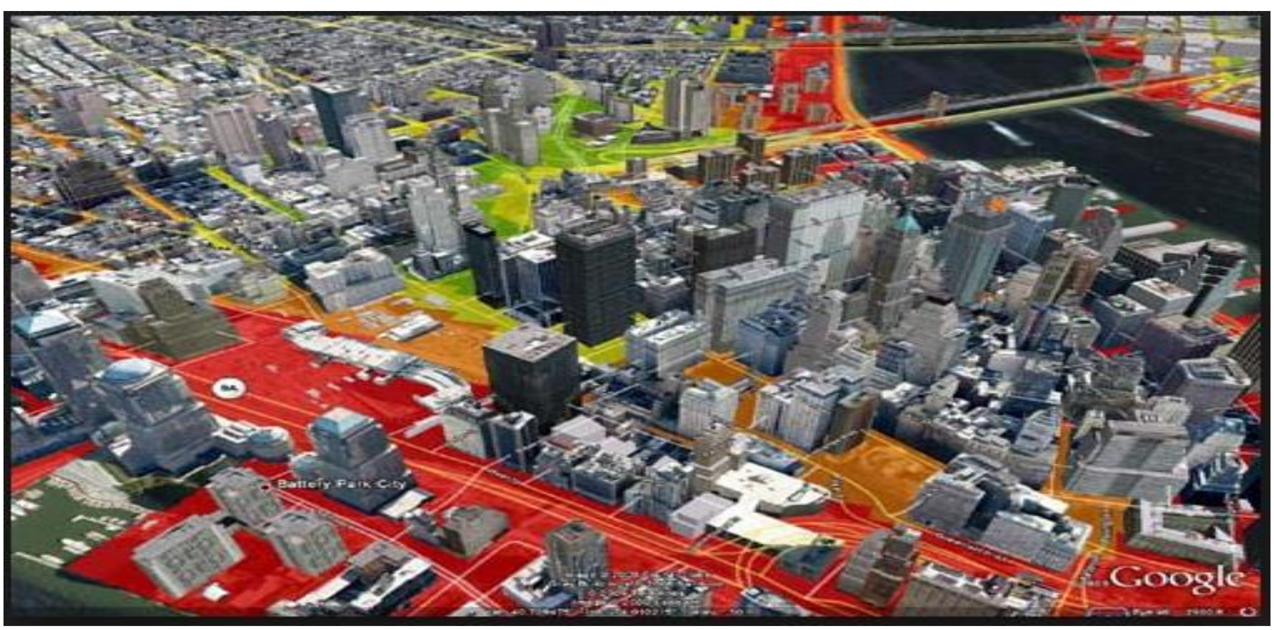
As described in the GIS analysis, the TBNC service area is located in the east side of southern Manhattan and is prone to floods due to its low elevation compared to adjacent neighborhoods and its proximity to the East River. A majority of the land area is publicly owned and zoned for residential use. Centuries of landfilling and bulk-heading have transformed the natural shoreline of tidal marshes and stream mouths into an industrial waterfront of slips and piers with an elevated highway, the FDR drive, located above the region (Culhane, 2012).

Although the historic district designation for TBNC classifies it as the nine-block area along the East River waterfront between the Brooklyn Bridge and the Manhattan Bridge, the Two Bridges Urban Renewal district expands the region north to the Williamsburg Bridge.

Geographic Vulnerabilities

Centuries of adding land surface and development along the East River has removed natural protective barriers from the city, such as sand dunes, and left only the East River Esplanade and elevated FDR drive pillars to protect TBNC against ocean storms. A lack of green infrastructure along the riverfront, which could serve as a buffer between the storm and the residential region, further exacerbates the impact of seasonal and high-impact storms on New York City and allows flood waters to easily inundate the area.

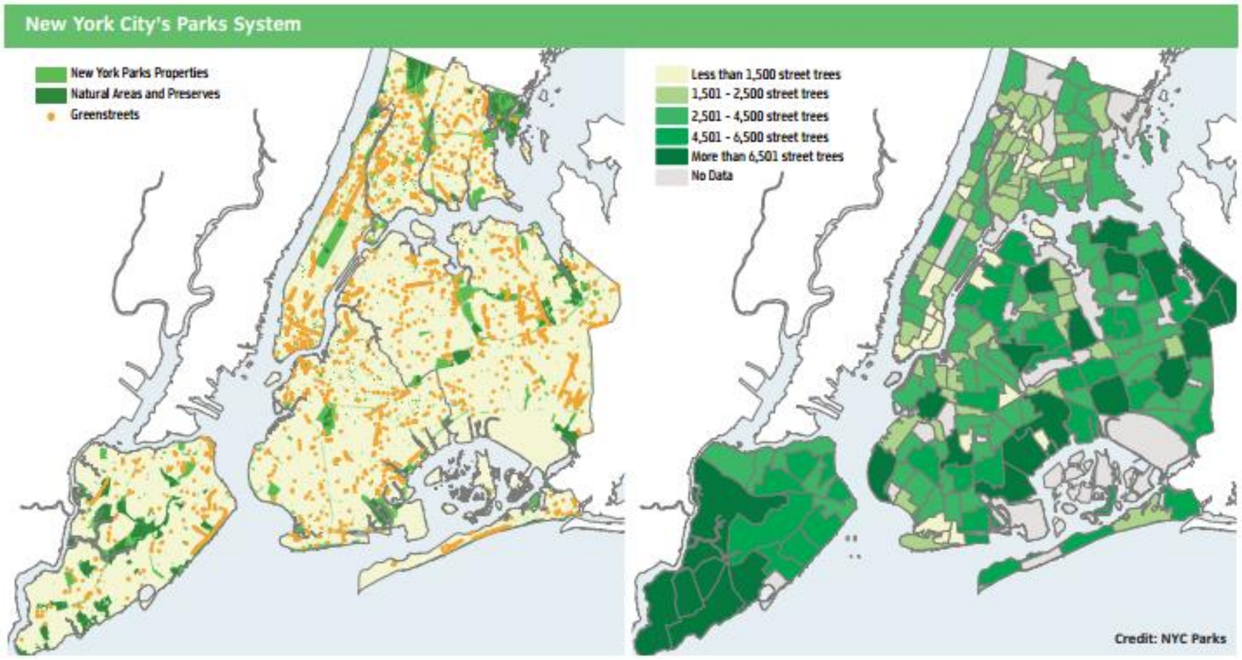
The TBNC service area is especially impacted by ocean storms because the community lies on or near the East River in Lower Manhattan. Not only does the community receive its own downpours and flooding, but because the community resides at a lower elevation than the rest of Lower Manhattan, flood waters from other communities drain into the TBNC area, adding to the community's flood levels.



(Smith, 2014)

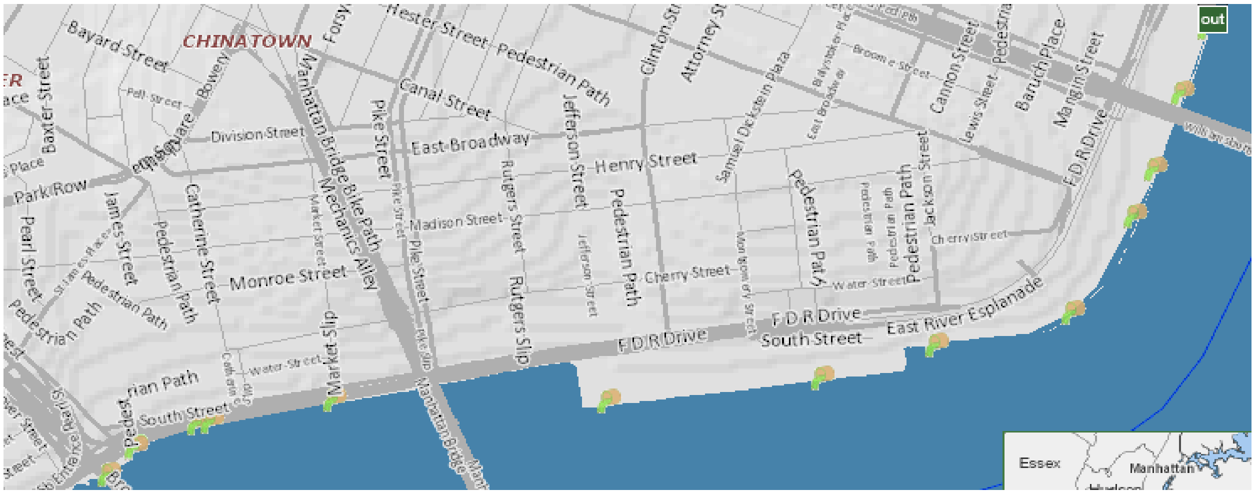
The area in green is the neighborhood west of the TBNC neighborhood and is at a higher elevation than the red area, which is the TBNC neighborhood. Stormwater runoff flows from the green areas (high elevation) into the red areas (low elevation).

Although the TBNC service area has a series of green streets, the area lacks the absorption benefits of parks and dense tree canopies (The City of New York, 2013).



(The City of New York, 2013)

Another major issue that the region faces during times of flooding is the stress placed on the combined sewer system (CSS), CSOs into nearby water bodies. A CSS is a sewer system that collects sewage and stormwater runoff into one combined pipe system. This type of sewer system is no longer used when building new infrastructure, but is in operation throughout New York City. During periods of heavy precipitation, if the CSS receives flows beyond the capacity of treatment plants, stormwater and untreated wastewater are discharged directly into New York City waterways (The City of New York, 2013). These overflows occur at designated CSO outfalls. There are sixteen CSO outfalls in the TBNC service area between the Brooklyn Bridge and Montgomery Street (Two Bridges Neighborhood Council, 2014). Green infrastructure can be used to minimize the amount of stormwater entering the CSS, leading to a reduction in capacity stress and decreasing the likelihood of raw sewage entering the East River. This will improve water quality in the East River and reduce potential negative environmental health impacts to nearby residents.



(New York City OASIS, n.d.)
The locations of the 16 combined sewer outflows in the TBNC service area.

As little as 1/20th of an inch of rainfall can trigger a CSO, where the system dumps sewage directly into the water (Schlanger, 2014). Additionally, during storm events, rainwater that falls on hard, impermeable surfaces like streets and sidewalks runs off into the storm drains bringing trash, oils, and other pollutants from the streets with it. According to the EPA, CSO's are the "largest category of our nation's wastewater infrastructure that still needs to be addressed" (Schlanger, 2014). In 2002, EPA estimated the national cost of CSO abatement to be around $44.7 billion (Schlanger, 2014).

Storm Surges in New York City

Although this paper does not provide green infrastructure suggestions to mitigate against large and infrequent storms such as Hurricane Sandy or Irene, these two hurricanes demonstrate, at large scale, the impacts of typical seasonal storms in New York City. These two hurricanes and their devastating impacts became the impetus for TBNC to seek advice on green infrastructure implementation.

Typical seasonal storms are capable of causing disruptions in the neighborhood. The type of disruption is similar to hurricane disruptions, although not similar in scale. Such disruptions include building damage (flooding, window and façade damage, and saltwater intrusion in electrical systems and HVAC equipment) and critical infrastructure damage (evacuation of hospitals, disabled power infrastructure, disrupted telecommunication infrastructure, and subway station flooding). A lack of electricity also means that several buildings are unable to pump water up past the sixth floor, leaving many residents and businesses without running water and sanitation facilities. Flooding can further the power damage, as many buildings' back-up generators and power equipment are located in the basements of their buildings - typically the first place to flood. Those who live in the basement, first, and second floors of some buildings receive full or partial flooding of their homes during storm events (The City of New York, 2013).

Economic Disparities and Communication Barriers

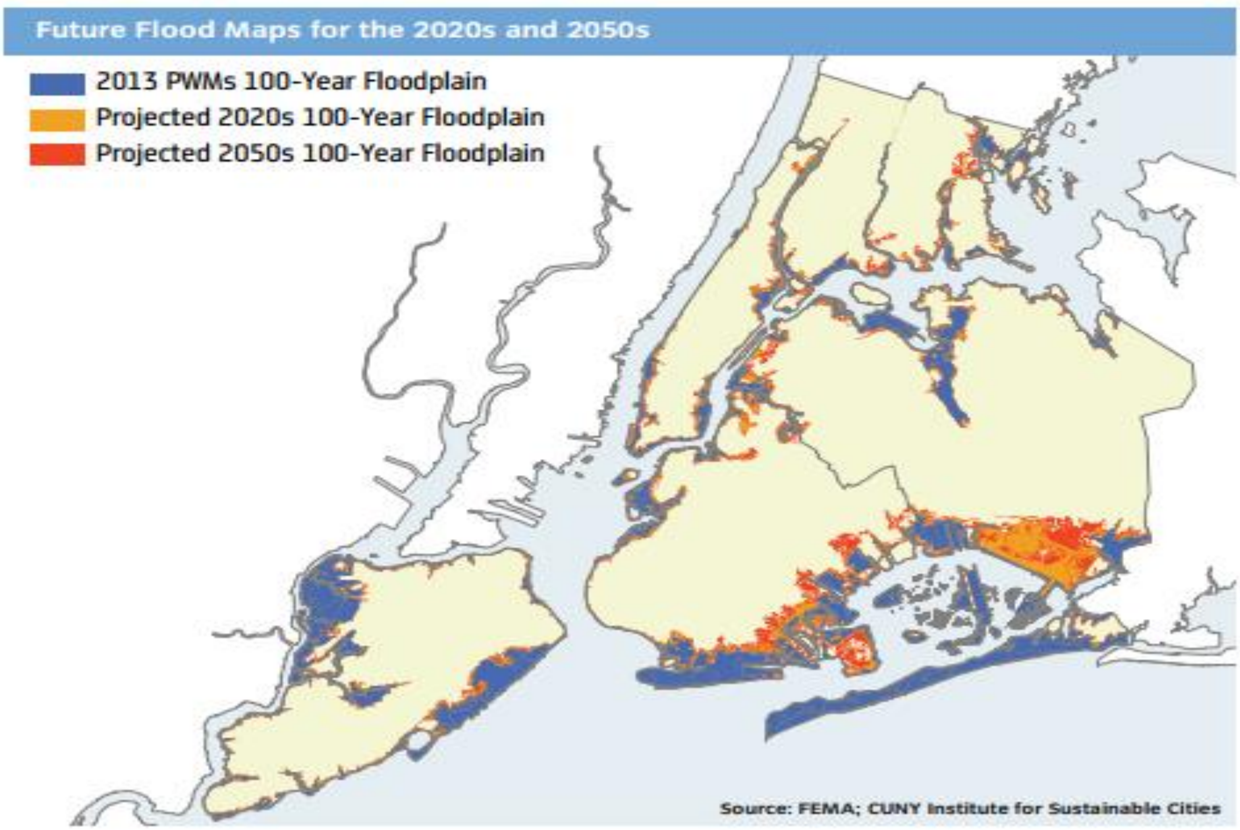
The TBNC service area is densely concentrated and features a unique demographic distribution compared to neighboring areas. Over 38,000 residents live in the TBNC service area and the population is comprised of a majority Asian population (58%), followed by Hispanic (23%), White (10%), African-American (8%), and Multiracial (1%) residents. Therefore, the community houses many non-English speakers, especially the majority Chinese population who may speak any one of numerous Chinese dialects. This population diversity contributes to the cultural richness of the area; however, it is also a major challenge when communicating with residents, especially in times of emergency. The area is also home to many elderly and disabled residents. The poverty rate in the area is 26.9%, with up to 82.5% of people living with low- to moderate-incomes. Over 85% of residents rely on rent stabilized or subsidized housing (K. Culhane, Presentation, September 25, 2014).

The combined economic and ethnic disparities of the TBNC community coupled with storm impacts on densely located critical infrastructure in Southern Manhattan make this area one of the most vulnerable in all of New York City. Residents of public housing developments are especially vulnerable to weather events, as many of these developments are located on the coastline. Although high-rise buildings like the NYCHA buildings aren't as adversely impacted as one-story buildings, they often lose mechanical building equipment housed in basements, rendering buildings uninhabitable and leaving residents stranded on upper floors. More than 400 NYCHA buildings containing approximately 35,000 housing units lose power, heat, or hot water during storm events (The City of New York, 2013). The TBNC service area contains several NYCHA buildings.

Future Risks

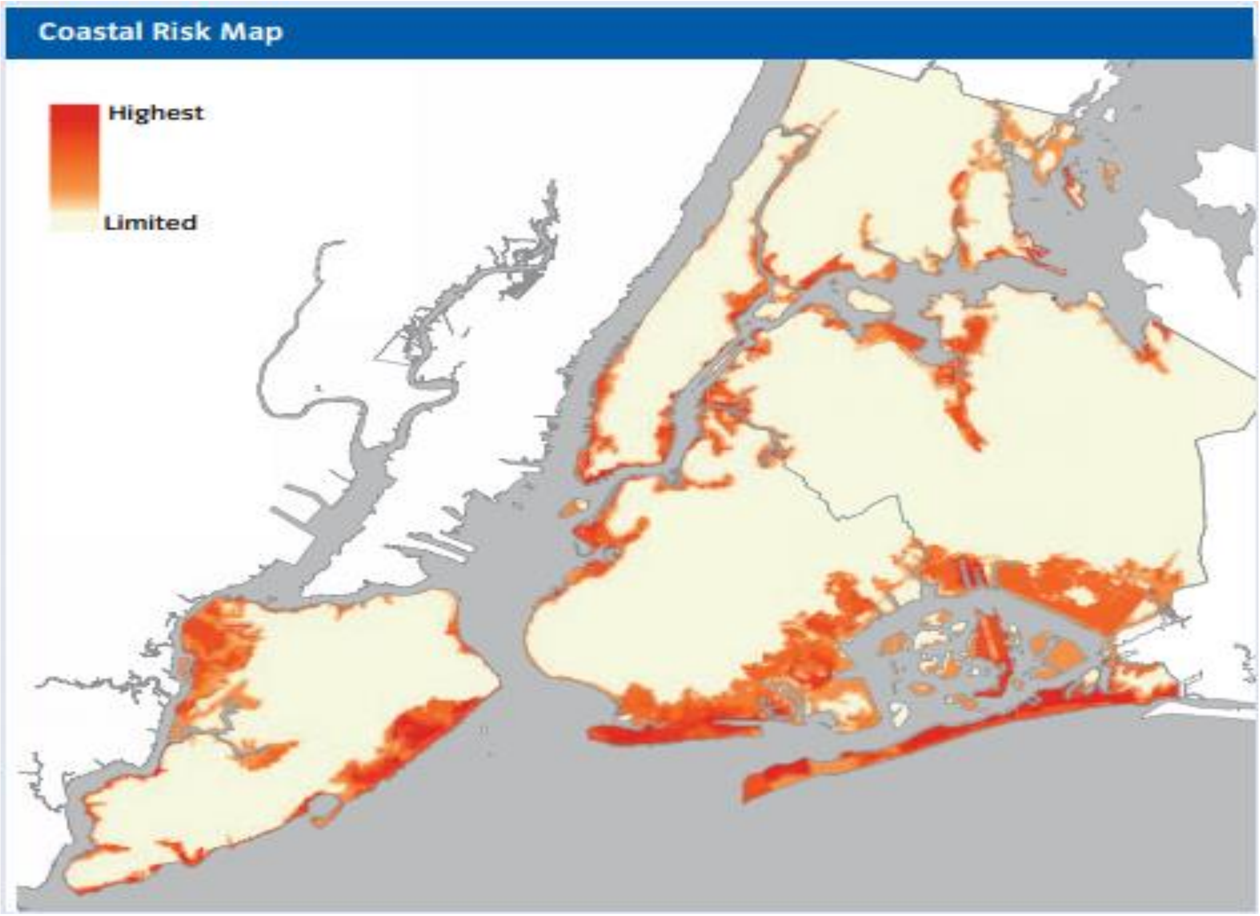
Average Precipitation Increase

Future climate change will leave the TBNC service area a more vulnerable place to work and live. Climate change factors continuously change the FEMA floodplain maps, making the area more susceptible to major flooding. The future 100-year floodplain maps provided by FEMA predict growing flood zones for New York City. These flooding changes are due to sea-level rise and increased precipitation in the northeast. Sea levels at the Battery in New York City have already risen 14% since 1900. By 2050 sea levels in New York City are expected to rise another 11-24 inches. These sea level changes have profound effects on daily life in lower Manhattan. For instance, projected sea level rise is likely to cause daily or weekly tidal flooding in low-lying neighborhoods (The city of New York, 2013).



