NYC Green Infrastructure Plan

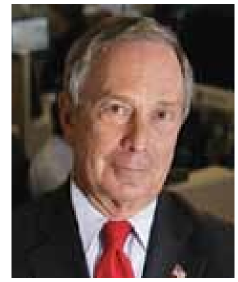
2011 UPDATE

NYC Environmental Protection

Michael R. Bloomberg, Mayor
Carter Strickland, Commissioner

NYC Green Infrastructure Plan



Michael R. Bloomberg
Mayor

Dear Friends:

One of the goals of our Administration's extensive environmental initiative, *PlaNYC*, is to restore coastal ecosystems by improving the quality of our waterways. Today, New York Harbor is the cleanest it has been in more than a century, thanks largely to the $9 billion that the City has invested in water quality since 2002. However, tough economic times require us to budget and spend especially responsibly. That is why we continue to work with our federal and state regulators to reform mandates and allow the City to invest in the infrastructure we need in the most cost-effective ways possible.

The *NYC Green Infrastructure Plan*, which changes the way the City manages rain-related pollution, is a major part of this effort. The joint economic and environmental analysis contained within the plan has shown that the cost of new green infrastructure and more efficient water management systems would save billions of dollars over more traditional fixes. By using green infrastructure technology to keep stormwater out of our sewers, we can reduce sewer overflows and promote the sustainability policies that will make New York greener and greater – and save taxpayers money, too.

The State has given us a green light to move forward with our plan, and we've backed up our proposal with significant resources – $1.5 billion over the next 20 years. Implementing the plan will require ongoing collaboration between key City agencies and the many civic leaders who are committed to improving our waterways. Our implementation of the *NYC Green Infrastructure Plan* will ensure that we all remain focused on the same goal: a cleaner and more accessible harbor that continues to benefit our great City.

Sincerely,

Michael R. Bloomberg
Mayor

Carter H. Strickland
Commissioner

Dear Friends:

From our pioneering work creating wetlands to handle stormwater in Staten Island's Bluebelts to our watershed management program that protects our drinking water from the Catskill Mountains, DEP has sought to use natural systems to perform our work where effective and economical. Together those programs have saved DEP ratepayers billions of dollars in avoided hard infrastructure such as storm sewers and filtration plants, while preserving large tracts of natural areas.

The *NYC Green Infrastructure Plan* continued that tradition by demonstrating that the widespread adoption of green roofs, bioswales, and other green infrastructure will absorb or delay runoff from storms, keep it out of our combined sewer system, and reduce the combined sewer overflows that are the primary source of pathogens in New York Harbor. In addition, we predicted that this approach would save billions of dollars and would also beautify our neighborhoods, increase property values, and improve air quality.

On March 13, 2012, DEP and the New York State Department of Environmental Conservation (DEC) finalized an historic agreement that incorporates an iterative, adaptive management approach, committing DEP to:

- Construct green infrastructure citywide that will manage 10% of the runoff from impervious surfaces by 2030;
- Construct $2 million of green infrastructure in three neighborhood demonstration areas;
- Construct $3.4 billion in grey infrastructure, of which $1.8 billion has already been incurred; and
- Publish 11 Long Term Control Plans for the control of combined sewer overflows by 2017.

In exchange, DEC has eliminated approximately $1.4 billion in grey infrastructure projects, and agreed to defer another $2 billion in additional grey infrastructure that had been proposed, providing DEP with the necessary time to build and monitor green infrastructure projects.

We didn't wait for this consent order to be finalized before getting to work. In 2011, the City created an interagency Green Infrastructure Task Force to identify opportunities to add green infrastructure to capital projects, created an Office of Green Infrastructure within DEP, launched a Green Infrastructure Grant Program, developed standard designs for green infrastructure, signed a memorandum of agreement for the maintenance of green infrastructure, and facilitated the creation of a Green Infrastructure Steering Committee comprised of community groups and other interested parties. This report provides details about those developments and more.

Together we can implement the *NYC Green Infrastructure Plan* and work towards a greener, greater New York.

Sincerely,

Carter H. Strickland, Jr.
Commissioner

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First Green Infrastructure Task Force Meeting

Created Position of Assistant Commissioner for Green Infrastructure

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Formed the Office of Green Infrastructure

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First Green Infrastructure Citizen's Group Meeting

First Green Infrastructure Steering Committee Meeting

Completed Replacement of CSO Outfall Signs

2011 Rain Barrel Giveaway

2010 Sept Oct Nov Dec | 2011 Jan Feb Mar Apr

On September 28, 2010, the City released the *NYC Green Infrastructure Plan* (the Plan), which set forth a series of initiatives and opportunities that dramatically change the way we manage stormwater. New York City, like other older urban centers, is largely serviced by a combined sewer system where stormwater and wastewater are carried through a single pipe. Even though treatment plants are designed to treat and disinfect twice the dry weather flow, during heavy storms the system can exceed its capacity and is designed to discharge a mix of stormwater and wastewater—called combined sewer overflow or CSO—into New York Harbor in order to prevent treatment plants from becoming compromised. Rather than build additional large storage tanks or tunnels to temporarily store stormwater at the end of the sewer system, the Plan determined that it was more cost-effective to first construct source controls and green infrastructure—including bioswales, green roofs, and subsurface detention systems—to control stormwater from impervious spaces such as roofs, sidewalks, and parking lots. Together with conservation measures and operational improvements, the widespread adoption of green infrastructure can reduce more CSOs at less cost than second-tier "grey" infrastructure. Moreover, green infrastructure projects provide many quality-of-life benefits to New Yorkers, by improving air quality, increasing shading, increasing property values, and improving our streetscape.

Over the course of the past year, DEP has made meaningful progress toward implementing the goals set forth in the Plan. By the end of October 2010, the City had already formed the inter-agency Green Infrastructure Task Force and had met to develop the project pipeline in order to add green infrastructure to existing and planned capital projects. By January 2011, DEP had appointed an Assistant Commissioner for Green Infrastructure, choosing Magdi Farag, an engineer with 50 years of drainage and sewer experience, and had formed the Office of Green Infrastructure of civil engineers and city planners to implement the Plan and oversee construction. In February, DEP held the first

Launched Webmap Application

Completion of Alley Creek CSO Facility

$3.8 Million in Green Infrastructure Grants Awarded

Completion of Green Infrastructure at the Bronx River Houses

Completed Green Roof at Jamaica Bay WWTP

Released RFP for CSO Monitoring

Adopted Stormwater Rules for New Development

May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | 2012 | Jan | Feb | Mar

Completed Paerdegat Basin CSO Facility

Completed Green Infrastructure at MTA Parking Lot

Completed Dean Street Bioswales

Completed Inflatable Dams

CSO order Adopted by DEC

Green Infrastructure Citizen's Group meeting, formed a steering committee made up of key stakeholders, and announced the first annual Green Infrastructure Grant Program. At the end of that month DEP announced that it had met a significant milestone by replacing all of the signs at CSO outfalls, thereby improving public notification.

As the seasons changed and spring's rains rolled in, we completed construction on pilot projects to test green infrastructure technologies, including a blue roof on a DEP facility in the Newtown Creek watershed, porous pavement at a DEP facility in the Jamaica Bay watershed, a pocket wetland at an MTA bus depot in Jamaica, and installation of monitoring equipment in bioswales and on a green roof. We also gave away 1,000 rain barrels to residents in Brooklyn, the Bronx, Queens, and Staten Island. And in May 2011, DEP completed CSO detention facilities at Paerdegat Basin and Alley Creek, together reducing the volume of CSOs by more than 1.4 billion gallons each year. In early June, after careful consideration of the many applications we received, DEP announced the winners of the Green Infrastructure Grant Program and awarded more than $3.8 million in awards. The Mayor's 10-year capital plan, adopted in June 2011, included $735 million for building green infrastructure. In September 2011, after several years of development, DEP released a proposed rule that requires enhanced on-site stormwater controls for new development and redevelopment.

In March 2012, DEP and the New York State Department of Environmental Conservation (DEC) amended a consent order to reduce CSOs which includes milestones for building green infrastructure and including those results in Long Term Control Plans (LTCPs). This consent order provides the certainty to continue the program while building in flexibility and accountability so that we can continually improve and refine our approach.

The first year of the program has been successful in establishing a foundation for green infrastructure citywide. In the Plan we committed to ten goals, which we have largely achieved.