(The City of New York, 2013)

Changing precipitation patterns also have sizable effects on flooding issues in the area. Some studies show that the northeast's precipitation patterns have already increased by 15% from 1900 (Walsh, 2013). From 1958 to 2012 the northeast has suffered from an increase of 71% in very heavy precipitation, and flood magnitude has increased 9% per decade from the 1920s through 2008 (Walsh, 2013). By 2050 annual average precipitation is expected to increase another 5-10% in the area, intense rainfall will likely increase 4%, and the 100-year flood is expected to increase in average still water flood height by one to two inches (The City of New York, 2013). Storm power dissipation is also expected in increase over time, and the area will very likely become a riskier place to live and work.



(The City of New York, 2013)

Average Temperature Increase
Increased storm frequency and intensity, and levels of precipitation will not be the only climate change factors that will affect New York City (International Panel on Climate Change, 2013). Increased temperatures will add another dimension to the vulnerability of the TBNC community. In some places around the world, temperatures are expected to increase by as much as 11 degrees Celsius by 2100 (International Panel on Climate Change, 2013). In the northeastern United States, temperatures have already increased an average of two degrees Celsius since 1900 and are expected to rise by another nine degrees by 2100 (Walsh, 2013). New York City's baseline average temperature is 54 degrees Fahrenheit. By 2020 New York will likely see an average two to three degree Fahrenheit increase from the baseline (Walsh, 2013), and by 2050 a four to six degree Fahrenheit increase from the baseline (The city of New York, 2013).

Extreme events such as heat waves, defined as a number of consecutive days at or above 90 degrees Fahrenheit, are also very likely to increase with time. New York City's baseline consists of an average of two heat waves per year with an average duration of four days. By 2020, heat waves are expected to increase to three to four per year with an average duration of five days, and by 2050 experts predict there to be approximately five to seven heat waves per year, lasting around six days per heat wave (The City of New York, 2013).

An increase in average temperature will be exacerbated in New York City due to the urban heat island effect. When the sun's infrared heat waves hit a surface, some of the rays are absorbed and some of the rays are reflected back into the atmosphere, based on the albedo or reflectivity of a surface. Dark-colored, dense materials with lower albedos, such as asphalt and brick, absorb more infrared heat and slowly dissipate this heat back into the atmosphere throughout the day after the sun has set. The high concentration of these materials in New York City causes the metropolitan area to be warmer than neighboring suburban areas covered in plentiful vegetation, with higher albedos.

Heat waves are extremely dangerous in an urban area, as more people die each year from heat waves than from any other environmental disaster (A. Freed, Class Lecture, September 22, 2014). Heat waves can be especially harmful in neighborhoods like Two Bridges, which have many low- to moderate-income, elderly, and non-English speaking residents. Low- to moderate-income residents are disproportionately affected by heat waves, as they may not have the financial means to purchase, operate, and maintain air conditioners and fans. Further, they may not be able to afford leaving New York City during heat waves to seek relief in cooler areas. The elderly are greatly affected because they are more susceptible to heat related illness and death. Non-English speakers are vulnerable because they may not understand safety warnings and instructions.

Fewer dark and dense surfaces, and more light-colored and vegetated surfaces, such as white roofs, green roofs, green spaces, and light-colored pavement will reduce the urban heat island effect in New York City. In turn, this will reduce reliance on energy-consuming air conditioners and fans, and propagate a more comfortable living experience and improved quality of life for urban New Yorkers.

Potential Funding Opportunities

Manhattan Borough President

The Manhattan Borough President (BP) is responsible for allocating funds to city agencies, cultural institutions, and nonprofit organizations in order to purchase or improve fixed assets, such as parks, buildings, and other infrastructure (Manhattan Borough President, 2014).

In order for an organization to receive a grant from the BP, the organization must meet the following requirements:

- The recipient organization must have one or more City operating contracts.
    - For real property projects, the contract must be for at least three consecutive fiscal years including the current fiscal year (2015), and have a minimal annual dollar amount of $50,000. (This requirement does not apply to Cultural Projects.)
- For real property projects, there must be a minimum City contribution of at least $500,000
- For projects involving movable property that has a minor degree of attachment to real property, the project must have a minimum City contribution of at least $250,000.
- For projects involving real property (such as construction or renovation), the property must be used and owned by the recipient organization (i.e. not rented) except for:
    - Property rented from an affiliate of the recipient organization (provided that either the two entities are under common corporate control or no rent is paid by the organization, and both entities are nonprofits and there is no mortgage on the property).
    - Governmental property

(Manhattan Borough President, 2014)

New York City's Green Infrastructure Grant Program

The service area in which the TBNC conducts its operations is not considered a priority sewer shed by the DEP. Priority sewer sheds are those which are charged to implement green infrastructure projects in order to achieve the largest reductions in CSOs. However, areas such as the TBNC service area, which are not located in priority sewer sheds, are still eligible for grant funding through the DEP's Green Infrastructure Grant Program. The program was created for private property owners and establishes a minimum requirement that owners manage the first inch of stormwater that their property receives (New York City Department of Environmental Protection, 2013). Eligible projects include blue roofs, green roofs, porous pavement, and rainwater harvesting. Funding is project dependent.

Green Infrastructure Tax Abatement Program

Recognizing the economic and environmental benefits provided by green roofs, the City has incentivized the construction of green roofs through its green roof tax abatement program. The program specifically identifies green roof benefits such as stormwater management, air quality improvement, reductions in energy use and urban heat island effect, etc. Introduced in 2008, New York City and New York State passed legislation to provide a one-year tax abatement of $4.50 per square foot up to $100,000, or the building's tax liability, whichever is less, for such projects (New York City Department of Environmental Protection, 2012). Further legislation passed in 2013 extended the program through March of 2018. At least 50% of eligible roof space must be covered by the green roof and must contain a growth medium of at least two inches. Among other requirements, at least 80% of the green roof must be covered by a vegetative layer of live plants.

Community Development Block Grant

The Community Development Block Grant (CDBG) program is a hallmark program of the U.S. Department of Housing and Urban Development (HUD). This program provides communities with resources to address a wide range of unique community development needs. Beginning in 1974, the CDBG program is one of the longest continuously run programs at HUD. The CDBG program provides annual grants to 1209 general units of local government and states according to their population, poverty index, and housing needs (*Community Development Block Grant Program*, 2014).

The CDBG program has eight unique programs. One program is the Disaster Recovery (CDBG-DR) assistance, whereby HUD provides flexible grants to help cities, counties, and states recover from presidentially declared disasters, especially in low-income areas, and is subject to availability of supplemental appropriations (*Community Development Block Grant Disaster Recovery Program*, 2014). Congress may appropriate additional funding for CDBG – DR grants to rebuild the affected areas and provide crucial seed money to start the recovery process. CDBG-DR assistance may fund a broad range of recovery activities, helping communities and neighborhoods that otherwise might not recover due to limited resources.

As a response to Hurricane Sandy, Congress appropriated CDBG supplemental funds in Public Law 113-2, for an amount of $15.18 billion. The total funding to date is shown in the table below.

Grantee	First allocation	Second allocation	Third allocation	Rebuild by design	Total funding To date
Connecticut	$71,820,000	$66,000,000	$11,459,000	$10,000,000	$159,279,000
New Jersey	1,829,520,000	1,463,000,000	501,909,000	380,000,000	4,174,429,000
New York	1,713,960,000	2,097,000,000	420,922,000	185,000,000	4,416,882,000
New York City	1,772,820,000	1,447,000,000	639,056,000	355,000,000	4,213,876,000
Rhode Island	3,240,000	16,000,000	671,000	N/A	19,911,000
Maryland	8,640,000	20,000,000	N/A	N/A	28,640,000
Total	5,400,000,000	5,109,000,000	1,574,017,000	930,000,000	13,013,017,000

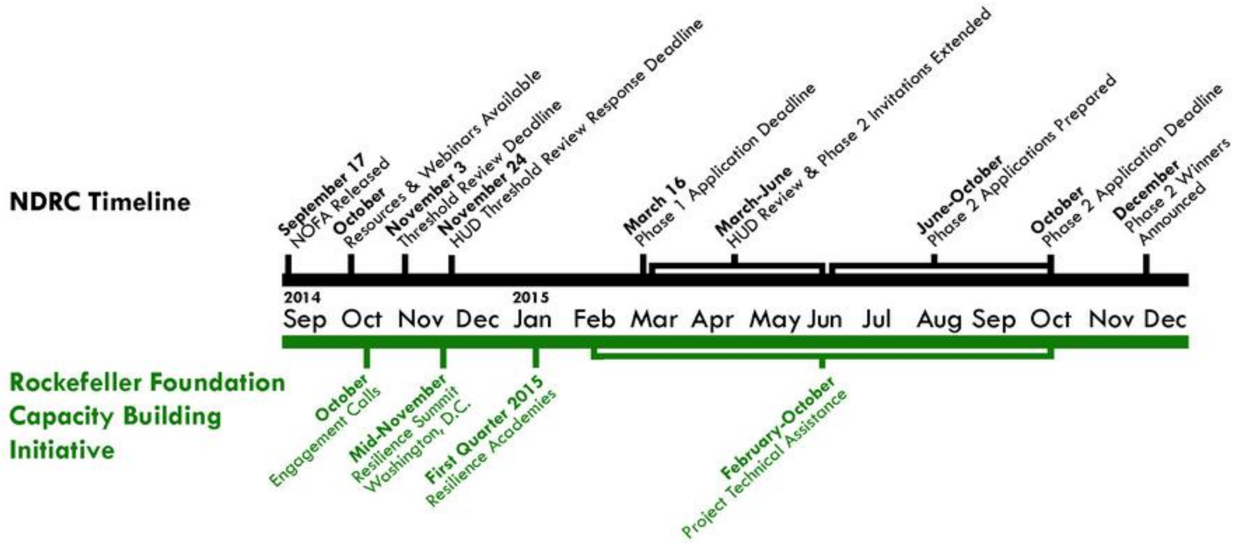
(Federal Register, 2014)

Rebuild by Design

Included in the Rebuild by Design awards is New York City's grant application called the Big U, which was awarded $335 million. The Big U is a protective system that stretches from West 57th street south to the Battery and up to East 42 Street, covering ten contiguous miles of low lying geography (Rebuild by Design, 2014). The plan describes flood protection strategies that double as community amenities.

National Disaster Reliance Competition

On June 14, 2014, President Obama announced the National Disaster Resilience Competition. Responding to demand from state, local, and tribal leaders who are working to increase the safety and security of their communities, the nearly $1 billion competition invites communities that have experienced natural disasters to compete for funds to help them rebuild and increase their resilience to future disasters. The competition allows 67 eligible governmental applicants to apply. Professionals and community groups can partner with eligible applicants. The Rockefeller Foundation is providing technical assistance for the process. The following timeline shows the key dates.



(The Rockefeller Foundation, 2014)

U.S. Department of Housing and Urban Development

One funding source for green infrastructure is through HUD, which has an Energy Performance Contracting (EPC) option. The EPC option is an innovative financing technique using cost savings from reduced energy consumption to repay the cost of installing energy conservation measures (*Community Development Block Grant Program*, 2014).

Summary of Funding Sources

Program Name	Source	Type	Amounts	Details
Enterprise Community Partners	CDFI – nonprofit loan fund	Grants; loan	Project Specific	Helps provide revitalization to in need communities
Disaster Relief Fund US	CDFI – nonprofit loan fund	Loans	$100k-$1M	Terms up to 5 years
Energy Performance Contracting (EPC)	U.S Department of Housing and Urban Development	Grant	Project Specific	Innovative financing technique using cost savings from reduced energy consumption to repay the cost of installing energy conservation measures
Manhattan Borough President Capital Project Grant	City of New York – BP Office	Grant	$5k-$500,000	Allocates funds for community improvement
Green Infrastructure Grant Program	City of New York- DEP	Grant	Project Specific	DEP funding for green infrastructure
Green Infrastructure Tax Abatement Program	City of New York	Tax Abatement	one-year tax abatement of $4.50 per square foot up to $100,000, or the building's tax liability	Green improvements to buildings
Community Development Block Grant (CDBG) – Disaster Recovery	U.S Department of Housing and Urban Development	Grant	Project Specific	Grants to rebuild the affected areas and provide crucial seed money to start the recovery process
National Disaster Reliance Competition	U.S Gov\ Rockefeller Foundation	Competition	Project Specific	Compete for funds to rebuild after a disaster
PlaNYC Schoolyards to Park Program	DEP- Trust for Public Land- DOE- SCA	Competition	$500k-$800k	Compete to retrofit old parks into green space

Proposed Solutions

Based on the neighborhood analysis and the storm-related health and environmental issues detailed in this paper, three possible green infrastructure solutions will be evaluated for implementation in the TBNC service area. These solutions include: greening parks and playgrounds, permeable pavements, and stormproof buildings.

GIS data was used to identify specific “hotspots,” or prime locations where green infrastructure can be most impactful. These locations include two TBNC-owned buildings at 80 and 82 Rutgers Slip, and P.S. 184 Shuang Wen School.

Permeable Pavement

Numerous hardscaped concrete and asphalt surfaces throughout the TBNC region prevent stormwater from effectively draining the area. Permeable pavement can be used in parking lots, on sidewalks, and on other hardscaped surfaces to improve drainage and reduce localized flooding. There are several permeable pavements available that allow water to seep into the ground and slowly filter into the sewer system, allowing for improved flood mitigation. Parking lots and sidewalks are a great place to implement permeable pavement because they do not receive the same rigorous wear and tear as streets, and are smaller and easier to maintain than city streets. Lightly colored pavers can also reduce urban heat island effect.

Permeable paving can be defined as a system with porosity and permeability high enough to allow water to readily pass and thus significantly influence hydrology, rooting habitat, and other positive environmental effects (Huffman, 2008). Permeable pavement systems typically consist of strong structural materials containing regularly interspersed void areas, which are filled with pervious materials such as gravel or sod (U.S. Environmental Protection Agency, 2012).

Permeable pavements can replace conventional, traditional impervious pavement techniques. Examples of impervious surfaces include: asphalt roads, concrete sidewalks, parking lots, building roofs, and areas of highly compacted soils such as in subdivisions. Replacing conventional surfaces with permeable ones helps to reduce the impacts of the stormwater runoff, sewer overflows, and over-flooded storm drains by allowing precipitation to infiltrate the soil below. Moreover, pollutants slowly filter through the crushed stone and soil layers, allowing natural filtration processes to improve water quality by retaining some pollutants that would otherwise enter streams and rivers with runoff.

A typical permeable pavement consists of a surface pavement layer, an underlying crushed stone reservoir layer, and a filter or fabric layer installed on the bottom. Depending on the amount of precipitation and the capacity of the soil to soak up rainwater, the size and extent of the crushed stone layer will vary.

Types of Permeable Pavement

Numerous types of permeable pavements are available, however, the most commonly used types include: pervious concrete, porous asphalt, and permeable pavers. Other types and variations exist, but these are the most popular and versatile designs. Permeable pavers are commonly used in residential properties since owners have the flexibility to choose the shape, size, color, and design to meet their individual needs. They can also be used in walkways, plazas, and parking areas for larger-scale projects. Pervious concrete and porous asphalt are more versatile than permeable pavers, and can be used in a wide variety of applications, such as resurfaced sidewalks, driveways, and parking areas (Prince George’s County Department of Environmental Resources, 2014).

The choice of material depends on the user’s needs, cost, material availability, constructability, and maintenance. All pavement choices have similar water retention capabilities, are similar in cost, and require comparable maintenance.

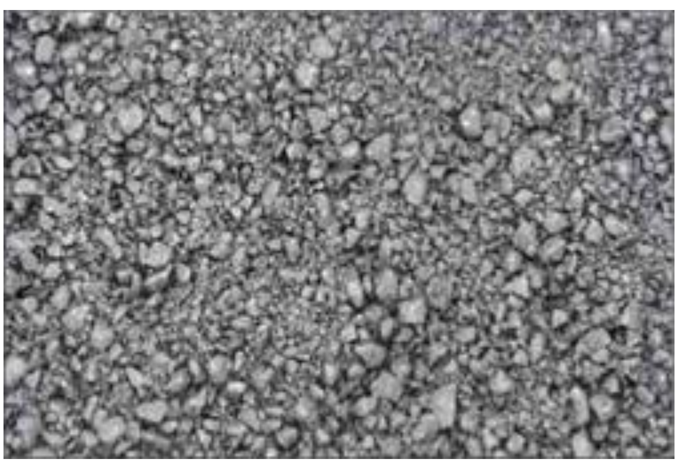
Pervious Concrete

Pervious concrete is the most versatile of porous materials. It can be used in parking areas, driveways, sideways, roadways, etc. Pervious concrete is attributed with long-term durability, high solar reflectivity, an ability to bare loads, maintaining its porosity, and can be used in many applications. It is a mixture of Portland cement, coarse aggregate or gravel, and water. Unlike conventional concrete, pervious concrete contains a void content of 15% to 35%, which is achieved by eliminating the finer particles, such as sand, from the concrete mixture. This empty space allows water to filter into the underlying soil instead of pooling on the surface or being discharged as runoff (Agouridis et al., 2011). The pervious concrete filters pollutants that can contaminate watersheds and harm sensitive ecosystems, eliminates hydrocarbon pollutants from asphalt pavements and sealers, and channels more water to tree roots and landscaping, decreasing the need for irrigation (Connecticut Housing Finance Authority, 2013).

Pervious Concrete (TecEco, n.d.)

In addition to the stormwater management benefits of pervious concrete, it also reduces urban heat island effect because it is lighter in color than traditional pavement. This light color is better at reflecting solar radiation than dark surfaces.

Porous Asphalt



Porous asphalt (Agouridis et al, 2011)

Porous asphalt is a standard asphalt mixture of both fine and coarse aggregate elements bound together by a bituminous binder. Unlike traditional asphalt, it uses less fine aggregate matter (Agouridis et al., 2011). Similar to pervious concrete, it contains a void content of 15% to 35% (Agouridis et al., 2011). It has a similar surface appearance as conventional asphalt, yet porous asphalt has a rougher texture. Its most distinctive positive attributes are installer availability, consistent color (always black), increased speed of construction and similar appearance to conventional asphalt pavement (Huffman, 2008). It promotes runoff infiltration and reduces the amount of pollutants carried to a storm drains and waterways (Nashville Civic Design Center, 2014). Porous asphalt can be used for parking lots, driveways, sidewalks, bike paths, playgrounds, and tennis courts. With proper maintenance, it has a minimum service life of 20 years (Nashville Civic Design Center, 2014).