GOALS AND ACHIEVEMENTS

#		
1	Goal	**Prepare a Green Infrastructure Fund**
	Steps Taken	The City has committed $187 million through Fiscal Year (FY) 2015. In addition, the City included $735 million for Green Infrastructure in its 10-year capital budget and is prepared to commit $1.5 billion through FY30.
	Status	***Goal Achieved***
2	Goal	**Create an inter-agency partnership – the Green Infrastructure Task Force – to incorporate stormwater management into roadway, sidewalk, and other capital projects and to provide for the maintenance of green infrastructure**
	Steps Taken	The City has created the Green Infrastructure Task Force, which is comprised of various City agencies. Since the release of the Plan, DEP has coordinated five Green Infrastructure Task Force meetings and has established a schedule of standing quarterly meetings. In addition, DEP has coordinated tours of various green infrastructure sites and has signed an agreement for maintenance of green infrastructure in the right of way.
	Status	***Goal Achieved***
3	Goal	**Build green infrastructure demonstration projects on a variety of land uses**
	Steps Taken	Several green infrastructure projects have been constructed on a variety of land uses, including blue and green roofs at schools and other facilities, subsurface perforated pipe systems under parking lots, permeable pavement on sidewalks, bioswales in the right of way, and rain gardens in public open spaces. Data collected over the next two years will be used to inform future green infrastructure projects.
	Status	***Goal Achieved***
4	Goal	**Partner with community groups to develop programs for the construction and maintenance of green infrastructure**
	Steps Taken	In 2011 the City introduced the Green Infrastructure Grant Program and awarded approximately $3.8 million to local organizations and private property owners to build green infrastructure projects on private property and public sidewalks. In addition, the City has formed the Green Infrastructure Citizen's Group and steering committee which is comprised of stakeholders from environmental justice, economic development, architecture and design, real estate, and other integral communities.
	Status	***Goal Achieved and Ongoing***
5	Goal	**Launch a comprehensive program to increase optimization of the existing system, including drainage plans, hydraulic studies, the survey and rehabilitation of 138 miles of interceptor sewers in two years, the inspection and repair of tide gates, and programs to prevent grease from obstructing the sewers**
	Steps Taken	Inspections of the structural condition of 138 miles of intercepting sewers are complete. DEP is reviewing the data and making repair plans for pipes with high levels of sedimentation.
	Status	***Goal Achieved and Ongoing***

6	Goal	**Develop a stormwater management standard for new construction and redevelopment that expands existing development**
	Steps Taken	Interagency, industry, and environmental stakeholder meetings and peer reviews were held during 2010 and 2011 to develop a stormwater management standard for new construction and redevelopment. The proposed rule and notice of public hearing were distributed on September 29, 2011. The performance standard was promulgated on January 4, 2012.
	Status	***Goal Achieved***

7	Goal	**Pilot sewer charges for stormwater for stand-alone parking lots**
	Steps Taken	Stand-alone parking lots with no water service are now charged $0.05 per square foot for wastewater services, a yearly average of $669 per lot. DEP billed $195,000 in stormwater charges for stand-alone parking lots in FY 2012. DEP has implemented a credit program to simultaneously waive charges for lots that demonstrate the ability to capture stormwater and prevent it from entering the sewer system, incentivizing the investment in different types of green infrastructure.
	Status	***Goal Achieved***

8	Goal	**Refine DEP models by including new impervious cover data and extending predictions to ambient water quality**
	Steps Taken	Immediately following the release of the Plan, DEP began recalibrating the InfoWorks models for six of the 13 watersheds using updated impervious data based on a 2009 satellite flyover and other data sources. Recalibration work and water quality modeling will continue pending contract approval and as DEP develops watershed specific Long Term Control Plans.
	Status	***Ongoing***

9	Goal	**Identify other funding for additional elements of the Green Infrastructure Plan**
	Steps Taken	The City has begun to identify other funding sources for elements of the Plan. Through the Green Infrastructure Grant Program, awardees will contribute nearly $700,000 to their construction projects. DEP is also pursuing opportunities for public-private partnerships as well as cost sharing with City Council Members using their discretionary funds.
	Status	***Ongoing***

10	Goal	**Replace all CSO outfall signs to reduce potential exposure.**
	Steps Taken	DEP has replaced signs at 410 CSO outfalls and received waivers from DEC for the remaining outfalls.
	Status	***Goal Achieved***

The Paerdegat Basin CSO Detention Facility, a cost effective grey infrastructure investment, can store up to 30 million gallons of untreated wastewater at a time.

1 BUILD COST-EFFECTIVE GREY INFRASTRUCTURE

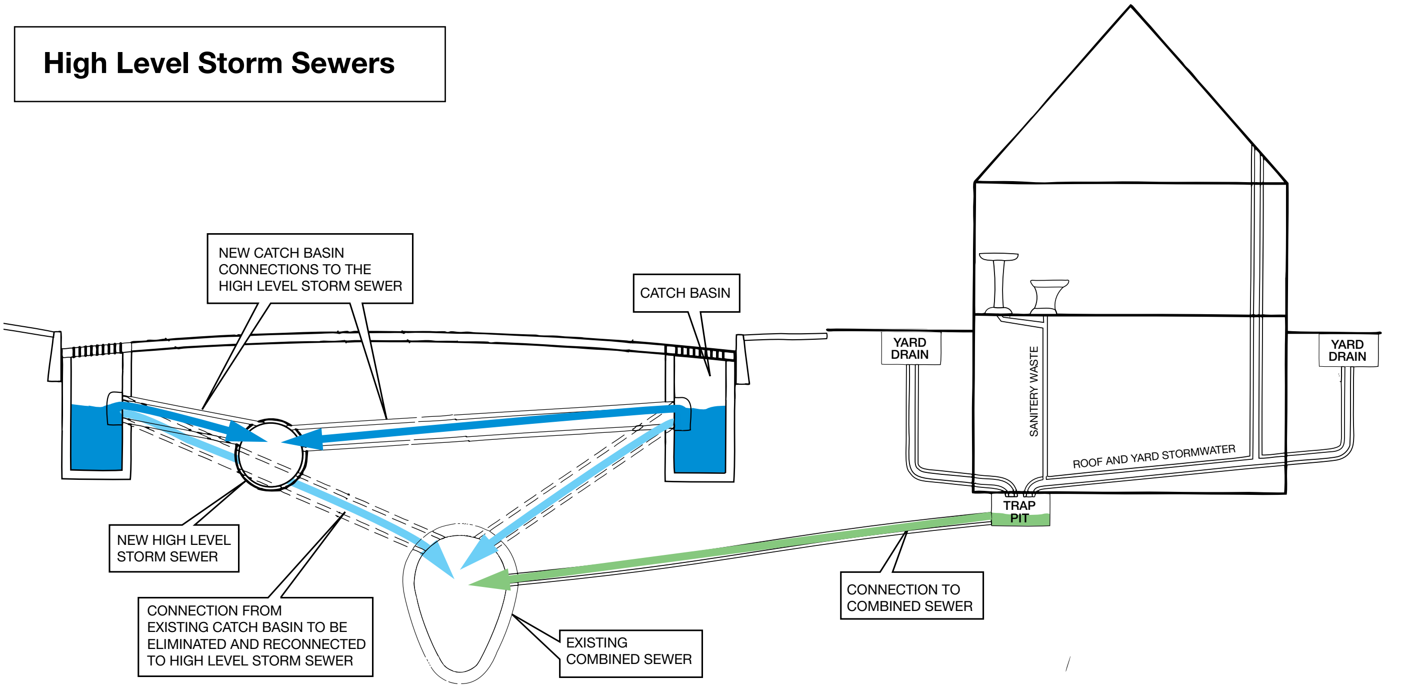
Over the next 20 years, DEP has committed to investing $2.9 billion in cost-effective grey infrastructure that will reduce the volume of CSOs by more than eight billion gallons per year. In the past year, DEP completed the Paerdegat Basin and Alley Creek CSO Detention Facilities, adding to the two recently completed or upgraded facilities at Flushing Bay and Spring Creek. The impact of these four facilities on CSO volumes and water quality will be measured through detailed post-construction monitoring over several years. DEP has constructed other sewer improvements, such as bending weirs and inflatable dams, that will reduce the number and intensity of CSOs. DEP is also in the process of maximizing the wet weather capacity of the sewer system leading to the Tallman Island Wastewater Treatment Plant (WWTP). For the next generation of cost-effective grey infrastructure controls, DEP is planning further sewer improvements, including more bending weirs, as well as High Level Storm Sewers (HLSS) to strategically separate street runoff from other wastewater flows.