Permeable Pavers

Permeable pavers are solid, concrete, or brick blocks that fit together to form a pattern with small aggregate-filled spaces in between, allowing stormwater to filter into the ground. These spaces typically account for 5% to 15% (for concrete blocks) and 20-50% (for brick blocks) of the paver's surface area (Agouridis et al, 2011). Permeable pavers are ideal for smaller applications, available in many different patterns, are load bearing, and are pre-manufactured off-site.

Permeable Pavers (Pavestone, n.d.)

Benefits of Permeable Pavement

Permeable pavements provide a number of benefits. The primary benefit is the ability to absorb rainwater following a storm. Unlike impervious surfaces where rainwater runs-off or drains to an area of lower elevation, permeable pavements allow rainwater to penetrate beneath the filtering media and recharge groundwater aquifers. The filtered rainwater can influence a site's hydrology and the rooting habitat of surrounding plants, which reduces the need of additional water resources for irrigation purposes.

Further, permeable pavement can be extremely cost-effective. According to the U.S. Environmental Protection Agency (2014), "because [permeable pavement] reduces the effective impervious area of a site, permeable pavement should receive credit for pervious cover in drainage system design. The infiltration rate of properly constructed pervious concrete and base generally exceeds the design storm peak rainfall rate" (*Pervious Concrete Pavement*, 2014). Specifically, pervious concrete can drastically reduce runoff, sometimes eliminating it entirely. Studies have shown that water can pass through pervious concrete at a rate of 3-5 gallons per minute per square foot (Huffman, 2008).

One of the advantages of selecting pervious concrete as a permeable pavement, as opposed to porous asphalt or permeable pavers, is its ability to help mitigate urban heat island effect. Generally, pervious concrete is light in color, and thus exhibits properties of higher solar reflectivity (high albedo). Asphalt, on the other hand, has lower solar reflectance properties, absorbing 85% to 95% of solar energy (U.S. Environmental Protection Agency, 2008). Surfaces with a high albedo reflect heat back into the atmosphere, inhibiting it to be absorbed by the material. When this happens, the air around the material is lower in temperature than darker surfaces. An increase in light-colored surfaces will reduce the ambient air temperature in cities, which will further reduce the energy required to cool buildings in the summer.

Building Site and Design Considerations

Permeable pavement systems can be installed in most places that conventional concrete or asphalt pavement is presently used. However, some properties of permeable pavements limit their applicability. Some important site considerations include:

- Areas where high traffic loads, in terms of volume and weight, and high speeds are encountered should be avoided. Low and medium traffic areas, such as parking lots, residential roads, pedestrian areas, etc. are better suited for permeable pavements.

- Areas with a slope of less than 0.5% are best for permeable pavement applications so that stormwater runoff is evenly distributed and has a chance to infiltrate the ground. Systems can be used on sites with slopes up to 5%.
- The underlying soil percolation rate should be a minimum of 0.5 inches per hour. If underlying soils do not meet the permeability requirement, then soils must be modified using gravel or an underdrain.
- Stone reservoirs should be flat.
- Areas near facilities that generate significant concentrations of pollutants, such as vehicle service areas, industrial chemical storage facilities, and gas stations, should be avoided.
- Exclude any surfaces that accumulate a lot of sediment and debris, as that can clog the surface and reduce the effectiveness of the system.

(Mukherjee, 2014; Agouridis et al., 2011; Maryland Center for Watershed Protection, 2010)

Maintenance

To ensure that the system continues to function properly, permeable pavements require maintenance on a regular basis. One of the most common problems that impact permeable pavement systems is clogging. Clogging takes place when sediment and other materials obstruct pores, resulting in reduced filtration. To prevent clogging and other possible problems, the following steps should be performed:

- Keep landscaped areas well maintained and prevent soil from being transported onto the pavement.
- Vacuum-sweep the surface, and follow with high-pressure jet hosing at least four times per year.
- Do not apply sand or ash to permeable pavement for snow removal purposes.
- In some instances, the use of brooms, hoses, and pressure washers for cleaning and clearing purposes can compromise the system's integrity.
- For paving stones, periodically add joint materials, such as sand, to replace any materials that have been lost.
- Repair cracking, splitting, or other damage to the pavement surface.
- Do not reseal or repave with impermeable materials.
- Post signs where permeable pavement is installed to advise maintenance crews of proper cleaning techniques.

(Prince George's County Department of Environmental Resources, 2014; Agouridis et al., 2011; Maryland Center for Watershed Protection, 2010; U.S. Environmental Protection Agency, 1999)

Costs

A number of factors affect the cost of permeable pavement, such as the availability of materials, transport, site conditions, stormwater management, projects size, contractor experience, and the method of installation (in the case of permeable pavers) (Agouridis et al, 2011). Initial costs for permeable pavements may be more than conventional materials. However, the use of permeable pavement can often eliminate the requirement for underground storm drainpipes and conventional stormwater systems. Cost savings due to decreased investments in reservoirs, storm sewer extensions, and the repair and maintenance of storm drain systems will off-set high initial purchase and installation costs (Low Impact Development Center, Inc., 2002). For example, porous asphalt can cost 10% more than conventional asphalt, yet the life cycle cost of the porous asphalt is 30% less than conventional asphalt (Ferguson, 1996).

Unfortunately, studies that compare construction, maintenance, and life cycle costs for stormwater management systems are limited. The wide range of site conditions and design requirements make it difficult to determine precise life cycle cost costs. Researchers recommend that each potential application be evaluated on a site-by-site basis. However, a range of cost estimates for the basic installation of permeable paver materials is given in the table below for comparison purposes.

Material costs for different permeable pavement materials

Paver System	Cost Per Square foot Installed Pavement
Pervious Concrete	\$2.00 to \$6.50
Porous Asphalt	\$0.50 to \$1.00
Permeable Paver	\$1.50 to \$5.75

(Whole Building Design Guide, 2010)

The breakdown of costs associated with developing a porous pavement system is shown in table below. Depending on the system specifics, project costs may vary.

Estimated costs for a porous pavement system

Component	Unit Cost	Total
Excavation Costs	740 yard^3 x \$5.00/yard^3	\$3,700
Filter Aggregate/Stone Fill	430 yard ^{3}x \$20.00/yard^3	\$14,800
Filter Fabric	760 yard^2 x \$3.00/yard^3	\$2,280
Porous Pavement	556 yard^2 x \$13.00/yard^2	\$7,228
Overflow Pipes	200 feet x \$12.00/feet	\$2,400
Observation Well	\$200 each	\$200
Grass Buffer	822 yard^2 x 1.50/yard^2	\$1,250
Erosion Control	\$1000	\$1,000
Subtotal		\$32,858
Contingencies (Engineering, Administration, etc.)	25%	\$8,215
Total		\$41,073

(Environmental Protection Agency, 1999)

For more accurate price comparison, costs of the full stormwater management paving system should be included in addition to initial installation costs. For instance, when costs for drains, reinforced concrete pipes, catch basins, outfalls, and stormwater connects are included, conventional paving systems cost between \$9.50-\$11.50 per square foot, compared to permeable pavement systems at \$4.50-\$6.50 per square foot (Belanger, 2008). However, annual maintenance costs for permeable pavement systems tend to be higher than those for conventional systems. Maintenance for permeable systems generally costs 1% to 2% of the construction cost (Prince George’s County Department of Environmental Resources, 2014).

When a life cycle cost analysis is considered for both materials, permeable pavement is cheaper. Projects that use permeable pavement typically save on infrastructure costs. Grading requirements for the pavement are also reduced because there is no need to slope the parking area to storm drains.

Funding

For this specific project, two sources of potential funding are available to increase permeable surface coverage through the Manhattan Borough President's Office and the DEP's Green Infrastructure Grant Program.

The Manhattan Borough President's Office offers funding for various capital projects throughout Manhattan. This grant funding is available for non-profit organizations such as TBNC and can be used for construction and reconstruction projects, such as replacing parking facilities with permeable pavements. In order for TBNC to receive funding, their subsidies for maintaining affordable housing must qualify as a New York City operating contract. Real property projects are eligible for a minimum city contribution of at least $500,000. The project must have a useful life of at least five years (Manhattan Borough President, 2014).

TBNC has already received a grant through DEP's Green Infrastructure Grant Program for a rain garden located in their service area. This program requires projects retain a minimum of one inch of stormwater runoff from the contributing impervious area (New York City Department of Environmental Protection, 2014). Installing permeable pavement can easily meet this one inch requirement.

According to the neighborhood analysis, TBNC's building at 80 Rutgers Slip is covered by 6,359 square feet of impermeable surface coverage. For every one inch of rainfall, this surface area can absorb approximately 3,964 gallons of water (New York City Department of Environmental Protection, 2014).

Recommendations for the Selected Site

An acceptable location to develop a case study for permeable pavement installation is in the back lot of the TBNC building at 80 Rutgers Slip, covering 6,359.76 square feet of surface area.

For this site, pervious concrete is the ideal material to use. Parking areas covered by pervious concrete offer superior performance when compared to other pavement alternatives. Because of its strength, durability, and minimal maintenance requirements, pervious concrete is an economical paving choice. According to the Southern California Ready Mixed Concrete Association, most parking areas, when properly constructed, will last 20-40 years (National Ready Mixed Concrete Association, 2011). In urban cities, pervious concrete is ideal because it reduces the need to rebuild storm sewer systems.

Despite its higher initial cost, pervious concrete is better suited for the area than porous asphalt because of its following comparative advantages:

- Significantly lower life-cycle cost
- Requires fewer repairs
- Has a longer life-span
- Minimizes the need for runoff retainers, thereby reducing property costs
- Limits overproduction since it is made directly onsite and on an as-needed basis

- Is recyclable

(Nashville Civic Design Center, 2014)

For the selected area, the table below shows the estimated minimum and maximum material cost for installing pervious concrete. The estimated material cost is $6.00 per square feet of installed pavement. For 80 Rutgers Slip, this will total $38,158.56. For maintenance, the area would require annual vacuum-sweeping or high pressure hosing, equal to $763 per year. For maintenance, the area would require annual vacuum-sweeping equal to $763 per year.

Material cost calculation for the selected area

Paver System	Cost Per Sq.Ft. Installed Pavement	Minimum Installed Pavement Cost	Maximum Installed Pavement Cost
Pervious Concrete	$2.00 to $6.50	$12,720	$41,338
Porous Asphalt	$0.50 to $1.00	$3,180	$6,360
Permeable Paver	$1.50 to $5.75	$9,540	$36,569

(Whole Building Design Guide, 2010)

Green Playgrounds and Community Spaces

The TBNC service area has numerous public parks, community spaces, and school playgrounds that are currently constructed using many impermeable materials like concrete, brick, and asphalt, and lack vegetation that is conducive to absorbing heat and water, and filtering toxins. By renovating playgrounds and public parks with green infrastructure, the community spaces will be better equipped to absorb water during rainfall and flooding events, and will be better designed to hold water and slowly release it into the city sewer system. The parks will also lower the ambient air temperature in the area and improve the neighborhood's air quality. Park and playground renovations described in this section will focus on reducing impermeable surface coverage by adding grass, plants, and trees to the space. Specific funding opportunities exist for transforming school playgrounds and making them accessible to the public when school is not in session.

Problem

TBNC's location in a low-elevation region of southern Manhattan directly adjacent to the East River and major motor vehicle thoroughfares like the FDR drive, is negatively impacting community members' health and quality of life. Insufficient stormwater management is causing local street flooding and CSO release directly into the East River. Close proximity to FDR Drive and the East River put the population at risk of airborne particulates emitted from vehicles and untreated sewage in the waterways.

Area Description

The expanded TBNC boundary is approximately 238 acres and contains 13 schools on nine distinct tax lots (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014). Four different schools are located at 220 Henry Street and two schools are located at 293 East Broadway. Within the region there are eight elementary schools: six public, one public charter, and one private/parochial. There are two public middle schools, one public junior/senior high school, one public high school and one K-12 private/parochial school. Two of these properties, elementary schools P.S. 126 Jacob August Riis and P.S. 184 Shuang Wen, experience some extent of flooding during storms (Federal Emergency Management Agency Modeling Task Force, 2014). Based on the 100-year floodplain maps, these properties will continue to be the most vulnerable within the TBNC service area (New York City Mayor's Office of Long Term Planning and Sustainability, 2014). Approximately 817 students attend P.S. 126 and 689 students attend P.S. 184 (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014). These two properties were selected for further analysis due to the high likelihood of further storm-related flooding.

See Appendix B for land cover data for the tax lot containing P.S. 126 Jacob August Riis and P.S. 184 Shuang Wen.

Funding Sources

One of the best ways to finance green infrastructure in the TBNC service area is to utilize the PlaNYC Schoolyards to Playgrounds Program. This program is part of a larger goal aimed at ensuring that all New Yorkers live within a 10 minute walk from a park by 2030 (New York City Department of Environmental Protection, 2013). Rebuilding schoolyards into parks so they are accessible by the community after school day's close disperses the higher costs of green infrastructure to a variety of funding sources while meeting the goals of all parties.

In 2011, an agreement was made between the DEP, Trust for Public Land (TPL), School Construction Authority (SCA), and the Department of Education (DOE) to fund $5 million of construction for 40 green infrastructure public school playgrounds over four years (New York City Department of Environmental Protection, 2013). An interview with MaryAlice Lee, TPL's Director of the New York City Playgrounds Program, revealed that to date, five green schoolyards have been opened and 15 more are either in planning or construction phases (M. Lee, Telephone Interview, November 6, 2014). There are still 20 schools to be slotted for the PlaNYC Schoolyards to Playgrounds Program. One of the pilot schools for this program was P.S. 261 Philip Livingston in Brooklyn, located in the Gowanus Canal CSO Tributary Area (New York City Department of Environmental Protection, 2013). The playground was designed to manage 500,000 gallons of stormwater per year (New York City Department of Environmental Protection, 2013). The green infrastructure elements chosen for the park include rain gardens, *Flexi Pave*, shade trees, and synthetic turf fields. The total cost of this project was $604,000, and the DEP contributed $263,000 of the total funds allocated to green infrastructure (New York City Department of Environmental Protection, 2013).

TPL estimates that the total budget for future projects will be between $500,000 and $800,000 per playground. This cost is dependent on the size of the playground, the percentage of reusable materials, and demolition costs. When choosing playgrounds to renovate, TPL gives priority to areas servicing poorer communities, with a sizeable youth population, available space, and GIS mapping of vulnerable areas. Typically, the schoolyard projects range from 23,000 square feet to half an acre (M. Lee, Telephone Interview, November 6, 2014).

In the unveiling of the pilot green playground at P.S. 261, the New York City Director of TPL highlighted the impact of green infrastructure on the community by saying, "In the advent of climate change and increased storm events, combining inner city recreation and new playgrounds where needed with the latest green infrastructure technologies that capture rain water is a win-win for a cleaner harbor and reduced local flooding in our neighborhoods" (The Trust for Public Land, 2013). The Schoolyards to Playground program is a successful strategy for leveraging public-private partnerships with the goal of retrofitting public property with green infrastructure.

Potential Measures

A school playground undergoing green infrastructure transformation will include a myriad of elements designed to capture and store rainwater, improve air quality, and most importantly, facilitate play. Early in the design process, engineers conduct geotechnical investigations to ensure that stormwater can infiltrate the existing subsoil beneath the playground. Designers then divide the site into various catchment areas, based on the existing grade of the land. Due to natural topographic and soil differences in sites, each playground will employ its own set of green infrastructure elements to best achieve the project's goals. Some such elements can include:

- Synthetic turf
- Playgrounds covered by porous asphalt
- Paths covered by permeable pavers

- Rain gardens
- Planter boxes
- Bioswales
- Rain barrels
- Small, medium, and large tree canopies
- Large and small bushes
- Storage shed with green roof
- Recycling center
- Benches
- Educational area/portable classroom
- Playground equipment
- Running track
- Basketball court
- Student murals

(Frost, 2013)

Specifically, rain gardens feature a 12 inch soil layer designed to maximize stormwater absorption into the soil beneath. The designers select plants based on their water tolerance. Synthetic turf fields feature a pervious playing surface on top of 12 inches of gravel, which holds stormwater until it can infiltrate the groundwater table. Permeable pavers are also installed over a gravel storage layer (New York City Department of Environmental Protection, 2013).

The design of the park involves an integrated process where the team consults designers, engineers, teachers, school administrators, maintenance staff, and students in a charrette process. In fact, TPL worked with a group of fourth grade P.S. 261 students in 2011 to explore conceptual design. Throughout the design process, engineers at the DEP review the hydraulic calculations and green infrastructure elements. The final location and size of each green infrastructure playground element is based on the needs of the school, the soil conditions, and the size of the impervious asphalt area to be managed (New York City Department of Environmental, 2013).

The P.S. 184 playground should be designed after similar and successful playgrounds implemented by the program, like P.S. 261 in Brooklyn. This playground is located at 314 Pacific Street, and features a rain garden, permeable pavers, shade trees, and a synthetic turf field, among other elements. The space consists of 23,000 square feet of pervious area and is able to store up to 500,000 gallons of water per year. The total cost of this project was $604,000; $263,000 of which was spent on green infrastructure (New York City Department of Environmental, 2013).

Using this sample playground area and cost, renovations cost approximately $26.26 per square foot. The existing recreational space at P.S. 184 Shuang Wen is approximately 49,523.25 square feet (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014), and will therefore cost an estimated $1,300,480.55 to renovate. However, it is not necessary that the entire playground be renovated. In order to provide funding for all 40 schoolyard projects, each project received between $500,000 and $800,000 (M. Lee, Telephone Interview, November 6, 2014). Therefore, TBNC could aim at an $800,000 renovation budget covering 30,464.58 square feet in order to be in range with the current project funding scope guidelines. This budget was developed based on client considerations and financing provided by the DOE, DEP, and TPL.

Some elements that should be strongly considered in the P.S. 184 design include: rain garden, synthetic turf, shade trees, educational space, porous pavement, phytoremediation to offset FDR pollutants, and student murals.

Economic, Social and Environmental Benefits

Water Runoff

Perhaps the most cited use for green infrastructure in park spaces is to capture storm and flood water runoff. Between 1982 and 2007 developed land use increased 56%. From 1945 to 2002 urban land area quadrupled. At this pace, the U.S. will have 68 million more acres of developed land by 2025. The fault with this increasing land coverage is that developed park land in New York City is primarily composed of paved and impermeable surfaces. Impermeable surfaces do not allow storm and flood waters to naturally and slowly filter into the ground, but instead these pavers increase the speed and amount of water runoff into nearby rivers, streams, and lakes (Garrison, 2011).

Flooding and river pollution are the two major concerns regarding runoff. Pavement has a runoff coefficient of 0.85 (New York City Department of Environmental Protection, n.d.), meaning that 85% of water falling on pavement is not absorbed and contributes to total flooding and runoff levels. In fact, FEMA estimates that 25% of economic losses from flood damage are due to urban drainage issues, not from being located in the flood plain. The EPA estimates that the cost of cleaning up flooded urban areas is between $900 million and $4.3 billion over a 15 year period (Garrison, 2011).

River pollution is a major problem in the New York City area due to the combined effects of impervious surface coverage and the city's CSS. When rainwater cannot be absorbed by paved parks, city streets, parking lots, building roofs, sidewalks, and other paved areas, the resulting runoff flows into the nearby Hudson River and East River, carrying with it pollutants from the city, including garbage, fertilizers, bacteria, pathogens, metals, oils, and animal waste. When as little as 25% of the surface area around a stream is impervious, the stream can no longer perform ecosystem services which filter runoff pollutants before entering the waterway. In fact, streams with up to 60% impervious surface area, constituting most streams in New York City, are no longer considered functioning streams, but simply conduits for flood waters (Garrison, 2011). Without natural filtration, rivers become severely degraded; urban runoff is the primary source of impairment for 13% of the nation's rivers, 18% of lakes, 32% of estuaries, and 55% of ocean shorelines (Odefey, 2012).