Paerdegat Basin CSO Detention Facility

On May 12, 2011, DEP completed construction of the Paerdegat Basin CSO Detention Facility, which has a maximum capacity of 30 million gallons per storm. An additional 20 million gallons of wastewater can be stored in the sewer lines. The stored wastewater is detained at the facility until the wet weather subsides, when it is then pumped to the nearby Coney Island WWTP. We estimate that this facility will prevent 1.2 billion gallons of untreated wastewater per year from being discharged into Paerdegat Basin, a 1.25 mile channel that is connected to Jamaica Bay. This decrease in CSOs will improve the water quality in Paerdegat Basin and Jamaica Bay, increase dissolved oxygen concentrations, decrease coliform levels, remove nearly all floatables such as plastic bottles, and capture up to 80% of “settleable” solids, which can create sediment mounds and cause unpleasant odors within the basin and the bay. Overall, the Paerdegat Basin facility will reduce combined overflow discharges into the basin by approximately 70%—from 1,833 million gallons to 555 million gallons per year.

Alley Creek CSO Detention Facility

DEP completed the Alley Creek CSO Detention Facility on May 25, 2011. This facility can store a maximum of five million gallons of combined wastewater that was previously discharged into Alley Creek and Little Neck Bay. This detention facility will result in immediate water quality im-



High Level Storm Sewers channel stormwater runoff from streets and sidewalks into a separate sewer from sanitary waste, alleviating pressure on the combined sewer during wet weather. When HLSS are installed, the connection from the catch basins to the combined sewer is eliminated.

provements in Alley Creek and Little Neck Bay, increasing dissolved oxygen concentrations, decreasing coliform levels, and reducing floatables and settleable solids within the creek and bay. Once a storm subsides, the detained wastewater is pumped to the Tallman Island WWTP for treatment. Now that the facility is in operation, the overall volume of combined overflows discharged into Alley Creek is expected to decrease from approximately 246 million gallons per year to 112 million gallons, a 54.4% reduction.

High Level Storm Sewers

High Level Storm Sewers (HLSS) alleviate pressure on the combined sewer system by removing street runoff before it enters the combined sewers and diverting it directly into the waterways through permitted outlets. DEP expects this strategic, partial separation of our sewer system to divert 50% of stormwater runoff from the combined system in the areas in which it is built, preserving capacity in combined sewers and reducing the volume of stormwater sent to treatment plants. However, because HLSS require a separate pipe and outlet to a waterbody, this strategy is most cost-effective in close proximity to the water's edge.

Tallman Island System Wet Weather Maximization

In 2011, DEP finalized designs that maximize the amount of wet weather flow sent to the Tallman Island WWTP. This two pronged approach includes operational changes to enhance sewer cleaning schedules to reduce system bottlenecks and construction of modifications to interceptors and specific regulators, such as lowering the regulator's overflow weir height to optimize volume capacity. DEP is in the process of awarding a construction contract to complete the wet weather maximization of Tallman Island system.

Cleaning catch basins increases the capacity of the sewer system.


DEP uses Vactor trucks to remove sedimentation from the sewer system, increasing its capacity to hold wastewater during wet weather.

2

OPTIMIZE THE EXISTING WASTEWATER SYSTEM

Since the release of the Plan, DEP has undertaken a series of initiatives to improve how we operate and maintain our infrastructure. These initiatives will institutionalize a higher level of system optimization than we have been able to achieve in the past, and will complement our cost-effective grey infrastructure investments that are also part of the Plan.

Interceptor Improvement Program

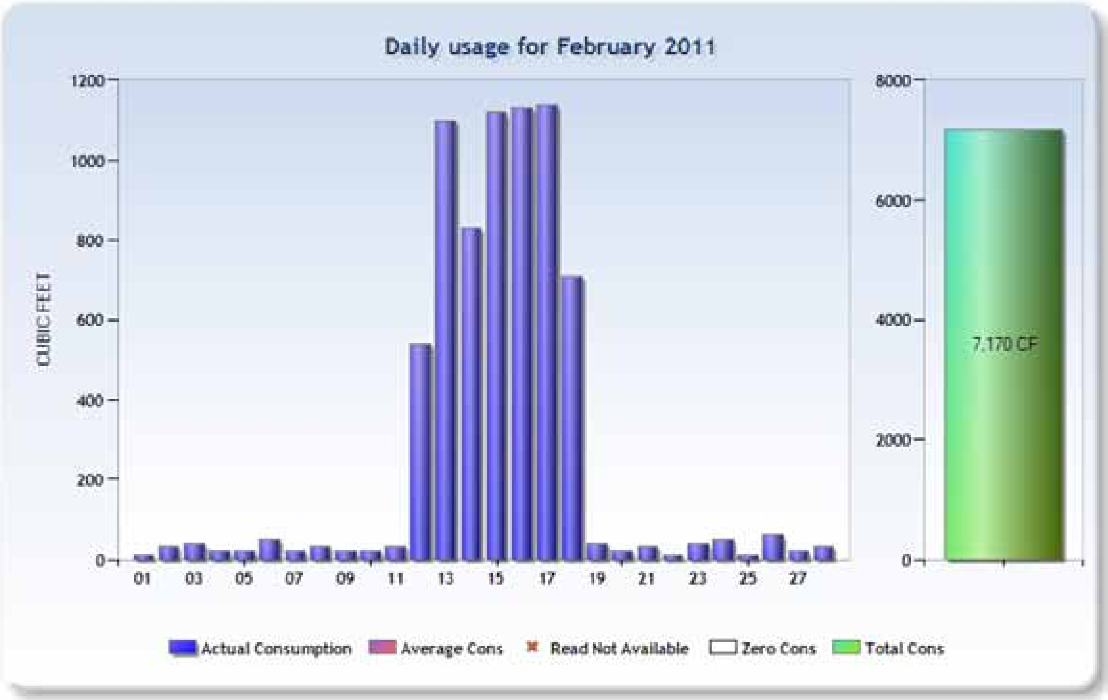
DEP established the Interceptor Improvement Program to maintain the 138 miles of intercepting sewers citywide in a state of good repair. Intercepting sewers are main sewer lines that receive wastewater from a combination of sanitary and storm sewers and transport it to WWTPs. Over the past year, DEP inspected all the intercepting sewers and evaluated the degree of sedimentation. In addition, DEP is reviewing the collected data and video of pipes that have a high level of sedimentation and is making plans for repairs and rehabilitation.

In addition to inspections, DEP is currently performing its own programmatic maintenance program using new Vactor trucks. Since July 2010, DEP has removed 4,490 cubic yards of sediment.

Drainage Basin	Sediment Removed (Cubic Yards)	Capacity Created (Gallons/Storm)
26th Ward	5	1,042
Bowery Bay	112	22,718
Coney Island	487	98,361
Hunt's Point *	-	-
Jamaica	1,115	225,124
Newtown Creek *	-	-
North River *	-	-
Oakwood Beach *	-	-
Owl's Head *	-	-
Port Richmond	22	4,342
Red Hook	15	3,030
Rockaway	477	96,342
Tallman Island	2,126	429,469
Ward's Island	131	26,459
TOTAL	4,490	906,887

* DEP is currently in the process of removing sewer sedimentation in the Coney Island and Rockaway drainage basins. Once these areas have been fully cleaned, DEP will begin to service the sewers in the remaining drainage areas.

When the cleaning is completed in mid-2012, the Interceptor Improvement Program will reduce CSOs by more than 50 million gallons a year.



When a spike in consumption is recorded by the AMR device, customers enrolled in the leak notification system receive emails to alert them to possible leaks on their property.

Tide Gate Maintenance Program

Tide gates prevent seawater from entering the sewer system at CSO outfalls. If a tide gate leaks, seawater can enter the system and reduce sewer capacity. In extreme cases, leaking tide gates can change the density of sanitary sewage so that it is harder to remove solids at treatment plants. DEP crews are responsible for correcting any conditions that they encounter during the inspections that impair the proper operation of the tide gates. In the last year, DEP inspected all 550 tide gates citywide, and repaired those that could be fixed with in-house capabilities. Repairs included removing the gates from the regulator and rehabilitating them in DEP workshops, working on the tide gates in place or, when the gates were beyond the capability of DEP staff, repairing them under a separate job order contract. Approximately 60 gates required extensive repairs that need a contractor or require complete replacement. Replacement and repair of those tide gates is underway.