Combined sewers systems do not treat stormwater and sewage through different piping systems. When heavy rains flood the system, runoff and sewage mix together and are dumped directly into nearby water bodies in order to protect overflows at treatment plants. During such events, approximately 89% of the water entering the water body is stormwater, 11% is raw sewage. This leads to impaired drinking water, beach closures, and habitat destruction (Garrison, 2011). Outbreaks of waterborne disease are highly correlated with heavy rainfall events due to CSOs, resulting in increased hospital visits, missed work days, and reduced tourist industry revenue along shorelines. Nitrogen poisoning from fertilizer runoff can cause methomoglobinemia, where nitrate and nitrite inhibits blood's ability to deliver oxygen to the body. Other illness can occur when people eat shellfish from impaired water bodies. And of course, when polluted bodies of water are used for recreation, people become sick: every year 3.5 million people become sick from contact with water contaminated by sewage (Odefey, 2012).

Sickness from impaired water bodies adds a large cost to the city. In 2011, 36% of beach closures in the U.S. were due to polluted runoff and stormwater. Two California beaches calculated the cost of illness from waterborne gastronomical disease resulting from impaired beaches. They found that water pollution cost $36.53 per person in lost work days and medical costs, not including the willingness to pay to avoid illness and lost recreational value Odefey, 2012). It is estimated that clean-up treatment costs $0.012 per cubic feet of water (Harnik & Welle, 2009), a large amount when scaled up to the New York City shoreline.

Installing green infrastructure in parks is a proven way to avoid the human and environmental harms associated with runoff pollution. Permeable parks restore and mimic natural conditions, negating the high runoff coefficient of impermeable pavement. Porous asphalt has a runoff coefficient of 0.7 (compared to non-porous asphalt at 0.85), and grassed areas, rain gardens, and vegetable swales have a runoff coefficient of 0.2 (New York City Department of Environmental Protection, n.d.). Therefore, when plants are used to replace paved areas, stormwater runoff into water bodies is reduced by 65%. With natural vegetation cover, less than 10% of fallen rain continues as runoff, and of that which is absorbed by the vegetation, 60% filters into the ground and 40% evaporates into the air. Leaf canopies and root systems are able to absorb rainfall, preventing it from entering the sewer system altogether. Root systems are also helpful in maintaining soil porosity, which increases soil's capacity for water storage. As plants take up rain water, they allow the rainwater to slowly enter the sewer system long after the storm event has passed. Water will also filter back into the groundwater table, increasing aquifer and drinking water stability. For the water that does runoff into the river, plants in nearby parks are able to remove pollutants directly from runoff waters by biologically and chemically degrading and eliminating them before the runoff enters the river (Garrison, 2011).

Boston, Massachusetts is a great example of green infrastructure's ability to reduce stormwater runoff. In Boston, existing tree cover reduces runoff by 314 million gallons per year, avoiding $142 million in city costs to deal with flooding and river impairment (Garrison, 2011). Comparatively, in Chicago, green infrastructure diverted over 70 million gallons of stormwater from CSOs in 2009 (Odefey, 2012). More specifically, for every 5% increase in tree cover, runoff is reduced by 2% (Armour, et al., 2014). Trees and bioswales are park elements that prove successful at capturing and storing stormwater (Center for Neighborhood Technology, 2010; Benepe, 2013).

Largely reducing the pressure on the sewer system is economically beneficial for New York City. Green infrastructure can prevent costs for replacing sewers, pipes, and other infrastructure because green infrastructure requires little maintenance cost (Garrison, 2011). Green infrastructure is more cost effective than gray (conventional) infrastructure in that it increases: the reliability of water quality in drinking water (by reducing treatment costs), predictability of water quality (by reducing long-term capital improvement needs), the longevity of water quality investments (through reduced wear on system components), and local real estate values (Odefey, 2012). In New Hampshire, green infrastructure saved 26% in stormwater management costs compared to gray infrastructure (Garrison, 2011). New York City predicts that combining green and gray infrastructure could save the city $1.5 billion over 20 years in CSO damages. The existing tree cover in New York City already gives the city a $36 million benefit per year from runoff reductions alone (Odefey, 2012). These major financial benefits of green infrastructure make it a smart and cost-effective method for designing parks in order to reduce stormwater runoff in New York City.

Air Pollution

Air pollution is another major concern in New York City, especially in the TBNC service area, as it is directly adjacent to FDR Drive. The city's air already consists of pollutants such as nitrogen dioxide, atmospheric ozone, sulfur dioxide, and particulate matter, among others. Further, the plethora of dark surfaces (asphalt park cover, roofs, streets, parking lots, etc.) lower air quality by heating up 50-90 degrees above green surface temperatures, accelerating chemical reactions which create smog and atmospheric ozone. These pollutants can worsen asthma, bronchitis, emphysema, and other respiratory diseases, as well as decrease lung functionality (Odefey, 2012).

Trees do an excellent job of mitigating air pollution. Greenery cools air through evapotranspiration: plants absorb water through their roots (transpiration) and release it back into the air (evaporation) (Odefey, 2012). This cooling effect inhibits chemical reactions which contribute to air pollution. Trees also provide air quality improvements through their ability to absorb pollutants. Trees' ability to reduce air pollution results in decreased sickness. A study in New York City found that asthma rates for children ages four to five fell by 25% for every 343 trees planted per square kilometer. The presence of street trees was also linked to a 29% reduction in early childhood asthma (Armour, et al., 2014). These improvements in air quality are linked to monetary benefits. New York City's existing tree coverage saves an estimated $60.1 million for particulate matter removal each year (Armour, et al., 2014). Adding green infrastructure to city parks and playgrounds is thus an efficient way to save cities money from health care costs and missed work days due to air pollution related illnesses.

Energy

Installing green infrastructure in cities can greatly reduce energy use. Green roofs are an obvious yet maintenance-intensive way to reduce a building's energy load. However, other simpler methods are just as effective. Trees planted in parks around a building can reduce wind speeds, thereby limiting building heat loss in the winter and saving money (Odefey, 2012). In fact, trees scattered throughout a neighborhood can reduce wind speeds up to 50%. These planted wind breaks can reduce annual building heating costs between 10% and 30% (Armour, et al., 2014).

Trees can also reduce building energy load by cooling the air surrounding the building, and limiting the urban heat island effect. Trees cool the air through shading and evapotranspiration. These shaded surfaces can be 20-40 degrees cooler than unshaded areas, reducing building cooling needs (Odefey, 2012). Pavement under a tree canopy can even be 23 degrees cooler than unshaded pavement. Trees and parks can reduce overall air temperature by 9 degrees and can be felt up to 330 feet from the site. Even small parks are helpful: parks of only 2.5-5 acres are on average 3.6 degrees cooler than their surrounding areas (Armour, et al., 2014). These decreases in the urban heat island effect will considerably reduce cooling requirements on buildings, saving owners and tenants money on electricity bills. In fact, for each tree planted in Chicago, buildings save $10.71 in energy costs per year (Armour, et al., 2014); in Berkeley, California each tree saves as much as $15 in energy costs, and in Cheyenne, Wyoming a single tree provides the city with an energy benefit of $11 per year (Odefey, 2012). These savings are significant and should be considered when choosing vegetation in parks throughout New York City.

Social

Green infrastructure in parks and playgrounds can provide benefits to the individual dwellers of a neighborhood. Green parks increase social welfare in many ways. Parks provide aesthetic appeal and beauty to a neighborhood (Garrison, 2011), promote exercise (Odefey, 2012), increase worker productivity (Armour, et al., 2014), improve mood through community cohesion (Garrison, 2011), decrease anxiety and stress, enable attention management and behavioral improvements (Odefey, 2012), improve childhood development, and improve mental health (Swain & Wright, 2014). One study finds that people reported lower levels of mental distress and higher levels of life satisfaction when living in greener areas (Armour, et al., 2014). Tangible benefits of green space have been documented in relation to exercise, sickness, and productivity. Studies suggest people living in “high greenery” places were 3.3 times as likely to exercise more frequently than those in the “lowest greenery” category (Armour, et al., 2014). Exercise reduces healthcare costs considerably: the average medical cost difference between an active adult under 65 and an inactive person is $250 per person, for adults over 65, the difference is $500 per person (Harnik & Welle, 2009). Another study finds that where people were living in an area with 90% green space only 10.2% of the population felt unhealthy; where people were living in an area with 10% green space (similar to New York City), 15.5% of the population felt unhealthy. Scaled to the population of New York City, this 5% increase in unhealthy individuals will constitute a large burden on the healthcare system. A final study concluded that desk workers who have a green, environmental view from their desk take 23% less time off sick than those with entirely urban views (Armour, et al., 2014). These effects of mental wellbeing limit physical maladies which are costly to the city.

Economic

Park access is also beneficial to the local economy. Building, design, and maintenance of parks all promote local job growth (Garrison, 2011). Parks can even generate money for the city; the average economic contribution per visit to a park in the U.S. is $1.19 for general park use (Harnik & Welle, 2009). This is made up of buying food and drink at the park, paying for park rides and exhibits, etc. Parks also contribute to the economic value of coastal cities by ensuring clean and safe coastal waters. 85% of U.S. tourism takes place on the coastline, with the average American spending ten recreational days each year on the coast. This tourism industry has spawned the growth of 28.4 million jobs along the coastline throughout the U.S. (Odefey, 2012). As a coastal city, New York City can greatly benefit from increasing green park coverage throughout the city.

Cost-Effectiveness

Overall, green infrastructure in parks and playgrounds is more cost effective than gray infrastructure alone. This is due in large part to the multiple benefits provided by green infrastructure (Garrison, 2011). For parks, these benefits include cleaner waters and flood protection, reduced air pollution and associated illness, lower building energy costs, improved mental and physical wellbeing, increased productivity, and tourist income. The U.S. EPA claims that using green infrastructure techniques can reduce upfront capital costs of infrastructure by 15% to 80% (Garrison, 2011). Throughout the life of the green infrastructure, operations and maintenance costs are far smaller than for gray infrastructure. Gray infrastructure requires infrequent yet costly maintenance; green infrastructure requires frequent but inexpensive maintenance. The American Society of Landscape Architects found that these low upfront and maintenance costs made green infrastructure projects cost less than or equal to gray infrastructure projects in 75.5% of surveyed projects (Odefey, 2012). In Lisbon, Portugal, for every $1 invested in tree management, the city saved $4.48 in energy, cleaner air, increased property values, decreased stormwater runoff, and lower carbon dioxide emissions (Odefey, 2012). In Marylan, Illinois, the town saved $3,500-$4,500 for every lot which employed green infrastructure techniques (Garrison, 2011). These savings could mean a lot for New York City. Building more pervious, shaded, and vegetated parks throughout New York City's most vulnerable areas is a cost-effective measure for increasing the city's climate resiliency. See Appendix C for cost and benefit details.

Final Recommendation

These findings are consistent with the recommendation that TNBC focus its efforts on advocating for the renovation of the P.S. 184 Shuang Wen schoolyard. The P.S. 184 schoolyard is almost completely composed of impervious asphalt with little to no vegetation. This particular school meets the essential criteria as a viable candidate for the PlaNYC Schoolyards to Playgrounds Program. These requirements stress that the playground must be located in a community vulnerable to flooding, that the existing schoolyard meets minimum square footage requirements, and that the playground will serve as a public park when school is not in session (M. Lee, Telephone Interview, November 6, 2014).

TBNC's ability to leverage their existing relationship with P.S. 184 Shuang Wen to influence a partnership between the school and TPL, local legislators, the DOE, and corporate sponsors will be beneficial for admittance into the PlaNYC Schoolyards to Playgrounds Program. TBNC's knowledge and ability to advocate for the community's need for more public green space and structural improvements to storm surge vulnerabilities will be invaluable to campaigning for one of the remaining 20 projects. TBNC should communicate with the school administration in order to form alliances with TPL, DOE, and DEP. These alliances will improve the school's chance of receiving grants under the program.

Though the water quality of the East River is severely polluted, the DEP has not declared the area a Priority CSO tributary. DEP Priority Areas are determined by annual CSO volume, frequency of CSO events, and outfalls that may be affected by Water Body/Watershed Facility Plans (New York City Department of Environmental Protection, 2013). Currently, P.S. 184 does not reside near one of these priority areas and is not considered a priority site in need of green infrastructure, according to PlaNYC's 2013 Green Infrastructure Annual Report (New York City

Department of Environmental Protection, 2013). In order to be considered for this program, TBNC can help communicate the flooding vulnerabilities of the community and the need for P.S. 184's acceptance as a priority site by the DEP. Though this DEP priority site recognition is an important criteria for the Schoolyards to Playgrounds Program, TPL will move forward with green renovation projects without the DEP's involvement, when financially feasible. One such example is the construction of the green schoolyard at P.S. 15, which resides in the community just north of TBNC and is also not in a Priority CSO tributary (M. Lee, Telephone Interview, November 6, 2014).

Replication

There are several opportunities for replication of green playgrounds and recreational spaces within TBNC. After P.S. 184 Shuang Wen, the next high priority school property is P.S. 126 Jacob August Riis. There are seven additional public school properties within the TBNC service area that could be evaluated for renovation. Based on successful completion and evidence of community benefits, this initiative could be expanded to other public and private properties within the TBNC service area and the greater New York City metropolitan area.

Building Resiliency

TBNC should demonstrate the successes of green infrastructure on buildings beginning with their own buildings. It is much easier from a management prospective to initiate pilot projects on TBNC-owned buildings than on other buildings, such as NYCHA properties.

Housing

Residential buildings in the TBNC service area are composed of predominantly public or Section 8 Voucher Housing. These types of buildings are outdated in function, construction, energy efficiency, and the needs of a changing society and climate. As TBNC is new to building resiliency, the organization should pilot green infrastructure projects on their own buildings, as it is easier from a management prospective. One building owned by TBNC is under Section 8 housing and will be used to demonstrate two areas where green infrastructure can improve building resiliency. These areas include water management and flood control, and energy efficiency.

Water Management and Flood Control

There are three main approaches to green infrastructures in buildings regarding water management and flood control: green roofs, green walls, and water reuse systems.

Green Roofs

Green roofs provide several benefits including rainwater mitigation, reduction of capacity stress on CSSs, reduction in air pollution and the urban heat island effect, and increased access to community space and improved human health.

Green roofs can hold rainwater and allow for a more controlled release into the combined sewer system. This will reduce localized street flooding and help prevent the release of raw sewage into the East River. Water absorbed by green roof plant life will later be evaporated back into the atmosphere and help to decrease the urban heat island effect.

In addition, plant growth on a roof takes in carbon dioxide and transforms it into sucrose, water, and air. Plants also absorb many toxins in the air such as nitrogen oxides, sulfur oxides, and other air pollutants. These processes improve air quality in the neighborhood and lead to improved human health.

Green roofs can also increase community resident access to green space, as parks, benches, and scenic views can be added features to the space. Green roofs are also able to grow food, which can be used within the building or as a neighborhood benefit in the form of a community garden.

TBNC's building at 80 Rutgers Slip is 83,904 square feet. Best-in-class green roof technologies can absorb 205,864 gallons of water over this surface area, collecting 12% to 15% of stormwater.

Green Wall

Most green walls are composed of a panel system made of oxidized aluminum sheets, with knots and creases to let plants grow, and grooves to promote water circulation. Beneath is a waterproof barrier between the panels and the wall so that moisture cannot degrade the wall façade. Additional space between the wall and the panel allow for proper ventilation.

The green wall should use plant species designed for the climate and suitable for a vertical garden. Some such species include geraniums, bromeliads, begonia, hosta, soleirolia soleirolii, hoya, iris japonica, dendrobium speciosum, Aeschynanthus radicans**,** *Acacia Cognata, Epipremnum,* Dracaena**,** *Stephanotis floribunda,* Epipremnum aureum**,** *Spathiphyllum wallisii, Codiaeum variegatum pictum,* and small ferns such as *Nephrolepis exaltata.* The plants should only be located on the brick façade of the wall, not over the windows to ensure that proper daylight can enter the space.

The green wall on the façade of the building can be fed through hydroponics, with an integrated drip irrigation system. The drip irrigation system can be fed by the building's water tank, which collects rainwater from the sky, as well as from a rooftop garden. In order to maximize water efficiency, the drip irrigation system should be set up to recycle water, using it over and over again until there is no water left. Water that filters to the bottom and is not used by any plants will be pumped back up to the top of the wall and filtered through the wall again.

A green wall has a minimum useful life of at least 25 years before major maintenance is required. However, the wall should receive regular maintenance from a company specialized in maintaining green walls. Maintenance will include checking for leaks and disruptions in the system, pruning the vegetation so that it does not interfere with window daylighting, removing dead plants, and replacing trays with live and seasonal plants.

The green wall benefits the building by protecting the façade from changes in heating and cooling, which expand and contract the wall, causing it to deteriorate. Further, the green wall protects the building by diverting water away from it during rainfall events. Like the green roof, the green wall will contribute to air quality improvements, reduced heating and cooling load, reduced noise pollution, reduced urban heat island effect, and will provide aesthetic pleasure. Although not commonly cited, the green wall can improve resident morale and productivity. Access to green space is often linked to improved mental wellbeing, a decrease in lost work due to sickness, and can even attract the best tenants because people like to live in spaces with vegetation.

A green wall on TBNC's 80 Rutgers Slip property can capture 0.3 gallons of water per square foot (Green Living Technologies, 2013).

<u>Water Reuse System</u>
Most buildings in the TBNC service area do not have a basement, so reuse storage systems should be installed on the roof. The collection and treatment of stormwater for reuse enables water to be used for a variety of applications including irrigation for gardens, green roofs and walls, non-potable applications such as laundry and toilet flush water, and occasionally for drinking water. The larges above ground tanks are usually 12,000 gallons with costs for treating wastewater and producing non-potable reuse water between \$9.00 and \$13.00 per 1,000 gallons. (State Fire Marshal Division, 2011; Clerico, 2010).

Building materials should be either pressure preservative-treated or meet the requirements established by FEMA. This includes floor sheathing, interior and exterior wall materials, wall coverings, and insulation. These materials usually do not absorb water, reducing material rotting and mold growth. Materials used on the first floor include pressure treated lumber and plywood, steel beams, marine grade plywood, ceramic and porcelain tile with mortar, or concrete tile with mortar. Materials for wall replacement include spray polyurethane foam insulation, non-paper-faced gypsum board, or water-resistant fiber-reinforced exterior grade gypsum board. Wall finishes should be polyester-epoxy paint or latex paint. Hardware should be composed of stainless or galvanized steel (Smart Rebuild New York State, 2014).

Housing Case Study

The Solaire is a 357,000 square-foot building located in lower Manhattan. The Solaire building uses an interesting and replicable stormwater reuse system. This system has a 10,000 gallon cistern in the building's basement, which acts as a reservoir for stormwater collected from the roof. The tanks use varying degrees of sand filtration and disinfection to meet the New York City water quality standards so that the filtered water can be used to irrigate the building's two green roofs (Natural Resources Defense Council, 2013). This is a fundable and potentially replicable case study for the TBNC property.