Demand Side Management

Over the past fifty years, New York City water consumption has continued to decline despite increases in population. Water consumption peaked in 1979, when slightly more than seven million New Yorkers consumed an average of 1.5 billion gallons of water each day—about 214 gallons per person. Last year, residential consumption was approximately 75 gallons per person per day. DEP projects that this trend will continue based on a variety of factors including new national low-water fixture standards, price signals, and conservation efforts.

As of March 2012, DEP installed Automated Meter Reading (AMR) devices for over 794,000 customers. The new AMR technology sends accurate readings to a computerized billing system up to four times a day and lets customers track their daily water use online. Now, 94% of DEP customers can monitor their water consumption to identify leaks and wasteful consumption patterns.

DEP developed a Leak Notification Program to alert customers of potential water leaks. Customers who enroll in the program receive an email whenever a spike in consumption meets DEP's criteria for a leak. Customers who do not enroll in the program receive a letter and phone call from DEP alerting them to a potential leak.

The existing demand management strategy consists of completing AMR installations, amending the water use rules to reflect technical and procedural changes, promoting water efficiency, offering reuse and education programs, and continuously tracking and projecting water demand. DEP is currently working with other City agencies to develop water efficiency strategies and pilots in City-owned buildings.

Moving forward, DEP will continue to replace large water meters and is planning a new fixture replacement program to reduce consumption levels amongst our most inefficient customers. Further research on conservation pricing and other strategies is in development. For more information on DEP's conservation efforts, see the water Conservation Report on our website.

The Green Infrastructure Task Force toured a variety of green infrastructure projects built by DEP across the city, including the bioswale pictured above.

3

CONTROL RUNOFF FROM 10% OF IMPERVIOUS SURFACES THROUGH GREEN INFRASTRUCTURE

Over the past year, DEP has worked with various City agencies to develop, design, construct, and monitor pilot green infrastructure projects. In that time, DEP launched the Green Infrastructure Task Force and the first ever Green Infrastructure Grant Program, adopted a new rule for stormwater management in new construction, and built green roofs, blue roofs, bioswales, rain gardens, and other types of green infrastructure across the city.

Green Infrastructure Task Force

In October 2010, DEP joined commissioners from various City agencies to achieve the common goal of managing stormwater by developing a pipeline of agency capital projects that could include green infrastructure. Since then, DEP led five Green Infrastructure Task Force meetings with representatives from the Departments of Design and Construction (DDC), Parks and Recreation (DPR), Transportation (DOT), Education (DOE), Sanitation (DSNY), and other City agencies.

In addition to the quarterly task force meetings, the agencies have developed standard designs and specifications for Right-of-Way (ROW) Bioswales and siting procedures.

Ensuring maintenance of green infrastructure has been a critical goal for the Green Infrastructure Task Force. In November 2011, DEP, DOT, and DPR signed an agreement providing that DPR will use Greenstreets crews to maintain vegetated green infrastructure in the right of way through June 2015. Greenstreets crews are trained to manage vegetated systems and are able to integrate green infrastructure sites into their current workflow, with additional support from DEP.

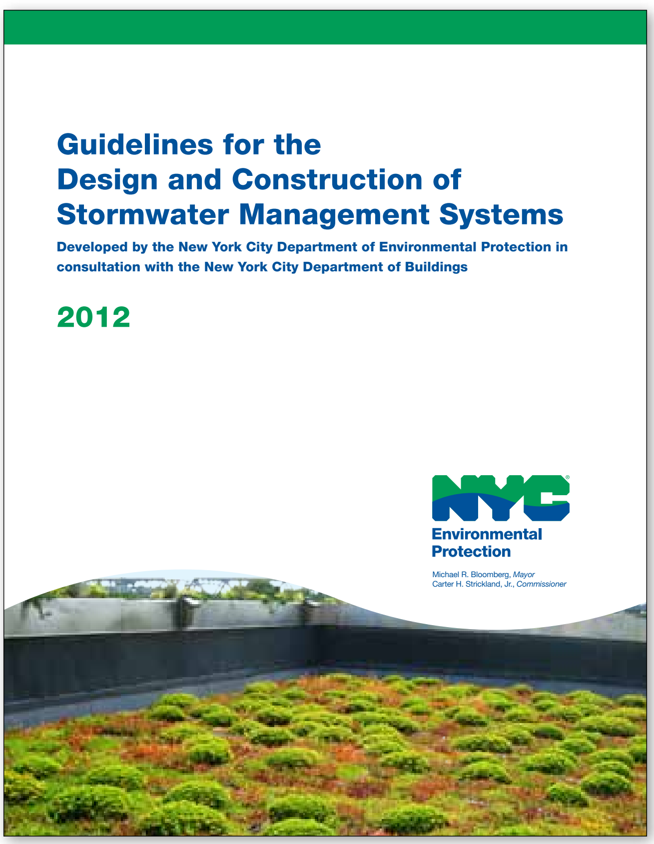
Stormwater Performance Standard and Opportunities in New Development

In January 2012, DEP adopted a rule requiring new construction and major building alteration projects to capture more stormwater runoff, to provide additional capacity in the combined sewer system, and to reduce street flooding. Enhancing an already existing requirement to manage stormwater, the rule means that developers will employ more green roofs, blue roofs, rain gardens, and detention techniques, and will also minimize impervious areas to the extent possible. For a typical site over 5,000 square feet in a combined sewer area, DEP estimates that the rule will limit stormwater discharge to 10% of its present permitted flow to the combined sewer system using cost-effective detention, infiltration, and recycling techniques.

The rule was developed over the past two years, with input from the building industry and environ-

Streetside infiltration swales, such as this one located in Brooklyn, can manage thousands of gallons of stormwater each year.

mental organizations, including the Real Estate Board of New York, Urban Green, the Regional Planning Association, American Institute of Architects, Buildings Sustainability Board, Citizens for Affordable Housing, and the Green Infrastructure Steering Committee. In addition, DEP conducted several task force meetings with the Mayor's Office of Long-Term Planning and Sustainability and other City agencies. Based on extensive feedback, the rule credits infiltration into soil, recycling for on-site use, and minimization of impervious surfaces, all of which can reduce the size of stormwater control systems.



Guidelines for the Design and Construction of Stormwater Management Systems

Developed by the New York City Department of Environmental Protection in consultation with the New York City Department of Buildings

2012

NYC Environmental Protection

Michael R. Bloomberg, *Mayor*
Carter H. Strickland, Jr., *Commissioner*

To assist with the implementation of the new rule, DEP released a companion document, *Guidelines for the Design and Construction of Stormwater Management Systems*, which provides guidance to the development community and applicants with the selection, planning, design and construction of onsite source controls. This guidance document was developed in consultation with the Department of Buildings and peer reviewed by experts in the industry. The Guidelines also include information for the proper operation and maintenance of stormwater management systems and feature a stormwater calculator to verify system sizing calculations. The information in the Guidelines will be continually updated to reflect the latest technology and best practices.

Green Infrastructure Retrofits

DEP has allocated $187 million in capital funds for FY12-FY15 to implement green infrastructure on public property in combined sewer areas. DEP works with the Green Infrastructure Task Force and the Green Infrastructure Citizen's Group to identify green infrastructure opportunities within priority watersheds and subwatersheds.

The Jamaica Wastewater Treatment Plant green roof manages more than 13,000 gallons of stormwater each year, reduces the building's absorption of ultraviolet light, and improves insulation.

Over the past year, DEP has worked with the Green Infrastructure Task Force partners including the New York City Housing Authority (NYCHA), DOE, School Construction Authority (SCA), DSNY, DDC-Structures Division and other groups such as the Trust for Public Land to identify opportunities for green infrastructure on City-owned property. After a detailed review, DEP selects properties that:

- are within combined sewer areas;
- have large impervious area or roofs to maximize stormwater capture; and
- are appropriate for onsite green infrastructure technologies such as blue roofs, green roofs, subsurface detention, and rain gardens.

Jamaica Wastewater Treatment Plant Green Roof

In October 2011, DEP completed a green roof atop the Jamaica WWTP. The green roof has the ability to absorb up to 13,000 gallons of stormwater annually, reducing runoff as well as the likelihood and intensity of CSO discharges into Jamaica Bay. The plantings at the Jamaica WWTP are grown in a specially-designed soil which sits on a drainage layer, absorbing rainfall and slowing runoff into the sewer system before it discharges into Jamaica Bay. DEP planted sedum, a hardy species chosen for its low maintenance needs and ability to withstand drought. The green roof also reduces the building's absorption of ultraviolet light and improves insulation, cooling the interior and increasing energy efficiency.

High Density Residential Green Infrastructure: The Bronx River Houses

Through a partnership with NYCHA, DEP selected the Bronx River Houses (BRH) to participate in a green infrastructure demonstration program because of its location within the Bronx River watershed, existing large roofs, and proportion of paved and grassed areas. The program at the BRH includes four types of green infrastructure appropriate for high-density residential complexes: a blue roof, rain gardens, perforated pipes, and stormwater chambers. Together the green infrastructure projects at the BRH will capture approximately 32,300 gallons of stormwater during a one-inch storm.

DEP installed stormwater chambers underneath the 9,100 square foot BRH North Parking lot. Stormwater chambers collect, clean, and hold stormwater so it can be slowly released into the sewer system or infiltrate into the ground. Stormwater enters the sewer inlets, runs through a pretreatment structure to collect sediment and debris, and is directed into the stormwater chambers. The stormwater chambers have an approximate capacity of 4,850 gallons per one-inch storm.

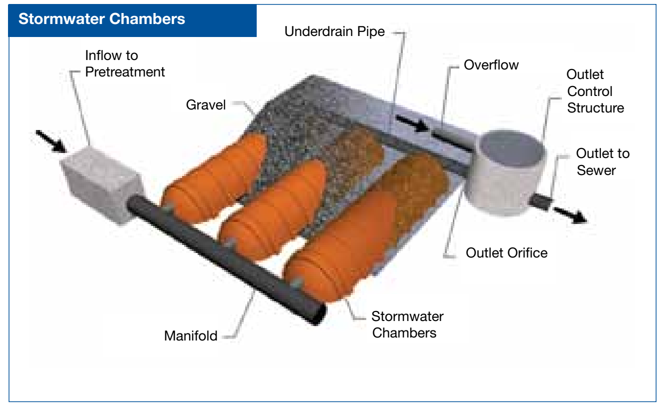
DEP installed a blue roof on a 1,675 square foot section of the BRH Community Center roof. A blue roof is a system that "detains" rainfall by slowing the flow of stormwater so that it will take hours to drain. The blue roof at BRH collects and stores rain in 180 small, aluminum trays, with gravel as ballast to prevent the trays from blowing away. Stormwater stored in the trays evaporates into the air or flows slowly through filter fabric to holes at the bottom of the tray and eventually into the roof drain. The blue roof can capture approximately 750 gallons of stormwater per one-inch storm.

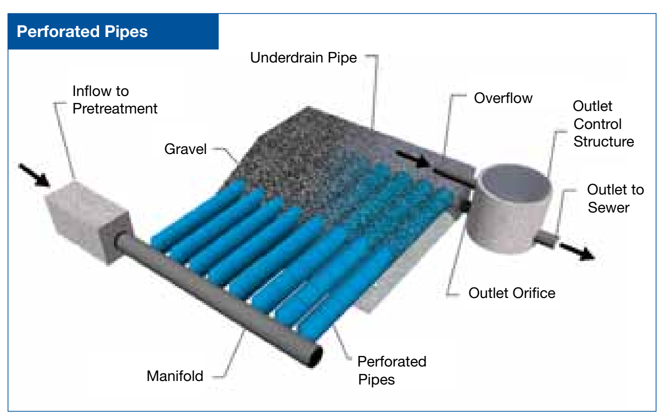
DEP constructed five rain gardens at the BRH to collect surface runoff from about 40,000 square feet of sidewalks and other paved areas. Rain gardens are shallow basins with underground, perforated drainage pipes that are covered with a layer of gravel, then a layer of soil, and are finally planted with a hardy species. Stormwater infiltrates the soil and is stored in the gravel layer during wet weather, and the plants take up much of the water through evapotranspiration. The pipes drain away excess water during severe storms. The five rain gardens can capture approximately 18,500 gallons of stormwater per one-inch storm.

DEP installed a perforated pipe system underneath the 7,500 square foot BRH South Parking Lot. A perforated pipe system is a subsurface system that collects, cleans, and holds stormwater so that it can be slowly released into the sewer system or infiltrate into the ground. The perforated pipe system can capture approximately 8,200 gallons of stormwater per one-inch storm.

Preliminary data indicates that the green infrastructure systems reduce peak runoff rates and the total volume of stormwater runoff into the sewer system. For example, during a storm with a total precipitation of two inches, the rain gardens captured all of the stormwater in the contributory drainage area. In a year with typical rainfall, DEP estimates that the four projects will manage more than one million gallons of stormwater.

Throughout the Bronx River Houses, DEP has installed interpretive signs in both English and Spanish. The signs feature illustrations of the water cycle and information on why and how green infrastructure systems are an important strategy in protecting our waterways. After the signs and green infrastructure had been installed for a few months DEP surveyed 75 people at BRH to better understand how residents felt about the new installations and whether DEP was effectively communicating the purpose of green infrastructure. Overall, the survey results indicate that residents





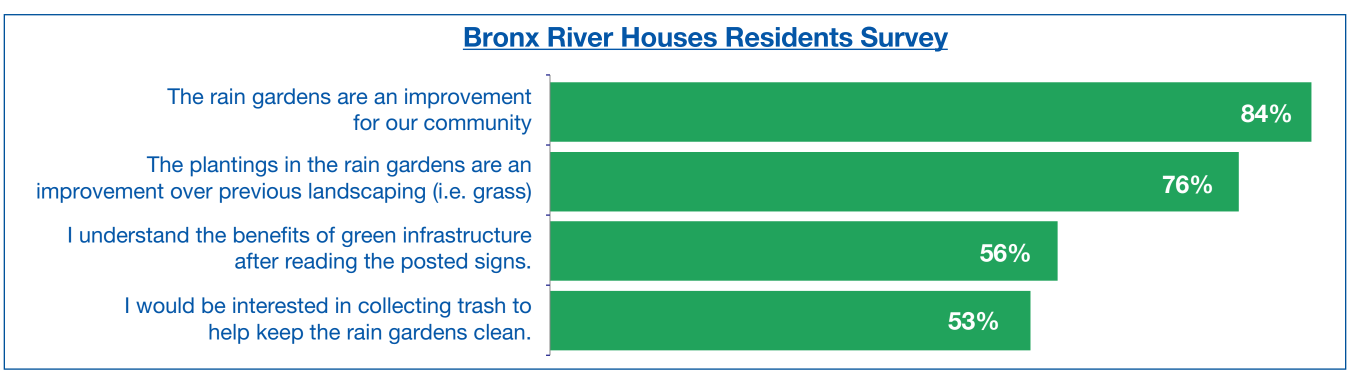
enjoy the green infrastructure, value their stormwater benefits, and would like to help install and maintain future green infrastructure systems.

Building on the success at the Bronx River Houses, DEP has partnered with NYCHA to introduce green infrastructure into additional properties. The agencies have begun a technical assessment for the Edenwald Houses, a 49-acre site in the Hutchinson River watershed, at the Seth Low Houses in the Jamaica Bay watershed, and at Hope Gardens in the Newtown Creek watershed.

Right of Way Bioswales and Greenstreets

Right of Way (ROW) Bioswales are similar to existing tree pits and are built within sidewalks upstream of existing catch basins to capture runoff from the street and sidewalk. Since 2009, DEP has been studying various types of green infrastructure systems in the right of way (see page 30).

In 2011, DEP began working with DDC, DOT, and DPR to create standard designs for ROW Bioswales and to coordinate siting procedures across the city. The design group meets on a weekly basis to analyze the performance of pilot right of way green infrastructure systems and modifies those designs to maximize stormwater capture, reduce cost, and make maintenance as unnecessary and safe as possible. The design group has already developed eight standard designs for ROW Bioswales and DEP will publish all approved standard specifications on its website. Standard ROW bioswales will be 20' long and 5' wide. Water will



In October 2011, DEP Commissioner Strickland unveiled the Dean Street bioswales in Brooklyn with DDC Commissioner David Burney, DOT Commissioner Janet Sadik-Khan, and DPR Commissioner Adrian Benepe.

enter the bioswale through various inlet structures and infiltrate into the underlying soil by traveling through a three-foot layer of soil and then a more porous two-foot layer of gravel.