Funding

The Citizens Committee for New York City awards micro-grants of up to $3,000 to resident-led groups to work on community and school improvement projects in New York City. They prioritize areas in low-income neighborhoods like TBNC (The New York Recovery Network, 2014).

Another funding opportunity is the National Science Foundation: Hazard Mitigation and Structural Engineering Grant. This grant supports fundamental research to mitigate impacts of natural disasters or human-caused hazards on civil infrastructure and to advance the reliability, resiliency, and sustainability of buildings, both commercial and residential (National Science Foundation, n.d.).

Other ongoing funding projects include the Hurricane Sandy Business Loan and Grant Program, and the Storefront Improvement Program. The City of New York and HUD are providing small businesses in New York City with disaster recovery loans and grants. Small businesses that sustained damage as a result of Hurricane Sandy can access up to $150,000 in loan funding. Moreover, the Small Business Storefront Improvement Program provides funding for building improvement materials to eligible small businesses and property owners impacted by Hurricane Sandy and located in evacuation zones one through six (The New York Recovery Network, 2014).

Energy Efficiency

Energy use in buildings has financial, environmental, and social implications. The building sector is the single largest user of energy in the United States, accounting for roughly 40% of total energy consumption (Transformation, 2014). New York City's energy use from buildings constitutes 75% of its greenhouse gas emissions (PlaNYC, 2014). Low-income renters are particularly burdened because their energy costs are equivalent to higher income renters, therefore energy costs make up a larger portion of their income. To reduce energy use and costs, landlords and tenants should invest in energy efficiency measures.

Challenges for Energy Efficiency

Perhaps the biggest problem for controlling energy costs in rental housing is the split incentives between landlords and tenants. Landlords decide building features that affect energy efficiency such as the quality of appliances, insulation, windows, and doors. Tenants make choices about energy use such as setting the thermostat, or deciding water temperature for showering or washing clothes. When renters pay for their energy use, the property owner has less reason to invest in energy efficiency measures.

Solutions to the Split Incentive

There are three ways to overcome the split incentive problem: use subsidies, regulate and mandate efficiency, and make energy costs more transparent so households can consider the information when choosing a place to rent. National, state, and local subsidies remain limited, but are described in the funding section below. However, New York City is a leader in energy efficiency regulation policy and is mandating improved building performance and requiring more transparency for renters.

In 2009, New York City adopted local laws that regulate energy efficiency. Local Law 85 requires all renovations that impact energy systems to meet the standards of the New York State energy code for all building renovations and repairs. Local Law 84 requires annual benchmarking data to be submitted by building owners for public disclosure, which will improve transparency of energy and water usage. Local Law 87 requires an energy audit and retro-commissioning of all equipment in large buildings every ten years (Transformation, 2014).

Impact of Energy Efficiency on Two Bridges

Energy efficiency investment has direct financial, environmental, and social impacts. TBNC's 82 Rutgers Slip building spends approximately $250k per year on electric and gas by using 721k kWh of electricity and 80 therms of gas (K. Culhane, Email Correspondence, November 13, 2014). This energy usage is equivalent to emitting 1.4 million pounds of CO_2e, or burning 3.4 railcars worth of coal (U.S. Environmental Protection Agency, n.d.). Cost effective energy retrofits have been found to reduce electricity and heating fuel by as much as 30% (U.S. Department of Housing and Urban Development, 2011). Savings of this magnitude would reduce the building's annual operating cost by $75,000.

Energy efficiency measures can also reduce energy costs for tenants, in both direct sub-metered energy and energy costs embedded in rents. Low income renters use a significantly larger proportion of their income on energy costs, so energy cost savings is extremely important to this demographic. Moreover, energy efficiency measures can create a healthier living environment, lowering incidences of asthma, and reduce pollution caused by energy production (Northeast Energy Efficiency Partnerships, 2014).

Green Infrastructure on Buildings and Housing Energy

Green walls and roofs can reduce the temperature fluctuations at a wall's surface between 90º Fahrenheit 140º Fahrenheit by limiting the movement of heat between building walls. Green walls and roofs cause this reduction by (Green Roofs for Healthy Cities, n.d.):

- Trapping a layer of air within the plant mass
- Reducing ambient temperature via evapotranspiration and shading
- Creating a buffer against wind during winter months

Funding Sources

As energy savings become more predictable and measurable, investors and lenders are becoming more comfortable funding energy efficiency projects. Overall, energy efficiency projects can be financed with the owner's capital, loans, or through investors working with Energy Service Agreements.

Building Owners

Under New York State Energy Research and Development Authority's (NYSERDA) Multifamily Performance Program (MPP), new construction of multifamily buildings and existing multifamily buildings are eligible for incentives that improve energy savings through energy efficiency or innovative energy solutions, such as renewable energy. Through this program, interested building owners must work with a Multifamily Performance Partner. Incentive amounts for exiting building are categorized into base incentives and performance incentives. Base incentives are awarded as a series of payments upon completion of certain project milestones. Performance incentives are available to projects that achieve a minimum 20% energy reduction. Affordable program incentives for low-income participants are capped at $1,300 per unit for Firm gas and $1,100 per unit for Non-Firm gas (New York State Energy Research and Development Authority, 2014).

The New York City Energy Efficiency Corporation (NYCEEC), a new nonprofit corporation, was created as a partnership between the City and energy efficiency leaders from the private and nonprofit sectors. NYCEEC will allocate $37.5 million DOE Energy Efficiency and Conservation Block Grant funds alongside foundation dollars and private investments for energy efficiency measures. NYCEEC will provide credit enhancement to help incentivize commercial lenders to offer loan and investment solutions for energy efficiency projects.

Renters

There are also energy efficiency programs for renters. The Department of Energy Weatherization Assistance Program developed procedures to facilitate the use of the Weatherization Assistance Program in HUD-subsidized and Low Income Housing Tax Credit (LIHTC) housing. This program funds local and regional organizations delivering energy efficiency services to renters (Energy.gov, 2014). TBNC's 80 Rutgers Slip building is a pre-approved multifamily building as part of the Low Income Housing Tax Credit (LIHTC) program. All weatherization services are provided without cost to the occupant; the cost is paid for by the program.

Another program is the Low Income Home Energy Assistance Program (LIHEAP), which provides resources to assist families with energy costs. LIHEAP administers federally funded assistance for managing costs associated with home energy bills, energy crisis, and weatherization and energy related minor home repairs (Office of Community Services, n.d.).

Recommendation

It is difficult to prioritize energy and water issues in a community such as Two Bridges. The TBNC community is vulnerable to storm-related water issues and has expressed a community-wide need to improve flood mitigation measures. However, energy use contributing to climate change is a more pressing issue on the national agenda. Therefore, TBNC should invest its time and money in green infrastructure projects that both reduce energy use and prevent flood events. Promoting and piloting the installation of green roofs can tackle both energy and water problems at once, and is therefore an ideal demonstration project for TBNC. Green roofs are cost effective ways to reduce the building's energy load, lessen the building's burden on the environment and natural resources, provide noticeable improvements to the comfort of its residents, reduce the urban heat island effect, capture and hold stormwater, and reduce the demand on potable water resources. Therefore, TBNC should hire an engineer to assess buildings within their portfolio, and those of groups with which they work, to determine which roofs can structurally support a green roof addition. Once a building is chosen, TBNC should pilot a green roof project aimed at providing residents with pleasant and accessible green space, reducing building energy load, and capturing and reusing stormwater.

Conclusion

Given the social and economic restraints of the community, the addition of permeable pavements at 80 Rutgers Slip and a park retrofit at P.S. 184 Shuang Wen are two feasible and meaningful pilot projects that could be spearheaded by TBNC. While the building retrofit will solve many of the community's problems and improve the area's climate resiliency, the initial capital expenditure required for such a project must be planned and budgeted years before the project will become feasible. For this reason, it is best for TBNC to begin with less expensive pilot projects and discuss building renovations at a more appropriate time. These pilot projects will be useful as demonstration cases both to the community and future investors as to the real benefits of green infrastructure. All projects discussed in this report are feasible, fundable, and replicable, and at scale, will yield tremendous benefits for the TBNC community.

Appendices

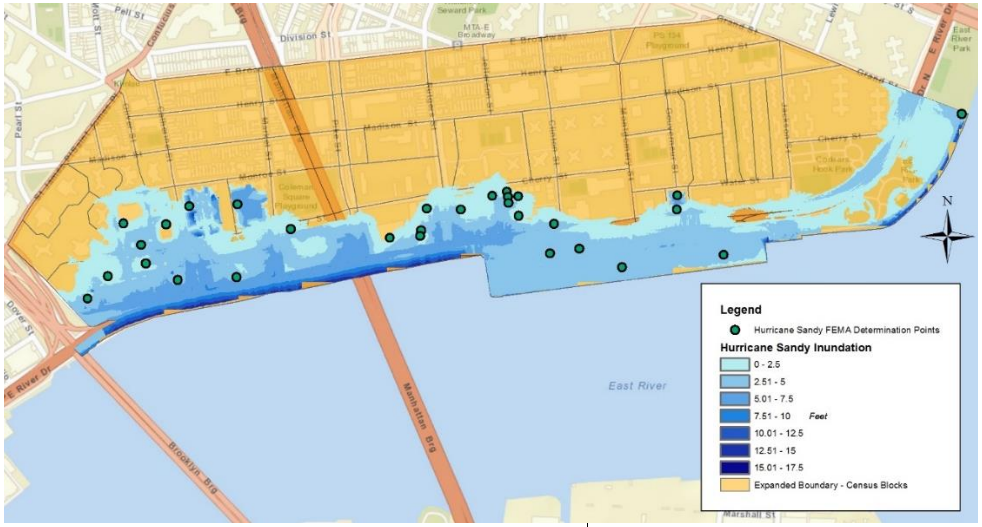
Appendix A

Geographic Area Comparison - Census Blocks

	Historic District		Montgomery Street Extent		Expanded Boundary	
Area - Census Blocks	1,106,781.80	square feet	7,049,148.83	square feet	10,348,079.34	square feet
	25.41	acres	161.83	acres	237.56	acres
Sandy Flood Zone	272,986.05	square feet	4,009,212.51	square feet	5,892,787.64	square feet
	6.27	acres	92.04	acres	135.28	acres
Sandy Flood %	24.66%	Of total	56.88%		56.95%	Of total
100-Year Flood Zone	272,986.05	square feet	4,208,761.00	square feet	6,092,336.13	square feet
	6.27	acres	96.62	acres	139.86	acres
100-Year Flood %	24.66%	Of total	59.71%		58.87%	Of total

Data Source: Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014)

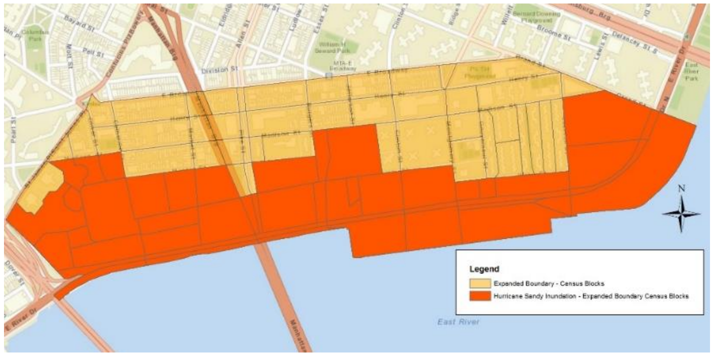
Geographic Area Comparison
Hurricane Sandy Flood Impact



Inundation				FEMA Determination Points	
Flood Inundation (ft)	**Range (ft)**	**Percentage**	**Total Percentage**	**Number of Points**	30
2.5	0-2.5	37.37%			
5	2.5-5	**43.58%**	**80.95%**	**Average Depth**	2.418 feet
7.5	5-7.5	**13.53%**	**94.48%**	**Minimum Depth**	0.297 feet
10	7.5-10	2.39%		**Maximum Depth**	**6.299 feet**
12.5	10-12.5	2.20%			
15	12.5-15	0.93%			
17.5	15-17.5	0.01%			
Mean	3.4				
Minimum	0.00001049			Depth in feet of inundation at each structure point relative to the ground surface	
Maximum	15.536				

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Sandy Flood Inundation (Federal Emergency Modeling Task Force, 2014); Determination Points (Federal Emergency Modeling Task Force, 2013)

Geographic Area Comparison – Census Blocks
Hurricane Sandy Flood Impact and Future Flood Projection



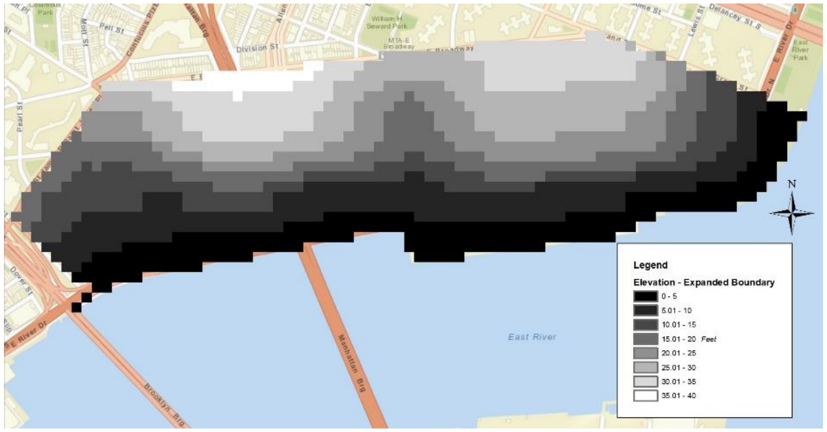
Hurricane Sandy Flood Impact

100-Year Flood Projection

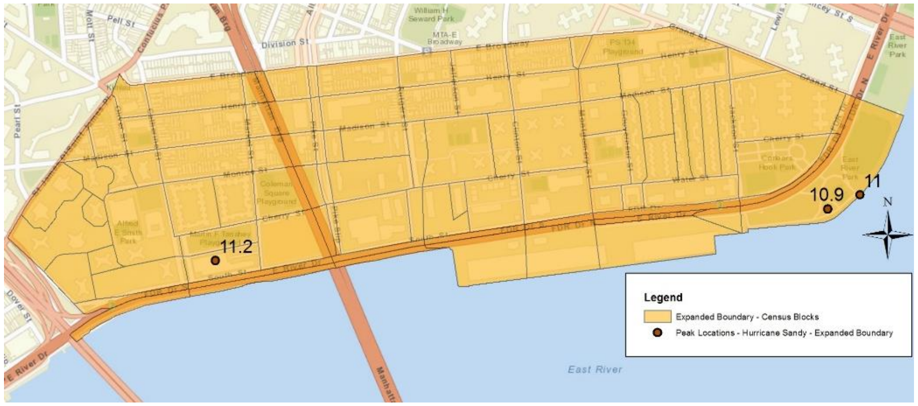
Historic District	1,106,781.80	square feet	**Historic District**	1,106,781.80	square feet
	25.41	acres		25.41	acres
Sandy Flood Area	272,986.05	square feet	*100-Year Floodplain*	272,986.05	square feet
	6.27	acres		6.27	acres
	24.66%	**of total area**		**24.66%**	**of total area**
Montgomery Street Extent	7,049,148.83	square feet	**Montgomery Street Extent**	7,049,148.83	square feet
	161.83	acres		161.83	acres
Sandy Flood Area	4,009,212.51	square feet	*100-Year Floodplain*	4,208,761.00	square feet
	92.04	acres		96.62	acres
	56.88%	**of total area**		**59.71%**	**of total area**
Expanded Boundary	10,348,079.34	square feet	**Expanded Boundary**	10,348,079.34	square feet
	237.56	acres		237.56	acres
Sandy Flood Area	5,892,787.64	square feet	*100-Year Floodplain*	6,092,336.13	square feet
	135.28	acres		139.86	acres
	56.95%	**of total area**		**58.87%**	**of total area**

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Sandy Flood Inundation (Federal Emergency Management Agency Modeling Task Force, 2014); 100-year flood plain (New York City Mayor's Office of Long Term Planning and Sustainability, 2014)

Geographic Area – Elevation and Hurricane Sandy Peak Flood Locations (Expanded Boundary)



Elevation



Hurricane Sandy Peak Locations

Elevation (Feet)	**% of total**	
0-5	16.97%	
5-10	17.35%	34.32% elevation 10 ft or less
10-15	12.27%	
15-20	12.50%	
20-25	11.67%	
25-30	15.30%	
30-35	11.97%	
35-40	1.97%	

Number of locations	8
Type	High water marks
Maximum Storm-Tide Elevation (feet)	11.2
Minimum Storm-Tide Elevation (feet)	10.9
Average Storm-Tide Elevation (feet)	10.9875

Data Source: Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included*), 2014); Elevation Data (U.S. Geological Survey, 1999); USGS Peak Flood Locations (U.S. Geological Survey, 2013)

Geographic Area Comparison – Tax Lots

	Historic District		Montgomery Street Extent		Expanded Boundary	
Tax Lot Area	758,684.00	square feet	6,237,570.00	square feet	8,614,366.00	square feet
	17.42	acres	143.19	acres	197.76	acres
Building Area	3,129,816.00	square feet	11,642,235.00	square feet	15,899,132.00	square feet
	71.85	acres	267.27	acres	364.99	acres

Data Source: Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014), Pluto Tax Lots (New York City Department of Planning, Information Technology Division, 2014)

Geographic Area Comparison – Tax Lots
Hurricane Sandy Flood Impact and Future Flood Projection (Expanded Boundary)

Hurricane Sandy Flood Impact

100-Year Flood Projection

Total Tax Lot Area	8,614,366.00	square feet	**Total Tax Lot Area**	8,614,366.00	square feet
	197.76	acres		197.76	acres
Sandy Flood Zone	5,536,290.00	square feet	**100-Year Flood Zone**	5,806,040.00	square feet
	127.10	acres		133.29	acres
	64%	**of total**		**67%**	**of total**
Total Building Area	15,899,132.00	square feet	**Total Building Area**	15,899,132.00	square feet
	364.99	acres		364.99	acres
Sandy Flood Zone	8,021,379.00	square feet	**100-Year Flood Zone**	8,665,432.00	square feet
	184.15	acres		198.93	acres
	50%	**of total**		**55%**	**of total**

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Pluto Tax Lots (New York City Department of Planning, Information Technology Division, 2014)

Geographic Area Comparison – Tax Lot Distribution

	Historic District				**Montgomery Street Extent**				**Expanded Boundary**			
	65.3% Residential				*62.9% Residential*				*60.8% Residential*			
Type	**Lots**	**Area (sq ft)**	**Area (acres)**	**% of total**	**Lots**	**Area (sq ft)**	**Area (acres)**	**% of total**	**Lots**	**Area (sq ft)**	**Area (acres)**	**% of total**
One & Two Family Buildings	1	4,310.70	0.10	0.57%	1	15,030.29	0.35	0.24%	3	55,338.54	1.27	0.64%
Multi - Family Walk- Up Buildings	26	112,078.32	2.57	14.77%	72	1,082,180.82	24.84	17.35%	72	1,328,124.95	30.49	15.42%
Multi - Family Elevator Buildings	3	12,932.11	0.30	1.70%	13	195,393.76	4.49	3.13%	24	442,708.32	10.16	5.14%
Mixed Residential and Commercial Buildings	85	366,409.89	8.41	48.30%	175	2,630,300.60	60.38	42.17%	185	3,412,543.28	78.34	39.61%
Commercial and Office Buildings	19	81,903.39	1.88	10.80%	36	541,090.41	12.42	8.67%	39	719,401.01	16.52	8.35%
Industrial and Manufacturing	9	38,796.34	0.89	5.11%	13	195,393.76	4.49	3.13%	13	239,800.34	5.51	2.78%
Transportation and Utility	0	-	-	0.00%	7	105,212.02	2.42	1.69%	8	147,569.44	3.39	1.71%
Public Facilities and Institutions	18	77,592.68	1.78	10.23%	47	706,423.59	16.22	11.33%	63	162,109.33	26.68	13.49%
Open Space and Outdoor Recreation	4	17,242.82	0.40	2.27%	18	270,545.20	6.21	4.34%	27	498,046.86	11.43	5.78%
Parking Facilities	9	38,796.34	0.89	5.11%	16	240,484.63	5.52	3.86%	16	295,138.88	6.78	3.43%
Vacant Land	2	8,621.41	0.20	1.14%	14	210,424.05	4.83	3.37%	14	258,246.52	5.93	3.00%
Unknown	0	-	-	0.00%	3	45,090.87	1.04	0.72%	3	55,338.54	1.27	0.64%
Total	**176**	**758,684.00**	**17.42**		**415**	**6,237,570.00**	**143.19**		**467**	**8,614,366.00**	**197.76**	

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included*), 2014); Pluto Tax Lots (New York City Department of Planning, Information Technology Division, 2014)

Geographic Area Comparison – Tax Lot Distribution
Hurricane Sandy Flood Impact and Future Flood Projection (Expanded Boundary)

Hurricane Sandy Flood Impact

Type	# Lots	Area (sq ft)	Area (acres)	% of total
One & Two Family Buildings	0		-	0.00%
Multi - Family Walk- Up Buildings	1	131,816.43	3.03	2.38%
Multi - Family Elevator Buildings	6	790,898.57	18.16	14.29%
Mixed Residential and Commercial Buildings	6	790,898.57	18.16	14.29%
Commercial and Office Buildings	2	263,632.86	6.05	4.76%
Industrial and Manufacturing	1	131,816.43	3.03	2.38%
Transportation and Utility	4	527,265.71	12.10	9.52%
Public Facilities and Institutions	6	790,898.57	18.16	14.29%
Open Space and Outdoor Recreation	9	186,347.86	27.23	21.43%
Parking Facilities	1	131,816.43	3.03	2.38%
Vacant Land	4	527,265.71	12.10	9.52%
Unknown	2	263,632.86	6.05	4.76%
Total	**42**	5,536,290.00	127.10	

31.0% Residential

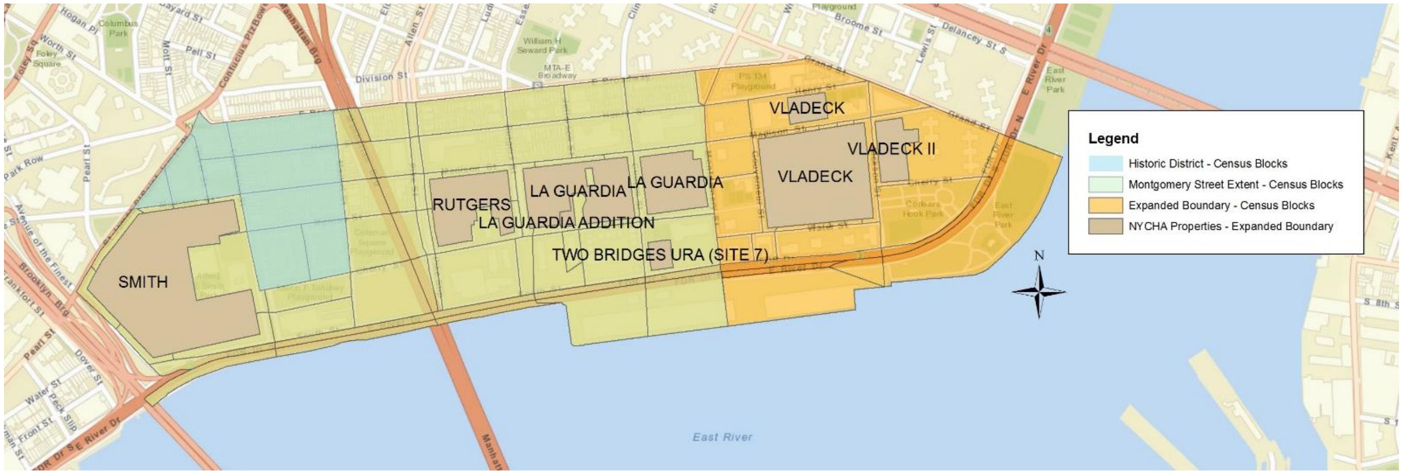
100-Year Flood Projection

Type	# Lots	Area (sq ft)	Area (acres)	% of total
One & Two Family Buildings	0	-	-	0.00%
Multi - Family Walk- Up Buldings	1	129,023.11	2.96	2.22%
Multi - Family Elevator Buildings	6	774,138.67	17.77	13.33%
Mixed Residential and Commercial Buildings	7	903,161.78	20.73	15.56%
Commercial and Office Buildings	2	258,046.22	5.92	4.44%
Industrial and Manufacturing	1	129,023.11	2.96	2.22%
Transportation and Utility	5	645,115.56	14.81	11.11%
Public Facilities and Institutions	6	774,138.67	17.77	13.33%
Open Space and Outdoor Recreation	10	1,290,231.11	29.62	22.22%
Parking Facilities	1	129,023.11	2.96	2.22%
Vacant Land	4	516,092.44	11.85	8.89%
Unknown	2	258,046.22	5.92	4.44%
Total	**45**	5,806,040.00	133.29	

31.1% Residential

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Pluto Tax Lots(New York City Department of Planning, Information Technology Division, 2014); Sandy Flood Inundation (Federal Emergency Management Agency Modeling Task Force, 2014); 100-year flood plain (New York City Mayor's Office of Long Term Planning and Sustainability, 2014)

New York City Housing Authority (NYCHA) Property Comparison

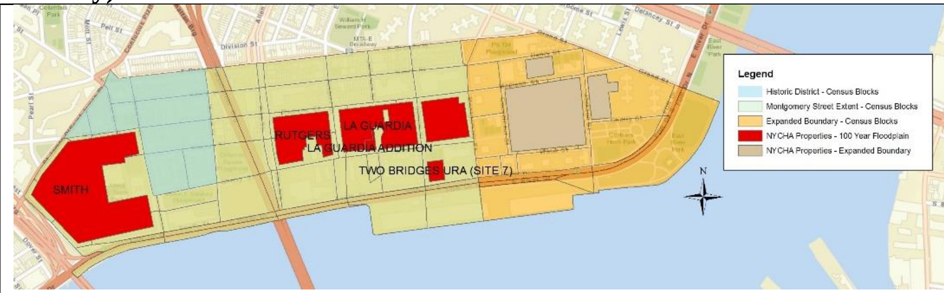


	Historic District		Montgomery Street Extent		Expanded Boundary	
Area - Census Blocks	1,106,781.80	square feet	7,049,148.83	square feet	10,348,079.34	square feet
	25.41	acres	161.83	acres	237.56	acres
NYCHA Properties						
Number	0	properties	5	properties	7	properties
Area	0	square feet	1,513,071.11	square feet	2,153,235.73	square feet
	0	acres	34.74	acres	49.43	acres
Percent of total area	**0%**		**21.46%**		**20.81%**	

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); NYCHA Properties (New York City Housing Authority, 2011)

New York City Housing Authority (NYCHA) Property
Hurricane Sandy Flood Impact and Future Flood Projection (Expanded Boundary)

Hurricane Sandy Flood Impact

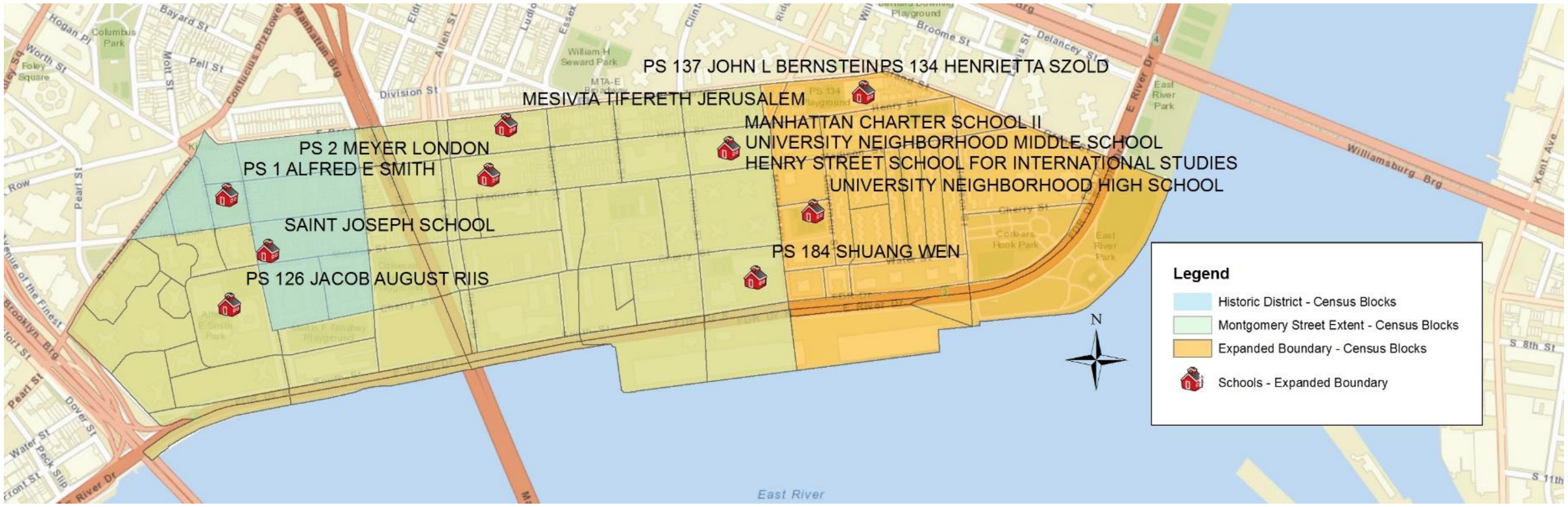


100-Year Flood Projection

Area - Census Blocks	10,348,079.34	square feet	**Area - Census Blocks**	10,348,079.34	square feet
	237.56	acres		237.56	acres
NYCHA Properties			**NYCHA Properties**		
Number	7	properties	**Number**	7	properties
Area	2,153,235.73	square feet	**Area**	2,153,235.73	square feet
	49.43	acres		49.43	acres
Percent of total area	20.81%		**Percent of total area**	20.81%	
Sandy Flood Zone	4	properties	**100-Year Flood Zone**	5	properties
	1,291,834.81	square feet		1,513,071.11	square feet
	29.66	acres		34.74	acres
	60.00%	**of total Two Bridges NYCHA**		**70.27%**	**of total Two Bridges NYCHA**

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included*), 2014); NYCHA Properties (New York City Housing Authority, 2011); Sandy Flood Inundation (Federal Emergency Management Agency Modeling Task Force, 2014); 100-year flood plain (New York City Mayor's Office of Long Term Planning and Sustainability, 2014)

School Property Comparison



	Historic District					**Montgomery Street Extent**					**Expanded Boundary**				
	2 Schools on 2 Tax Lots					*10 Schools on 7 Tax Lots*					*13 Schools on 9 Tax Lots*				
Schools Type	#	Lot Area	Building Footprint Area	# Floors	**Open Area**	#	Lot Area	Building Footprint Area	# Floors	**Open Area**	#	Lot Area	Building Footprint Area	# Floors	**Open Area**
Elementary - Private/Parochial	1	0.46	0.44	5.00	**0.01**	1	0.46	0.44	5.00	**0.01**	1	0.46	0.44	5.00	**0.01**
Elementary - Public	1	0.18	0.17	5.00	**0.01**	4	8.11	3.30	16.00	**4.82**	6	8.64	3.82		4.82
Elementary - Public Charter	0	0	0	0	**0**	1	0	0	0	**0**	1	0	0	0	**0**
High School - Public	0	0	0	0	**0**	0	0	0	0	**0**	1				
Junior/Senior High School - Public	0	0	0	0	**0**	1	0	0	0	**0**	1	0	0	0	**0**
K-12 School - Private/Parochial	0	0	0	0	**0**	1	0.09	0.07	5.00	**0.02**	1	0.09	0.07	5.00	**0.02**
Middle School - Public	0	0	0	0	**0**	2	2.15	0.84	4.00	**1.30**	2	2.15	0.84	4.00	**1.30**
Total Area		0.64	0.61		**0.03**		10.53	4.38		**6.15**		11.44	5.27		**6.17**

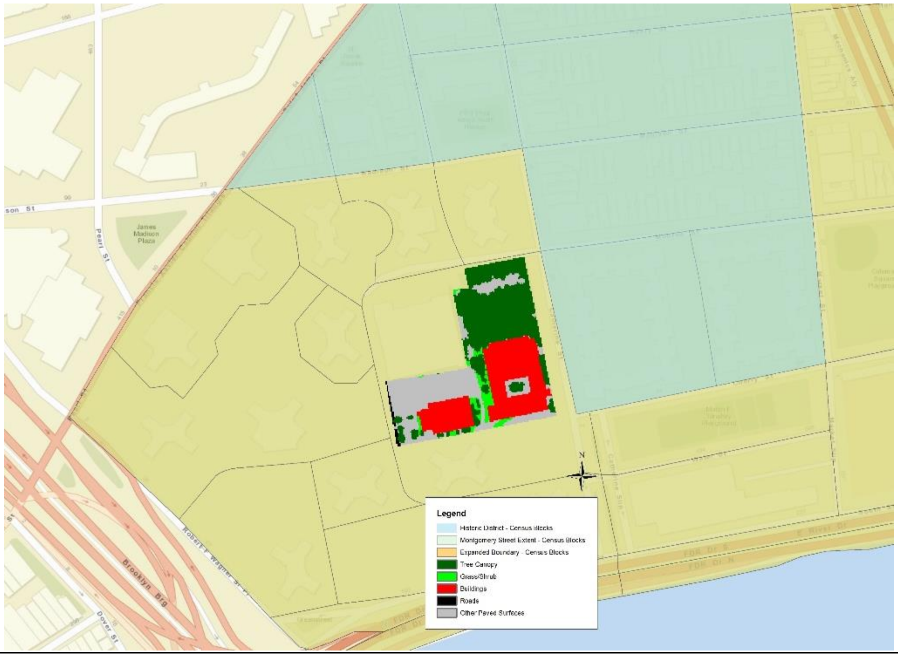
Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included*), 2014); Facilities – Schools (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014)

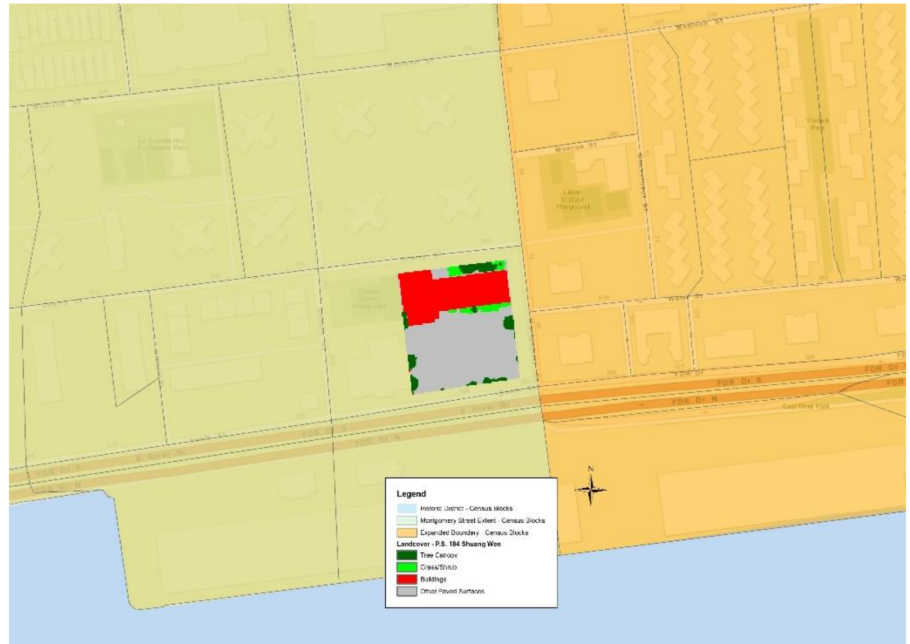
School Property Comparison
Hurricane Sandy Flood Impact and Future Flood Projection (Expanded Boundary)

Schools Type	#		Lot Area		Building Footprint Area		# Floors	Open Area	
			Sq. ft.	Acres	Sq. ft.	Acres		Sq. ft.	Acres
Elementary School - Private/Parochial	0								
Elementary School - Public	2	PS 126 Jacob Riis	117,191	2.69	36,250	0.83	4	80,941	1.86
		PS 184 Shuang Wen	84,902	1.95	35,750	0.82	4	49,152	1.13
Elementary School - Public Charter	0								
High School - Public	0								
Junior/Senior High School - Public	0								
K-12 School - Private/Parochial	0								
Middle School - Public	0								
Total Number	**2**								
Total Area			**202,093**	**4.64**	**72,000**	**1.65**		**130,093**	**2.99**

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Facilities – Schools (*BYTES of the BIG APPLE - Selected Facilities and Program Sites* 2014); Sandy Flood Inundation (Federal Emergency Management Agency Modeling Task Force; 2014); 100-year flood plain (New York City Mayor's Office of Long Term Planning and Sustainability, 2014)

Land Cover Comparison - Schools





P.S. 126 Jacob Riis

Land Cover Type	Area (sq. ft.)	Area (acres)	% of total
Tree Canopy	42,994.54	0.99	37%
Grass/Shrub	4,657.14	0.11	4%
Bare Earth	0	0.00	0%
Water	0	0.00	0%
Buildings	35,586.70	0.82	30%
Roads	835.20	0.02	1%
Other Paved Surfaces	**33,117.42**	**0.76**	**28%**
Total	117,191.00	2.69	

P.S. 184 Shuang Wen

Land Cover Type	Area (sq. ft.)	Area (acres)	% of total
Tree Canopy	5,722.65	0.13	7%
Grass/Shrub	3,058.51	0.07	4%
Bare Earth	0	0.00	0%
Water	0	0.00	0%
Buildings	26,597.60	0.61	31%
Roads	0	0.00	0%
Other Paved Surfaces	**49,523.25**	**1.14**	**58%**
Total	84,902.00	1.95	

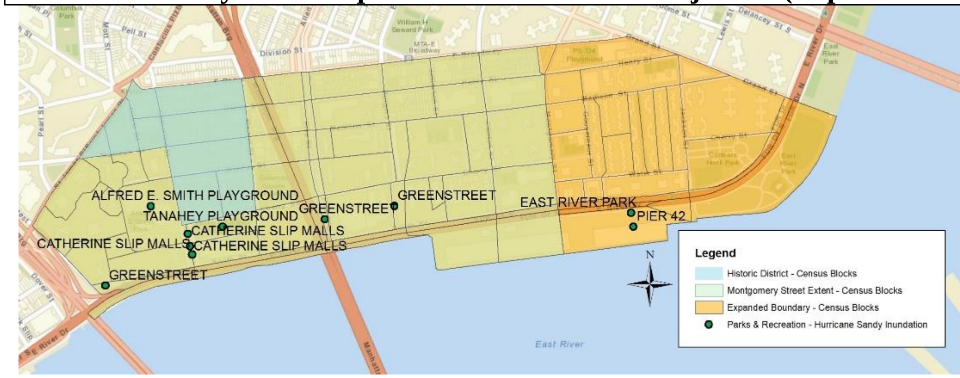
Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included*), 2014); Facilities – Schools (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014); Sandy Flood Inundation (Federal Emergency Management Agency Modeling Task Force, 2014); 100-year flood plain (Mayor's Office of Long Term Planning and Sustainability, 2014)