While designs were being completed, DEP reviewed all capital roadway and sewer projects plans for FY12-FY13 to incorporate bioswales into existing contracts. By integrating ROW Bioswales into existing capital projects, DEP is able to build green infrastructure quickly and at a reasonable cost. DEP and DDC have already constructed a system of four ROW Bioswales in the Gowanus Canal watershed in Brooklyn. Over the next year, DEP will construct at least 42 more bioswales throughout the Bronx, Brooklyn, and Queens.

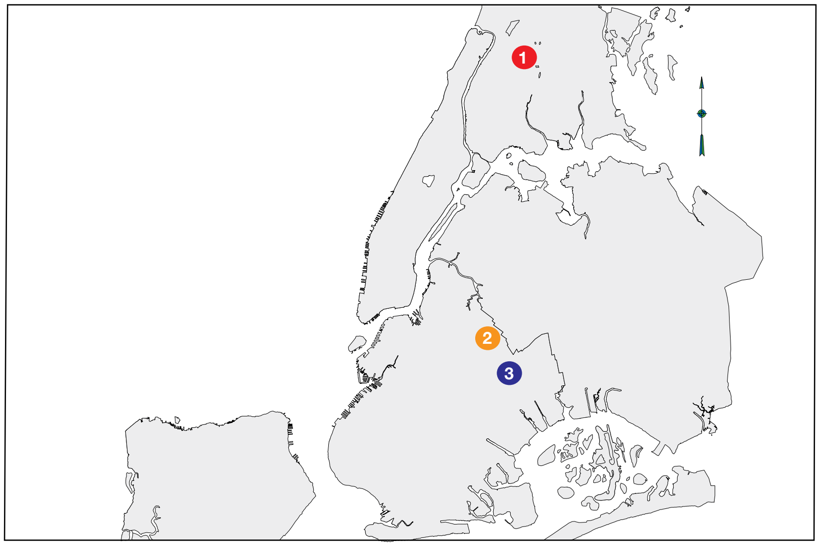
DPR has been constructing Greenstreets in unused areas of the City's right of way for decades. Greenstreets have served many functions such as improving air quality and beautifying neighborhoods. Until now, Greenstreets were not designed to manage stormwater because most Greenstreets were built in unused areas of the roadway, which tended to be high points. In 2011, DEP began funding DPR's Greenstreets program. Greenstreets have been typically sites in unused areas of the roadbed which are most often high points that are unfit to manage stormwater. New Greenstreets will still target unused portions of the right of way so long as they are able to collect enough stormwater to justify the investment. Every new Greenstreet will have a unique design tailored to the distinct drainage patterns and existing right of way, and will be able to collect stormwater in areas that standard ROW Bioswales would be less effective. DPR will build at least 80 new Greenstreets per year (40 in the spring, 40 in the fall) with the first batch of Greenstreets in Spring 2012.

North and South Conduit Bioretention Zone

In 2011, DEP completed the North and South Conduit Avenue stormwater bioretention and treatment zone within an existing grass-covered roadway median to help improve harbor water quality in Jamaica Bay. The 13,000 square-foot bioretention zone is a below-ground water-retention system comprised of vegetation, sand, and soil. This project has the capacity to divert at least 200,000 gallons of stormwater that would otherwise flow into the combined sewer system–roughly 90% of the stormwater that accumulates within the drainage area during a moderate storm.

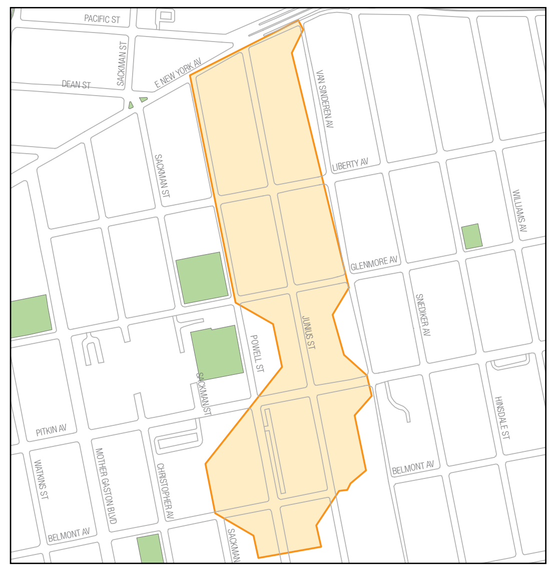
Select Bus Service Stations

DEP has partnered with DOT and DPR to install and maintain bioswales at Select Bus Service stops, including along Nostrand Avenue in Brooklyn. Construction on the bioswales is anticipated to begin in 2012. Bioswales in the Select Bus Service stations will be similar to other green infrastructure systems in the right of way and will be highly visible.



DEP identified three Neighborhood Demonstration Areas in the Bronx River, Jamaica Bay, and Newtown Creek watersheds to test the effectiveness of green infrastructure systems on a neighborhood scale.

Neighborhood Demonstration Area 1: Bronx River Watershed



Neighborhood Demonstration Area 2: Jamaica Bay Watershed

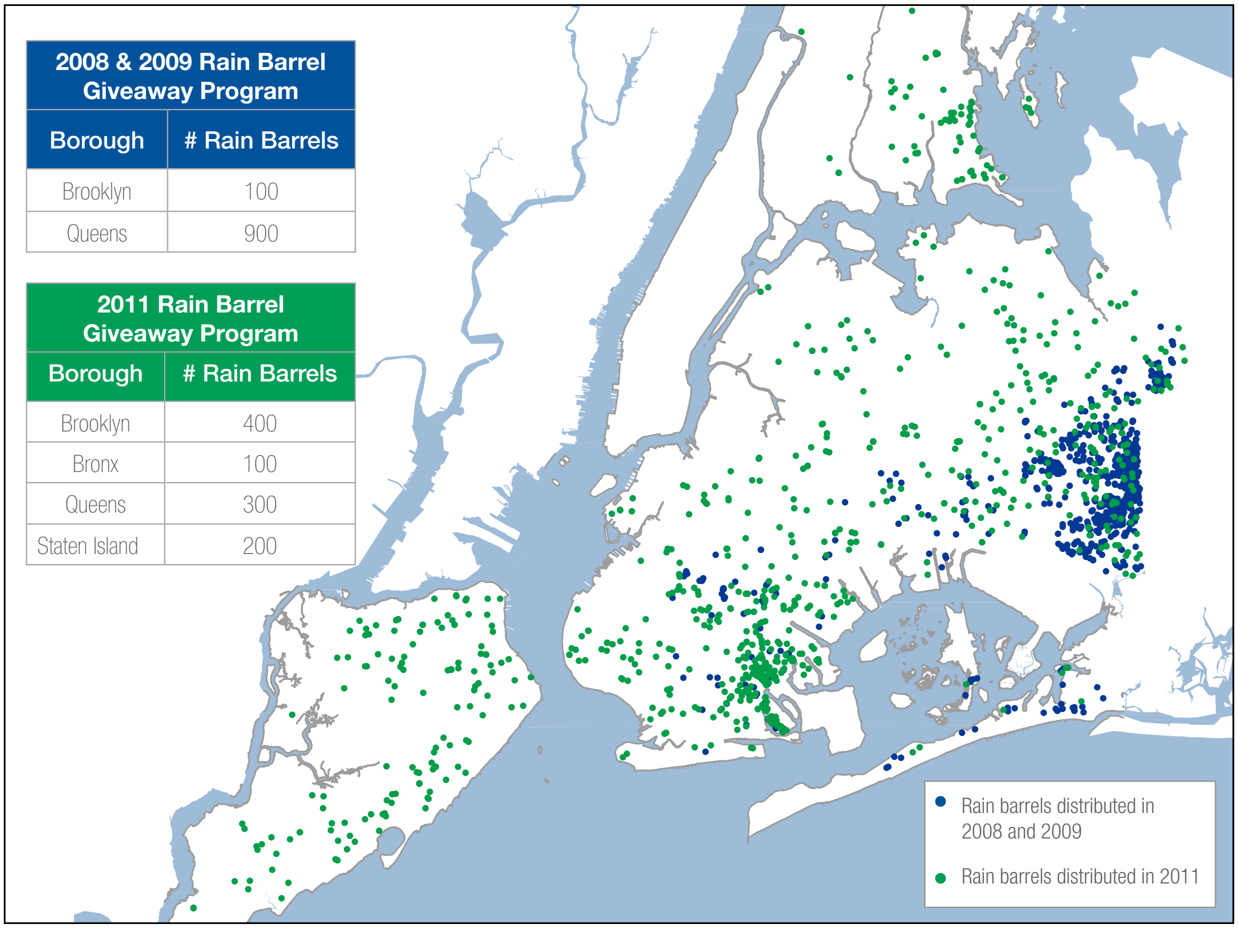
Neighborhood Demonstration Area 3: Newtown Creek Watershed

Neighborhood Demonstration Areas

In consultation with DEC, DEP identified three Neighborhood Demonstration Areas to test the effectiveness of green infrastructure systems on a larger scale. These areas are located within the Bronx River, Jamaica Bay, and Newtown Creek watersheds and were chosen because underlying sewers are suitable for monitoring. In each of the Demonstration Areas DEP has identified opportunities such as bioswales and Greenstreets in the right of way and onsite detention and retention opportunities on public property.