Recreational Facilities and Parks Comparison

	Historic District					Montgomery Street Extent					Expanded Boundary				
Recreation/Park Type	#	Lot Area	Building Area	**Open Area (sq ft)**	**Open Area (Acres)**	#	Lot Area	Build Area	**Open Area (sq ft)**	**Open Area (acres)**	#	Lot Area	Building Area	**Open Area (sq ft)**	**Open Area (acres)**
Beach, Garden, Cemetery, Natural Area, Parkway - NYC	0	0	0	**0**	**0**	0	0	0	**0**	**0**	1	2.96	2.16	**34,492.03**	**0.792**
Building/Institution, Athletic/Recreation Facility - NYC	0	0	0	**0**	**0**	0	0	0	**0**	**0**	2	1.57	0.00	**68,466.23**	**1.57**
Joint NYCDOT/DPR Landscaped Area (Greenstreet)	1	0.01	0.00	**261.36**	**0.006**	14	1.20	0.00	**52,054.20**	**1.20**	17	1.55	0.00	**67,605.12**	**1.55**
Park/Playground - NYC	1	0.45	0.00	**19,690.32**	**0.452**	10	8.02	0.99	**306,118.05**	**7.03**	15	23.32	1.20	**963,237.72**	**22.11**
Public Library - Branch	1	0.09	0.08	**400.00**	**0.01**	1	0.09	0.08	**400.00**	**0.009**	1	0.09	0.08	**400.00**	**0.009**
Triangle, Plaza, Mall, Lot, Strip - NYC	1	0.14	0.00	**6,076.01**	**0.139**	2	0.39	0.00	**16,966.01**	**0.39**	2	0.39	0.00	**16,966.01**	**0.39**
Total	**4**	**0.68**	**0.08**	**26,427.69**	**0.61**	**28**	**9.69**	**1.07**	**375,538.26**	**8.62**	**35**	**29.87**	**3.45**	**1,151,167.11**	**26.43**

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Facilities – Recreational Facilities and Parks (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014)

Recreational Facilities and Parks Comparison
Hurricane Sandy Flood Impact and Future Flood Projection (Expanded Boundary)



Hurricane Sandy Flood Impact

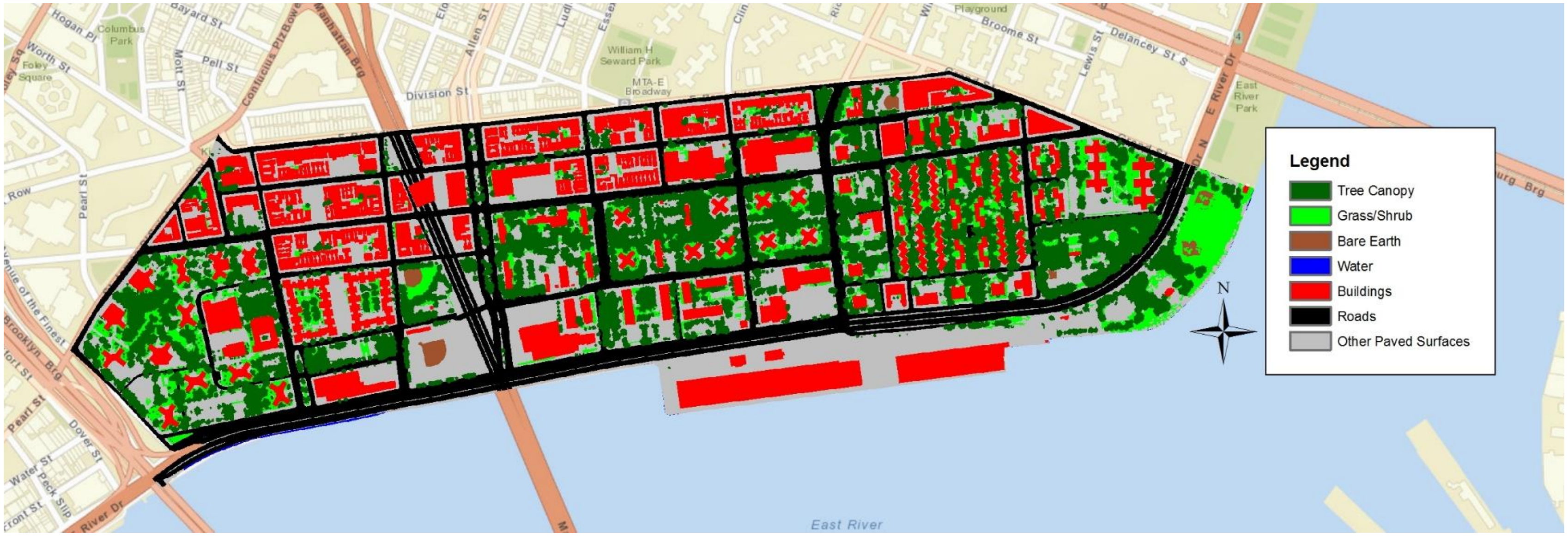
Recreation/Park Type	Quantity	Open Area (sq. ft.)	Open Area (acres)
Beach, Garden, Cemetery, Natural Area, Parkway - NYC	1	34,492.03	0.79
Building/Institution, Athletic/Recreation Facility - NYC	0	0	0
Joint NYCDOT/DPR Landscaped Area (Greenstreet)	5	22,912.56	0.53
Park/Playground - NYC	3	268,144.25	6.16
Public Library - Branch	0	0	0
Triangle, Plaza, Mall, Lot, Strip - NYC	1	10,890.00	0.25
Total	**10**	336,438.84	7.724

100-Year Flood Projection

Recreation/Park Type	Quantity	Area (sq. ft.)	Area (acres)
Beach, Garden, Cemetery, Natural Area, Parkway - NYC	1	34,492.03	0.792
Building/Institution, Athletic/Recreation Facility - NYC	0	0	0
Joint NYCDOT/DPR Landscaped Area (Greenstreet)	6	23,914.44	0.55
Park/Playground - NYC	3	268,144.25	6.16
Public Library - Branch	0	0	0
Triangle, Plaza, Mall, Lot, Strip - NYC	1	10,890.00	0.250
Total	**11**	337,440.72	7.747

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Facilities – Recreational Facilities and Parks (*BYTES of the BIG APPLE - Selected Facilities and Program Sites*, 2014); Sandy Flood Inundation (Federal Emergency Management Agency Modeling Task Force, 2014); 100-year flood plain (New York City Mayor's Office of Long Term Planning and Sustainability, 2014)

Land Cover Comparison



	Historic District			Montgomery Street Extent			Expanded Boundary		
Land Cover Type	Area (sq. ft.)	Area (acres)	% of total	Area (sq. ft.)	Area (acres)	% of total	Area (sq. ft.)	Area (acres)	% of total
Tree Canopy	91,322.82	2.10	8.25%	1,480,597.64	33.99	21.00%	2,538,125.40	58.27	24.53%
Grass/Shrub	27,422.95	0.63	2.48%	292,226.18	6.71	4.15%	637,091.81	14.63	6.16%
Bare Earth	0	0	0.00%	27,530.64	0.63	0.39%	47,681.31	1.09	0.46%
Water	0	0	0.00%	11,915.84	0.27	0.17%	13,031.81	0.30	0.13%
Buildings	454,877.10	10.44	41.10%	1,759,602.99	40.39	24.96%	2,341,712.23	53.76	22.63%
Roads	188,855.63	4.34	17.06%	1,560,219.60	35.82	22.13%	2,093,963.80	48.07	20.24%
Other Paved Surfaces	344,303.32	7.90	31.11%	1,917,055.93	44.01	27.20%	2,676,489.40	61.44	25.86%
Total	1,106,781.80	25.41		7,049,148.83	161.83		10,348,095.78	237.56	

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included*), 2014); Land cover Raster (New York City Department of Parks and Recreation, 2014)

Land Cover
Hurricane Sandy Flood Impact and Future Flood Projection (Expanded Boundary)

Hurricane Sandy Flood Impact

100-Year Flood Projection

Land Cover Type	% of Flood Area	Area (sq. ft.)	Area (acres)
Tree Canopy	26.07%	1,536,044.55	35.26
Grass/Shrub	7.90%	465,513.04	10.69
Bare Earth	0.71%	41,641.93	0.96
Water	0.22%	13,031.67	0.30
Buildings	16.53%	974,161.98	22.36
Roads	19.85%	1,169,519.96	26.85
Other Paved Surfaces	28.73%	1,692,874.52	38.86
Total		5,892,787.64	135.28

Land Cover Type	% of Flood Area	Area (sq. ft.)	Area (acres)
Tree Canopy	26.27%	1,600,687.09	36.75
Grass/Shrub	7.84%	477,934.58	10.97
Bare Earth	0.68%	41,642.09	0.96
Water	0.21%	13,031.72	0.30
Buildings	16.42%	1,000,625.18	22.97
Roads	20.11%	1,224,900.29	28.12
Other Paved Surfaces	28.45%	1,733,515.19	39.80
Total		6,092,336.13	139.86

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Land cover Raster (New York City Department of Parks and Recreation, 2014); Sandy Flood Inundation (Federal Emergency Management Agency Modeling Task Force, 2014); 100-year flood plain (New York City Mayor's Office of Long Term Planning and Sustainability, 2014)

Land Cover
80 Rutgers Slip

Land Cover Type	Area (sq. ft.)	Area (acres)	% of Total
Tree Canopy	2,415.79	0.06	12%
Grass/Shrub	2,919.08	0.07	15%
Bare Earth	0	0.00	0%
Water	0	0.00	0%
Buildings	8,400.37	0.19	42%
Roads	0	0.00	0%
Other Paved Surfaces	6,359.76	0.15	32%
Total	20,095.00	0.46	

Data Source(s): Census Blocks (*BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)*, 2014); Land cover Raster (New York City Department of Parks and Recreation, 2014)

Appendix B

P.S. 126 Jacob August Riis

The tax lot containing P.S. 126 Jacob August Riis tax lot also features the Alfred E. Smith Playground, which provides about 1.75 acres of park and playground space to community residents. P.S. 126 is located about two blocks from the FDR drive and the East River.

P.S. 126	School	Building Footprint	Open Space	Tree Canopy	Buildings	Paved Surfaces	Grass & Shrubs	Roads
Percent	100%			37%	30%	28%	4%	1%
Square Feet	117,191	36,250	80,941	42,994.54	35,586.70	33,117.42	4,657.14	835.20
Acres	2.69	0.83	1.86	0.99	0.82	0.76	0.11	0.02

(New York City Department of Parks and Recreation, 2014; New York City Department of Planning, Information Technology Division, 2014)

P.S. 184 Shuang Wen

The tax lot containing P.S. 184 Shuang Wen is located directly adjacent to the FDR drive, with Pier 35 acting as the only barrier between the school's recreational area and the East River.

P.S. 184	School	Building Footprint	Open Space	Tree Canopy	Buildings	Paved Surfaces	Grass & Shrubs
Percent	100%			7%	31%	58%	4%
Square Feet	84,920	35,750	49,125	5,722.65	26,597.60	49,523.25	3,058.51
Acres	1.95	0.82	1.13	0.13	0.61	1.14	0.07

(New York City Department of Parks and Recreation, 2014; New York City Department of Planning, Information Technology Division, 2014)

Appendix C

Sorted by Type of Green Infrastructure

Type of Green Infrastructure	Benefit Area	Benefit	Unit	Cost	Unit	Special Comments	Source
Mature Deciduous Tree	Runoff	500-700	gallons water/year			intercepts	Garrison, 2011
Mature Evergreen	Runoff	4,000	gallons water/year			intercepts	Garrison, 2011
Crabtree	runoff	292	gallons of water			(22ft tall, 21ft spread) intercepts	Center for Neighborhood Technology, 2010
Red Oak	runoff	1129	gallons of water			(40ft tall, 27ft spread) intercepts	Center for Neighborhood Technology, 2010
Hackberry	runoff	2162	gallons of water			(47ft tall, 37ft spread) intercepts	Center for Neighborhood Technology, 2010
80 Foot Beech tree	air pollution	2 family homes	carbon absorbed/tree				Swain & Wright, 2014
Bioswale	runoff	3	gallons/cubic feet			water removed	Benepe, 2013
Boston Tree Cover	Runoff	314,000,000	gallons water/year			intercepts	Garrison, 2011
		$ 142,000,000.00	$/year			saves	
Stret Trees	runoff	$ 36,000,000.00	$/year			reducing runoff	Odefey, 2012
tree cover	air pollution	$ 60,100,000.00	$/year			particulate matter reduction	Swain & Wright, 2014
Tree Cover	air pollution	0.22	tons/year/tree			air pollution removal	Swain & Wright, 2014
		$ 190.47	$/year/tree			air pollution removal saving	
Tree Cover	air pollution	2.13	tons/year/tree			carbon storage	Swain & Wright, 2014
		$ 4,416.67	$/year/tree			carbon storage savings	
Tree Cover	air pollution	9.75	tons CO_2/year/tree			carbon sequestration	Swain & Wright, 2014
		$ 15.51	$/year/tree			carbon sequestration savings	
Tree Cover	energy efficiency	10.71	$/year/tree			building energy reduction	Swain & Wright, 2014
tree cover	energy efficiency	50%				wind speed reduction	Swain & Wright, 2014
Tree Cover	energy efficiency	10-30%	$/year			heating cost reduction	Swain & Wright, 2014
tree cover	Cost-effectiveness	$ 203.22	$/year/tree			benefit NYC tree canopy	Swain & Wright, 2014
				$ 40.66	$/year/tree	maintenance cost	
Shaded surfaces	urban heat island	13	degrees (celcius) cooler			than unshaded surfaces	Swain & Wright, 2014
Shaded surfaces	urban heat island	20-40	degrees cooler			than unshaded surfaces	Odefey, 2012
Shaded surfaces	urban heat island			50-90	degrees hotter	than unshaded surfaces	Odefey, 2012
Parks	urban heat island	2	degrees (celcius) cooler/hectare			than surrounding areas	Swain & Wright, 2014
Tree Managemnt	Cost-effectiveness	$ 4.48	saving	$ 1.00	invested in trees	Savings per investment	Odefey, 2012
Tree Managemnt	urban heat island	$15	$/tree			reduced energy cost	Odefey, 2012
Tree Managemnt	urban heat island	$ 11.00	$/tree			energy benefit	Odefey, 2012
Flood Damage	runoff			$2.67 billion	$/year	flood damage in U.S.	Garrison, 2011
				$176 million	$/storm	flood damage in U.S.	
Waterbourne disease	health			$ 36.53	$/person	cost of gastronomical disease	Odefey, 2012
Water treatment	runoff			$ 0.012	$/cubic foot	water treatment cost	Harnik & Welle, 2009
Water clean-up	runoff			$63-69 million	$/year	planning	Garrison, 2011
				$900 million - $4.3 billior	$/15 years	implementation	
Permeable pavement	runoff			$0.50	$/gallon	marginal cost	Odefey, 2012
		18 million	gallons water			removed from CSO	
Exercise	health	$250	$/adult under 65			medical savings	Harnik & Welle, 2009
		$500	$/adult over 65			medical savings	
Tourism jobs	economy	28.3 million	jobs			on coastline	Odefey, 2012
Fisheries	health			$ 22,000,000.00	$/year	shellfish contamination	Odefey, 2012

Park value	economy	5%	value of properties within 500 feet				Harnik & Welle, 2009
Park value	economy	$1.91	$/visit			general park use	Harnik & Welle, 2009
Green Space	health	5%	more people feel healthy			with more access to green space	Swain & Wright, 2014
Green Space	health	3.3	times as likely to exercise			with more access to green space	Swain & Wright, 2014
Green Space	productivity	23%	less time off work			with more access to green space	Swain & Wright, 2014
General Green Infrastructure	runoff	70 million	gallons water/year			diverted from CSO overflow	Odefey, 2012
General Green Infrastructure	runoff	$ 75,000,000.00	$/year			save from CSO damage	Odefey, 2012
General Green Infrastructure	runoff	26%				saves	Garrison, 2011
General Green Infrastructure	air pollution	$ 870.00	$ saved/ton CO_2 removed				Harnik & Welle, 2009
		$ 6,127.00	$ saved/ton nitrogen dioxide removed				
		$ 6,127.00	$ saved/ton ozone removed				
		$ 4,091.00	$ saved/ton particulate matter removed				
		$ 1,500.00	$ saved/ton sulfur dioxide removed				
General Green Infrastructure	City savings	3,500-4,500	$/lot			saves	Garrison, 2011
Up-front construction costs	Cost-effectiveness	15-80%				saves	Garrison, 2011

Sorted by Benefit Area

Type of Green Infrastructure	Benefit Area	Benefit	Unit	Cost	Unit	Special Comments	Source
Mature Deciduous Tree	Runoff	500-700	gallons water/year			intercepts	Garrison, 2011
Mature Evergreen	Runoff	4,000	gallons water/year			intercepts	Garrison, 2011
Boston Tree Cover	Runoff	314,000,000	gallons water/year			intercepts	Garrison, 2011
		$ 142,000,000.00	$/year			saves	
Crabtree	runoff	292	gallons of water			(22ft tall, 21ft spread) intercepts	Center for Neighborhood Technology, 2010
Red Oak	runoff	1129	gallons of water			(40ft tall, 27ft spread) intercepts	Center for Neighborhood Technology, 2010
Hackberry	runoff	2162	gallons of water			(47ft tall, 37ft spread) intercepts	Center for Neighborhood Technology, 2010
Stret Trees	runoff	$ 36,000,000.00	$/year			reducing runoff	Odefey, 2012
Bioswale	runoff	3	gallons/cubic feet			water removed	Benepe, 2013
Permeable pavement	runoff			$0.50	$/gallon	marginal cost	Odefey, 2012
		18 million	gallons water			removed from CSO	
General Green Infrastructu	runoff	26%				saves	Garrison, 2011
General Green Infrastructu	runoff	70 million	gallons water/year			diverted from CSO overflow	Odefey, 2012
General Green Infrastructu	runoff	$ 75,000,000.00	$/year			save from CSO damage	Odefey, 2012
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				$176 million	$/storm	flood damage in U.S.	
Water treatment	runoff			$ 0.012	$/cubic foot	water treatment cost	Harnik & Welle, 2009
Water clean-up	runoff			$63-69 million	$/year	planning	Garrison, 2011
				$900 million - $4.3 billio	$/15 years	implementation	
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Tree Cover	air pollution	0.22	tons/year/tree			air pollution removal	Swain & Wright, 2014
		$ 190.47	$/year/tree			air pollution removal saving	
Tree Cover	air pollution	2.13	tons/year/tree			carbon storage	Swain & Wright, 2014
		$ 4,416.67	$/year/tree			carbon storage savings	
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		$ 15.51	$/year/tree			carbon sequestration savings	
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		$ 6,127.00	$ saved/ton nitrogen dioxide removed				
		$ 6,127.00	$ saved/ton ozone removed				
		$ 4,091.00	$ saved/ton particulate matter removed				
		$ 1,500.00	$ saved/ton sulfur dioxide removed				
Waterbourne disease	health			$ 36.53	$/person	cost of gastronomical disease	Odefey, 2012
Fisheries	health			$ 22,000,000.00	$/year	shellfish contamination	Odefey, 2012
Exercise	health	$250	$/adult under 65			medical savings	Harnik & Welle, 2009
		$500	$/adult over 65			medical savings	
Green Space	health	5%	more people feel healthy			with more access to green space	Swain & Wright, 2014
Green Space	health	3.3	times as likely to exercise			with more access to green space	Swain & Wright, 2014
Green Space	productivity	23%	less time off work			with more access to green space	Swain & Wright, 2014
Shaded surfaces	urban heat island	20-40	degrees cooler			than unshaded surfaces	Odefey, 2012
Shaded surfaces	urban heat island	13	degrees (celcius) cooler			than unshaded surfaces	Swain & Wright, 2014
Parks	urban heat island	2	degrees (celcius) cooler/hectare			than surrounding areas	Swain & Wright, 2014
Shaded surfaces	urban heat island			50-90	degrees hotter	than unshaded surfaces	Odefey, 2012
Tree Managemnt	urban heat island	$15	$/tree			reduced energy cost	Odefey, 2012
Tree Managemnt	urban heat island	$ 11.00	$/tree			energy benefit	Odefey, 2012

Tree Cover	energy efficiency	10.71	$/year/tree			building energy reduction	Swain & Wright, 2014
Tree Cover	energy efficiency	10-30%	$/year			heating cost reduction	Swain & Wright, 2014
tree cover	energy efficiency	50%				wind speed reduction	Swain & Wright, 2014
Park value	economy	5%	value of properties within 500 feet				Harnik & Welle, 2009
Park value	economy	$1.91	$/visit			general park use	Harnik & Welle, 2009
Tourism jobs	economy	28.3 million	jobs			on coastline	Odefey, 2012
tree cover	Cost-effectiveness	$ 203.22	$/year/tree			benefit NYC tree canopy	Swain & Wright, 2014
				$ 40.66	$/year/tree	maintenance cost	
Tree Managemnt	Cost-effectiveness	$ 4.48	saving	$ 1.00	invested in tree	Savings per investment	Odefey, 2012
General Green Infrastructu	Cost-effectiveness	3,500-4,500	$/lot			saves	Garrison, 2011
Up-front construction costs	Cost-effectiveness	15-80%				saves	Garrison, 2011

References

Agouridis, C.T., Villines, J.A., Luck, J.D., (2011). *Permeable Pavement for Stormwater Management.* University of Kentucky College of Agriculture Cooperative Extension Service: Lexington, KY.