- Neighborhood Demonstration Area 1, in the Bronx River watershed, has the opportunity for 19 Greenstreets and bioswales and offers options for green infrastructure on schools.
- Neighborhood Demonstration Area 2, in the Jamaica Bay watershed, has the opportunity for 32 bioswales and offers options for green infrastructure on NYCHA and other city owned property.
- Neighborhood Demonstration Area 3, in the Newtown Creek watershed, has the opportunity for 18 bioswales and offers options for green infrastructure on schools and NYCHA.

DEP installed monitoring devices and rain gauges in Fall 2011 to gather baseline wet weather flow data within the combined sewer pipe. Between Spring and Summer 2012, DEP will construct green infrastructure on public property and in the right of way in all three areas. Once construction is complete, DEP will collect and analyze monitoring data to determine the changes in wet weather flows within the Demonstration Areas. The data captured from the three Demonstration Areas will inform future siting for green infrastructure installations, the cost effective installation rate, and the CSO Long Term Control Plans.



2008 & 2009 Rain Barrel Giveaway Program	
Borough	# Rain Barrels
Brooklyn	100
Queens	900

2011 Rain Barrel Giveaway Program	
Borough	# Rain Barrels
Brooklyn	400
Bronx	100
Queens	300
Staten Island	200

DEP has distributed more than 2,000 rain barrels to homeowners across the outer boroughs.

Rain Barrel Giveaway Program

Rain barrels connect directly to a building's existing downspout to collect water for irrigation needs; homeowners then connect a hose in the spigot of the rain barrel for irrigation and gardening purposes, such as watering lawns and gardens. Rain barrels can capture thousands of gallons of water each year to be used by homeowners, rather than running into catch basins where it can contribute to CSOs. Each rain barrel has the capacity to collect up to 55 gallons of stormwater at a time, which reduces localized street flooding and the demand on the city's drinking water system during drought conditions.

DEP's Rain Barrel Giveaway Program initially began as a pilot program in 2008, when 250 rain barrels were given to homeowners in the Jamaica Bay watershed. The program was expanded in 2009 due to the public's overwhelmingly positive response. In 2009, the program offered 750 barrels to homeowners in the Jamaica Bay watershed. In 2011, DEP redoubled its efforts, distributing an additional 1,000 free rain barrels to New Yorkers in Brooklyn, the Bronx, Queens, and Staten Island. The Rain Barrel Giveaway Program saves customers money for watering lawns and gardens that would otherwise come from their taps. Also, installing and maintaining rain barrels requires minimum work.

The Rain Barrel Giveaway Program has been a resounding success as New Yorkers waited on line for over two hours before each of three giveaway events in 2011. After all 1,000 rain barrels had been given away, DEP was forced to turn away many eager recipients. Because the program has been so popular, in 2012 DEP anticipates a large program in partnership with retail and hardware stores.

The Green Infrastructure Grant Program awarded more than $3.8 million in its inaugural year to projects ranging from porous concrete to green roofs. Queens College, part of the City University of New York, was awarded $375,000 to construct three separate green infrastructure projects on its campus, including rain gardens on common area plazas.

Green Infrastructure Grant Program

In 2011, DEP introduced a grant program to fund green infrastructure projects on private property. The Green Infrastructure Grant Program was open to private property owners, businesses and 501(c)(3) organizations to fund projects that use green infrastructure to reduce or manage stormwater on private property or on public sidewalks. An interagency committee reviewed more than 50 applications and awarded $3.8 million for projects including:

The 217 Park Row Co-op was awarded $166,000 to build a green roof that will manage approximately 255,000 gallons of stormwater per year and will reduce CSOs to the East River. This project also includes a research study on migrating birds and breeding bird habitats with Fordham University.

AWISCO, in partnership with the Newtown Creek Alliance and Highview Creations LLC, was awarded $206,000 to build a green roof on an industrial building in Maspeth. This green roof will manage over 390,000 gallons of stormwater per year and will reduce CSOs to Newtown Creek.

The Brooklyn Greenway Initiative was awarded $462,000 to install infiltration planters and porous concrete in the sidewalk along an entire block of Columbia Street. The project will remove street runoff from the combined sewer system by directing the water into the planters. The project will reduce CSOs to the East River by managing approximately 285,000 gallons of stormwater per year.

The Brooklyn Navy Yard, in partnership with Brooklyn Grange, was awarded $592,000 to construct a 40,000-square-foot commercial rooftop farm. The rooftop farm will manage over one million gallons of stormwater per year and reduce CSOs to the East River. The production of fresh local produce will create opportunities for urban agriculture jobs training and volunteerism, education, and advocacy.

Forest House was awarded $180,000 to install an integrated cistern system that will manage over 491,000 gallons of stormwater per year that would otherwise flow into sewers and contribute to overflows to the East River. The system will use weather information and real-time monitoring to actively manage the stormwater detention and discharge functions of cisterns.

Geosyntec Consultants were awarded $111,000 to construct an intelligent distributed cistern system that will manage 78,296 gallons of stormwater per year. This dynamic technology will use real-time weather monitoring to actively manage the stormwater detention and discharge functions of the cisterns.

The Lenox Hill Neighborhood House was awarded $40,000 to build two rooftop gardens that will manage up to 63,000 gallons of stormwater per year and provide its clients with fresh vegetables and educational programs. The rooftop gardens will capture rain water, reducing CSOs to the East River.

New York Restoration Project (NYRP) was awarded nearly $245,000 to install a right-of-way bioswale that will divert stormwater flow from the street into a rain garden that features native plants and trees. The project will manage approximately 130,000 gallons of stormwater per year and will reduce CSOs to the Gowanus Canal. The design also includes a small Education Station that will function as a remote weather monitoring station and outdoor classroom hub.

Osborne Association was awarded $288,000 to build an alternating blue roof and green roof system on its building in the Bronx. This project will manage over 240,000 gallons of stormwater per year and will reduce CSOs to the East River. The Osborne Association is partnering with multiple Bronx community leaders to incorporate a green job curriculum for formerly incarcerated New Yorkers at this site.

Queens College was awarded $375,000 to retrofit three different areas on their campus, which will reduce CSOs to Flushing Creek. In total, the project will manage over 707,000 gallons of stormwater per year through the use of porous concrete and rain gardens that will infiltrate and retain water using native plants and trees.

Upon completion, these projects are estimated to manage more than 4.1 million gallons of stormwater each year. Monitoring data from select sites will be collected over the next three years to better understand sustainability co-benefits such as energy use reduction, pollutant uptake and avoidance, urban heat island benefits, and neighborhood aesthetic benefits. DEP has renewed the grant program for 2012, due to the success of its inaugural year. Applicants will now be able to submit their applications online. DEP hosted application workshops in the Bronx, Brooklyn, Queens and Staten Island to assist in the application process.

Under PlaNYC, the City aims to increase opportunities for recreation on the waterfront. DEP uses landside and water quality models to understand the impacts of proposed development on the City's waterbodies.

4 INSTITUTIONALIZE ADAPTIVE MANAGEMENT, MODEL IMPACTS, MEASURE PROGRAM ELEMENTS, AND MONITOR WATER QUALITY

In order to meet the goals of the consent order with DEC, DEP will continue watershed-level planning assessments to identify new opportunities for green infrastructure, build a foundation for Long Term Control Plans (LTCPs), and improve existing models to better project future water quality conditions in the City's surrounding waterbodies. Under Mayor Bloomberg's *PlaNYC*, the City aims to increase opportunities for recreation along the City's waterfront. In order to do so, DEP continues to rely on landside and water quality models to understand the impacts of proposed capital investments as well as new development, population growth, and climate change on New York City's waterbodies.