Armour, T., Armour, S., Hargrave, J., & Revell, T. (2014). *Cities Alive: Rethinking Green Infrastructure*. London, England.

Belanger, P. (2008). *Urban Stormwater Economics: Comparative Cost-Benefit Study of Site Technologies & Strategies for the City of Toronto.* Retrieved November 10, 2014 from http://www.daniels.utoronto.ca/sites/daniels.utoronto.ca/files/old/Kesik_TGDS_CB-Study_Oct2008_Appendix_D.pdf.

Benedict, M. A. (2002). Green Infrastructure: Smart Conservation for the 21st Century. *Renewable Resources Journal*. Retrieved October 10, 2014 from http://www.sprawlwatch.org/greeninfrastructure.pdf.

Benepe (2013). *Green Infrastructure: The Design Element Part II*. Playground Professionals. Retrieved 2 November, 2014 from http://www.huffingtonpost.com/adrian-benepe/green-infrastructure-the-design_b_3985047.html.

Bullitt Foundation. (2013). *Building Features-Waterworks*. Retrieved October 29, 2014, from http://www.bullittcenter.org/building/building-features/waterworks/.

Center for Neighborhood Technology (2010). *The Value of Green Infrastructure: A Guide to Recognizing its Economic, Environmental and Social Benefits*. Chicago, Illinois.

Clerico, Edward A. (2010). *Water Sustainability and International Innovation*. Coalition for Alternative Wastewater Treatment. Retrieved from http://www.ndwrcdp.org/documents/DEC7SG06/DEC7SG06_fordecsite.pdf.

Connecticut Housing Finance Authority (2013). *Standards of Design and Construction*. Retrieved November 24, 2014 from http://www.chfa.org/content/Multifamily%20Document%20Library/2013StandardsFinal_122812.pdf.

Culhane, K. (2012). *Making Connections: Planning for Green Infrastructure in Two Bridges*. Retrieved October 18, 2014 from http://urbanomnibus.net/2012/08/making-connections-planning-for-green-infrastructure-in-two-bridges/.

Culhane, K. (2014). *Two Bridges Energy Data* [Email Correspondence]. New York, New York.

Culhane, K. (2014). *Two Bridges Presentation* [Presentation]. New York, NY; Columbia University.

Dircke, P., Aerts, J., & Molenaar, A. (2010). *Connecting Delta Cities*. Retrieved from http://www.rotterdamclimateinitiative.nl/documents/RCP/English/CDC-Book-II.pdf.

Energy.gov. (2014). *Retrofit Incentives for Multifamily Buildings*. Retrieved from www.energy.gov: http://energy.gov/eere/wipo/retrofit-incentives-multifamily-buildings.

Federal Emergency Management Agency Modeling Task Force. (2013). *FEMA MOTF Hurricane Sandy Impact Analysis - Building Point Damage Determination Estimates* [Data file]. Retrieved November 11, 2014 from http://content.femadata.com/GISData/MOTF/Hurricane%20Sandy/determination_points_11_04_2013_1900PST.zip.

Federal Emergency Management Agency Modeling Task Force. (2014). *FEMA MOTF Hurricane Sandy Impact Analysis - NYC_Feb14Final1MSurgeDataClipped [Data file]*. Retrieved October 31, 2014, from http://www.arcgis.com/home/item.html?id=307dd522499d4a44a33d7296a5da5ea0

Federal Register. (2014). *CDBG-DR Laws, Regulations, and Federal Register Notices*. Vol. 79: Issue 200. Retrieved from https://www.hudexchange.info/cdbg-dr/cdbg-dr-laws-regulations-and-federal-register-notices/.

Ferguson, B.K., (1996). *Preventing the problems of urban runoff*. Renewable Resources Journal, Retrieved from http://fergusonsportal.macmate.me/Portal/Fergs_Papers_files/Preventing...Renew%20Rsrc%20Jrnl%20%2796.pdf.

Freed, A. (2014). *Climate Change Science and Impacts* [Class Lecture]. New York, NY; Columbia University.

Frost, M. (2013). P.S. 261 Playground Design [Online image]. Retrieved November 28, 2014 from http://www.brooklyneagle.com/articles/new-%E2%80%98green%E2%80%99-playground-ps-261-will-help-prevent-flooding-gowanus-canal-2013-09-20-224600.

Garrison, N. (2011). *Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows*. Retrieved October 27, 2014 from http://www.nrdc.org/water/pollution/rooftopsii/.

Green Living Technologies. (2013). *Anthropologies Green Wall*. Retrieved from http://www.greenroofs.com/projects/pview.php?id=703.

Green Roofs for Healthy Cities. (n.d.). *Green Walls Benefits*. Retrieved December 1, 2014, from http://www.greenroofs.org/index.php/about/green-wall-benefits.

Harnik, & Welle. (2009). *Measuring the Economic Value of a City Park System*. Washington, D.C.

Huffman, D. (2008). *Pervious Pavement: An Infiltration BMP – A LID Technique*. Portland, OR.

International Panel on Climate Change. (2013). Retrieved from http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf.

Kato, S. (2011). Green Infrastructure for Asian Cities: The Spatial Concepts and Planning Strategies. *Journal of the 2011 International Symposium on City Planning*. Retrived from http://www.academia.edu/1579869/Green_Infrastructure_for_Asian_Cities_The_Spatial_Concepts_and_Planning_Strategies.

Kerssen, A. (2010). *Green Roofs in Netherland*. Retrieved September 29, 2014, from http://livingroofs.org/green-roofs-netherlands.

Licata, A., Nauta, T., & Cohn, A. (2010). *Brooklyn and Rotterdam Waterfront Exchange News*. Retrieved October 21, 2014, from New Blue/Green Life in SW Brooklyn: http://www.nautilus-international.com/news/b-rxnews_web.pdf.

Lee, M. (2014). *Interview on the Parks to Playgrounds Program with the Trust for Public Land* [Telephone interview]. New York City, NY.

Low Impact Development Center, Inc., (2002). *Permeable Paver Costs*. Retrieved November 18, 2014, from http://www.lowimpactdevelopment.org/qapp/lid_design/permeable_pavers/permpaver_costs.htm.

Manhattan Borough President. (2014). *Capital Grants Program*. Retrieved October 23, 2014, from Capital Grants Program: http://manhattanbp.nyc.gov/html/budget/capital-grants.shtml.

Maryland Center for Watershed Protection (2010). *New York State Stormwater Design Manual*. Retrieved November 18, 2014 from http://www.dec.ny.gov/docs/water_pdf/swdm2010entire.pdf.

Mukherjee, D. (2014). Manage Storm Water by Using Porous Pavement. Journal of Mechanical and Civil Engineering, 11(4). Retrieved November 10, 2014 from http://www.academia.edu/7824632/Manage_Storm_Water_by_Using_Porous_Pavement.

Nashville Civic Design Center (2014). *Permeable Paving*. Retrieved November 20, 2014, from http://www.sitemason.com/files/hgCJgI/Permeable%20Paving.pdf.

National Ready Mixed Concrete Association (2011). *Pervious Pavement.* Retrieved November 15, 2014 from http://www.perviouspavement.org/benefits/structural.html.

National Science Foundation. (n.d.) *Hazard Mitigation and Structural Engineering Grant*. Retrieved November 30, 2014, from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13358.

Natural Resources Defense Council. (2013). *Case Study: the Solaire*. Retrieved from http://www.nrdc.org/buildinggreen.

New York City Department of City Planning. (2014). *BYTES of the BIG APPLE - Census Blocks 2010 (Water Areas Included)* [Data file]. Retrieved October 1, 2014 from http://www.nyc.gov/html/dcp/html/bytes/districts_download_metadata.shtml.

New York City Department of City Planning. (2014). *BYTES of the BIG APPLE - Selected Facilities and Program Sites* [Data file]. Retrieved October 1, 2014, from http://www.nyc.gov/html/dcp/html/bytes/dwnselfac.shtml.

New York City Department of Environmental Protection. (2013). *2013 Annual Report*. New York, NY: New York City.

New York City Department of Environmental Protection. 2014. *Green Infrastructure Grant Program Frequently Asked Questions*. Retrieved November 25, 2014 from: http://www.nyc.gov/html/dep/pdf/green_infrastructure/2014_gi_grant_program_faq.pdf.

New York City Department of Environmental Protection. (2012). *NYC Green Infrastructure Plan: 2012 Green Infrastructure Pilot Monitoring Report.* New York City Department of Environmental Protection: New York, NY.

New York City Department of Environmental Protection. (n.d.). *Stormwater Management System Calculator*. Accessed 29 October, 2014.

New York City Department of Parks and Recreation. (2014). *Land Cover Raster Data (2010)* [Data file]. Retrieved October 31, 2014, from https://data.cityofnewyork.us/Environment/Landcover-Raster-Data-2010-/9auy-76zt.

New York City Department of Planning, Information Technology Division. (2014). *BYTES of the BIG APPLE - PLUTO and MapPLUTO* [Data file]. Retrieved October 1, 2014, from http://www.nyc.gov/html/dcp/html/bytes/applbyte.shtml#pluto.

New York City Housing Authority. (2011). *Map of NYCHA Developments* [Data file]. Retrieved October 31, 2014 frin https://data.cityofnewyork.us/Housing-Development/Map-of-NYCHA-Developments/.

New York City Mayor’s Office of Long Term Planning and Sustainability. (2011). *PlaNYC A Greener, Greater New York*. Retrieved from http://www.nyc.gov/html/planyc/html/publications/publications.shtml?process=1&keyword=PlaNYC.

New York City Mayor's Office of Long Term Planning and Sustainability. (2014). *Southern Manhattan Floodplain* [Data file]. Retrieved October 1, 2014 from https://data.cityofnewyork.us/Environment/Southern-Manhattan-Flood-Plain/d35k-mhy5.

New York City Mayor's Office of Long Term Planning and Sustainability. (2008). *Sustainable Stormwater Management Plan.* Retrieved from http://smedia.nyc.gov/agencies/planyc2030/pdf/nyc_sustainable_stormwater_management_plan_final.pdf.

New York City OASIS. (n.d.). *New York City OASIS* [Data file]. Retrieved from http://www.oasisnyc.net/map.aspx.

New York State Department of Environmental Conservation. (2014). *New York City CSO Consent Order, Long Term Control Plans, and Green Infrastructure*. Retrieved from http://www.dec.ny.gov/chemical/77733.html.

New York State Department of Environmental Conservation. (2012). *NYSDEC & NYCDEP Announce Groundbreaking Agreement to Reduce Combined Sewer Overflows Using Green Infrastructure in New York City* [Press release]. Retrieved from http://www.dec.ny.gov/press/80919.html.

New York State Energy Research and Development Authority. (2014). *Multifamily Performance Program*. Retrieved from http://www.nyserda.ny.gov/Energy-Efficiency-and-Renewable-Programs/Multifamily-Performance-Program/Multifamily-Performance-Program.aspx.

Northeast Energy Efficiency Partnerships. (2014). *Affordable Multifamily Housing Efficiency Project*. Retrieved from http://www.neep.org/sites/default/files/resources/multifamily-housing-energy-efficiency-FS.pdf.

Odefey. (2012). *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide*. American Rivers. Retrieved from http://www.americanrivers.org/assets/pdfs/reports-and-publications/banking-on-green-report.pdf.

Office of Community Services. (n.d.). *About LIHEAP*. Retrieved November 20, 2014 from http://www.acf.hhs.gov/programs/ocs/programs/liheap/about.

Pavestone. (n.d.). *Uni Eco-Stone*. Retrieved November 26, 2014 from http://www.pavestone.com/uni-eco-stone/.

Prince George's County Department of Environmental Resources (2014). *Guidelines for Permeable Pavement*. Retrieved November 2, 2014 from http://www.princegeorgescountymd.gov/sites/StormwaterManagement/Resources/BMP/Documents/4_Guidelines%20for%20Permeable%20Pavement.pdf.

PlaNYC. (2014). *Overview of Greener, Greater Buildings Plan*. New York City.

Rebuild By Design. (2014). *Big U*. Retrieved October 18, 2014 from http://www.rebuildbydesign.org/project/big-team-final-proposal/.

Schlanger, Z. (2014). *If It's Raining, NYC's Raw Sewage Is Probably Pouring Into the Waterways.* Retrieved October 14, 2014 from http://www.newsweek.com/it-raining-nycs-raw-sewage-probably-pouring-waterways-260784.

Smart Rebuild New York State. (2014). *Flood Resistant Building Material and Where to Use Them*, New York Rising. Retrieved from http://stormrecovery.ny.gov/sites/all/themes/nysandyredesign/files/SMART_Rebuild_FS9.pdf.

Smith, S. (2014). *Dr. Howard Botts on Storm Surge*. Retrieved from http://www10.giscafe.com/nbc/articles/view_article.php?articleid=812066&page_no=1.

State Fire Marshal Division. (2011). *Above Ground Storage Tank Plan Review Information Sheet*. Minnesota State Department of Public Safety. Retrieved from https://dps.mn.gov/divisions/sfm/fire-code/Pages/Fire-Code-Homepage.aspx.

Swain & Wright. (2014). *Cities Alive: Rethinking Green Infrastructure.* ARUP. London, England.

TecEco. (n.d.). *Permecocrete Pervious Concrete.* Retrieved November 26, 2014 from http://www.tececo.com/products.permecocrete.php.

The City of New York. (2013). *A Stronger, More Resilient New York.* Retrieved 10 18, 2014, from http://www.nyc.gov/html/sirr/html/report/report.shtml.

Two Bridges Neighborhood Council. (2014). *Two Bridges Neighborhood Council*. Retrieved October 10, 2014, from http://www.twobridges.org.

The New York Recovery Network. (2014). *E-Bulletin*. Retrieved November 30, 2014, from http://www.fema.gov/media-library-data/1414788268408-113d82cc0996e2f802018fa0b5db7010/NYRN_E-bulletin_July_16_2014_508.pdf.

The Rockefeller Foundation (2014). *Resilience*. Retrieved from http://www.rockefellerfoundation.org/our-work/current-work/resilience/national-disaster-resilience-competition.

The Trust for Public Land. (2013). *"Green" Playground at P.S. 261 in Brooklyn Will Manage Stormwater*. Retrieved from http://www.tpl.org/media-room/green-playground-ps-261-brooklyn-will-manage-stormwater.

Transformation (2014). *Building Energy Performance Policy*. Retrieved from www.imt.org: http://www.imt.org/policy/building-energy-performance-policy.

U.S. Department of Housing and Urban Development. (2014). *Community Development Block Grant Disaster Recovery Program*. Retrieved from https://www.hudexchange.info/cdbg-dr/.

U.S. Department of Housing and Urban Development. (2014). *Community Development Block Grant Program*. Retrieved from http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/community development/programs.

U.S. Department of Housing and Urban Development. (2011). *Quantifying Energy Efficiency in Multifamily Rental Housing*. Retrieved from http://www.huduser.org/portal/periodicals/em/summer11/highlight1.html.

U.S. Environmental Protection Agency. (n.d.). *Greenhouse Gas Equivalency Calculator*. Retrieved November 20, 2014 from http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results.

U.S. Environmental Protection Agency. (2012). *Permeable Pavers*. Retrieved November 18, 2014, from http://www.epa.gov/oaintrnt/stormwater/pavers.htm.

U. S. Environmental Protection Agency. (2008). *Reducing Urban Heat Islands: Compendium of Strategies - Cool Roofs*. Retrieved from http://www.epa.gov/heatislands/resources/pdf/CoolRoofsCompendium.pdf.

U.S. Environmental Protection Agency. (1999). *Storm Water Technology Fact Sheet: Porous Pavement*. Retrieved from http://www.nepis.epa.gov/.

U. S. Environmental Protection Agency. (2014). *What is Green Infrastructure?*. Retrieved October 28, 2014, from http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm.

U.S. Environmental Protection Agency. (2014). *CSO Control Policy*. Retrieved from http://water.epa.gov/polwaste/npdes/cso/CSO-Control-Policy.cfm

U.S. Environmental Protection Agency. (2014). *Pervious Concrete Pavement*. Retrieved from http://water.epa.gov/polwaste/npdes/swbmp/Pervious-Concrete-Pavement.cfm.

U.S. Geological Survey. (1999). *New York City Area Digital Elevation Model, 1 Arc Second (feet)* [Data file]. Retrieved from http://sedac.ciesin.columbia.edu/geonetwork/srv/en/cu-gis_metadata.show?id=3595&currTab=advanced.

U.S. Geological Survey. (2013). *USGS Flood Information - Additional Links to Hurricane Sandy - All Storm Tide Gage Data and High-Water Marks* [Data file]. Retrieved October 31, 2014, from http://wim-project-data-east.s3.amazonaws.com/data/Sandy/USGS_hurricane_sandy_data.mdb.

Walsh, J. E. (2013). *Our Changing Climate*. Retrieved 10 18, 2014, from Changing Climate Impacts in the United States: The Third National Assessment: http://nca2014.globalchange.gov/report/our-changing-climate/introduction#intro-section-2.

Whole Building Design Guide (2010). *Permeable Pavement Systems*. Retrieved October 28, 2014 from http://www.wbdg.org/ccb/ARMYCOE/COETN/technote11.pdf.