Institutionalizing Adaptive Management

DEP has spent the last year working with DEC to agree to a consent order that adopts many of the goals of the Plan into a formal commitment from the city to the state. The January 2012 consent order commits DEP to construct green infrastructure that will manage stormwater on 1.5% of impervious surfaces in combined sewer areas by 2015, 4% by 2020, 7% by 2025, and 10% by 2030. The agreement also requires DEP to build and monitor green infrastructure on 80 acres across the Newtown Creek, Bronx River, and Jamaica Bay watersheds to verify the concepts on a neighborhood scale.

In addition, DEP has committed to spend a minimum of $2 million to construct neighborhood scale green infrastructure demonstration studies along with an additional $3 million in funding for the Green Infrastructure Grant Program over three years. DEP has also committed to moving forward with $3.4 billion in grey CSO controls. In exchange, DEC agreed to eliminate some of the more costly mandated CSO controls that will save approximately $1.4 billion in grey infrastructure projects and achieve equivalent CSO reductions and to defer an additional $2 billion that would have been spent on CSO storage tunnels in Newtown Creek and Flushing Bay. This will allow additional time to evaluate and implement green infrastructure that is anticipated to be more cost effective and achieve environmental benefits beyond just CSO reduction.

DEC also agreed to an adaptive management approach that allows DEP to propose alternative ways to meet its green infrastructure performance targets, and to make up for any missed targets by changing its investment and design strategy to reflect current conditions and up-to-date information.

Subwatershed planning allows DEP to identify opportunities for green infrastructure on existing public facilities and other areas within priority CSO outfalls.

Watershed-Level Planning

DEP is currently performing outfall-specific analyses to identify drainage areas for near-term implementation of green infrastructure. DEP identified specific outfalls and related drainage areas based on several factors including the results of cost-benefits analyses in the Plan, ongoing assessments of different storms and related frequencies of CSO events, and continued discussions with DEC for the development of LTCPs.

DEP has identified existing public facilities and sections of the right-of-way within the Gowanus Canal, Hutchinson River, Flushing Bay, Bronx River and Newtown Creek watersheds for green infrastructure implementation. DEP is using this data to initiate multiple green infrastructure design and construction contracts. The results of these analyses will be used to track progress towards the 10% green infrastructure goal and related milestones, and to develop watershed-specific application rates for green infrastructure to be used during future system and water quality modeling.

Modeling Landside Infrastructure and Water Quality

DEP continues to review and adjust model inputs in order to accurately reflect actual system and water quality conditions. DEP uses models to project current and future conditions within a defined area and assess the impact of system improvements. DEP employs several models to develop CSO and water quality improvement projects including InfoWorks, a model of the city's hydrology and hydraulics that represents the sewer system, wastewater conveyance, treatment facilities, and point discharges of treated and untreated flows based on surface coverage, topography, and rainfall in delineated drainage areas.

In conjunction with this "landside" model, DEP relies on several water quality models to reflect in-water conditions based on different inflows (i.e., combined sewer overflows, stormwater discharges, and overland flow) and physical conditions that may affect the chemical and biological attributes of a waterbody. Computer generated water quality models incorporate a number of variables such as wind, tides, solar radiation, pollutant loads, and deposition of organic matter. In turn, water quality models project baseline and future conditions related to bacteria and dissolved oxygen concentrations that can be compared to state water quality standards and limits. DEP employs water quality modeling to demonstrate compliance with the Clean Water Act and related federal and state mandates in place to protect public health and safety, and the ecological integrity of waterbodies.

Since 1909, the City of New York has been collecting water quality data in the harbor. In the last year, DEP has increased the number of sampling stations and, for the first time ever, has published recent and historical water quality data online before submitting reports to the state.

Measuring Program Performance and CSOs

Over the past year DEP has continued constructing the new Citywide Collection Facilities Integrated Supervisory Control and Data Acquisition System (CCFISS) which will be operational at over 100 regulators and CSO facilities, and 95 wastewater pumping stations. In the regulator facilities, CCFISS employs ultrasonic level sensors in the different chambers including conductivity sensors in the tide chambers, float switches on the overflow bench, and level sensors in the channels. These sensors provide real-time information about the status and performance of the infrastructure, and can alert DEP staff of any aberrations to normal operation, such as tide gate leakage. While the sensors can indicate whether there is a likely overflow, they are not able to determine the actual volume of a CSO event. At completion, the system will have the capability to remotely control sluice gates at 60 regulators and 12 Beach Sensitive Pump Stations near the Coney Island, Orchard, and Rockaway beaches, among others.

Research and Development for Measuring CSOs

In Fall 2011, DEP solicited proposals from contractors to develop a real-time monitoring system to measure the volume of combined sewer overflows, supplementing and enhancing our telemetering at over 100 outfalls near beaches and other bathing areas. In 2012, the monitoring system will be installed at five regulators with a mean dry flow of at least five million gallons per day to measure the volume of overflows from outfalls in the combined sewer system and report results in real time. This system will help DEP optimize the existing sewer system, provide more effective notification to the public, and respond to emergencies.

Monitoring Ambient Water Quality

The City of New York has collected water quality data in the harbor since 1909 through the Harbor Survey Program. This data is used by regulators, scientists, educators, and citizens to assess trends and improvements in water quality. Over the past year, DEP has increased the number of sampling stations in the Harbor Survey Program from 60 in 2010 to 72 in 2011. At each of these sites, DEP collects data on more than 20 water quality parameters including key indicators such as concentrations of fecal coliform and enterococci bacteria, dissolved oxygen, chlorophyll ‘a’, and Secchi transparency. Every year DEP publishes a report on water quality throughout the harbor.

In 2011, DEP began posting recent and historical water quality data from the survey program online, in advance of submitting reports to the state.

Commissioner Strickland presenting the NYC Green Infrastructure Plan to stakeholders at the first Green Infrastructure Citizen's meeting in Winter 2011.

5

ENGAGE AND ENLIST STAKEHOLDERS IN STORMWATER MANAGEMENT

New Yorkers are passionate about their city and each day more people are rediscovering the city's beautiful harbor waters. As more people are finding ways to connect with the city's waters, DEP is working hard to harness this positive energy, engage the public, and improve water quality by constructing green infrastructure.

Notification Systems

DEP has worked to improve our existing notification systems, develop new means of communication with the public, and engage stakeholders in stormwater management in their communities. We have replaced signs at 410 combined sewer outfalls at a cost of $1 million with new signs that are easier to read from a distance, have clearer warnings for wet weather events, and have graphic images that convey unambiguous warnings about recreational use to English and non-English speakers alike.

DEP has continued to improve upon its Waterbody Advisory webpage showing real-time advisories for secondary contact for 25 waterbodies in the New York Harbor, including plans to integrate our water body advisories into the Notify NYC system to allow users to request notifications about specific water bodies.

Green Infrastructure Citizen's Group

In February 2011, DEP held the first meeting for the Green Infrastructure Citizen's Group. This open meeting attracted individuals and organizations who have requested to receive updates on DEP's green infrastructure projects. Citizen's Group members receive periodic emails and announcements in addition to meeting approximately one to two times a year. DEP held a second Citizen's Group meeting in November 2011. DEP will continue to hold public meetings to report on the progress of green infrastructure throughout the city.

Green Infrastructure Steering Committee

The Green Infrastructure Steering Committee is comprised of a cross-section of stakeholders from environmental justice, economic development, architecture and design, real estate, and other integral communities who are experts in stormwater management related issues in New York City. The Steering Committee meets quarterly and serves as a liaison between the Citizen's Group and DEP in order to represent respective ideas and concerns. Agenda items cover a wide range of topics including the proposed Stormwater Performance Standard and the creation of a Green Infrastructure Vendor Directory.

Fostering Stewardship of Green Infrastructure

Over the past year, DEP has given multiple presentations to elected officials, community boards, and neighborhood groups regarding green infrastructure construction projects and the three Neighborhood Demonstration Areas. During these presentations stakeholders have the opportunity to ask questions about green infrastructure.

In addition, DEP notifies property owners of green infrastructure construction by:

- Meeting with the community;
- Incorporating information on green infrastructure into project-specific flyers and newsletters;
- Sending letters directly to the abutting property owners explaining the benefits of green infrastructure, offering stewardship guidance, and showing a project map with approximate locations; and
- Sending postcards to residents within a two-block radius briefly explaining the benefits of green infrastructure and providing contact information for questions.

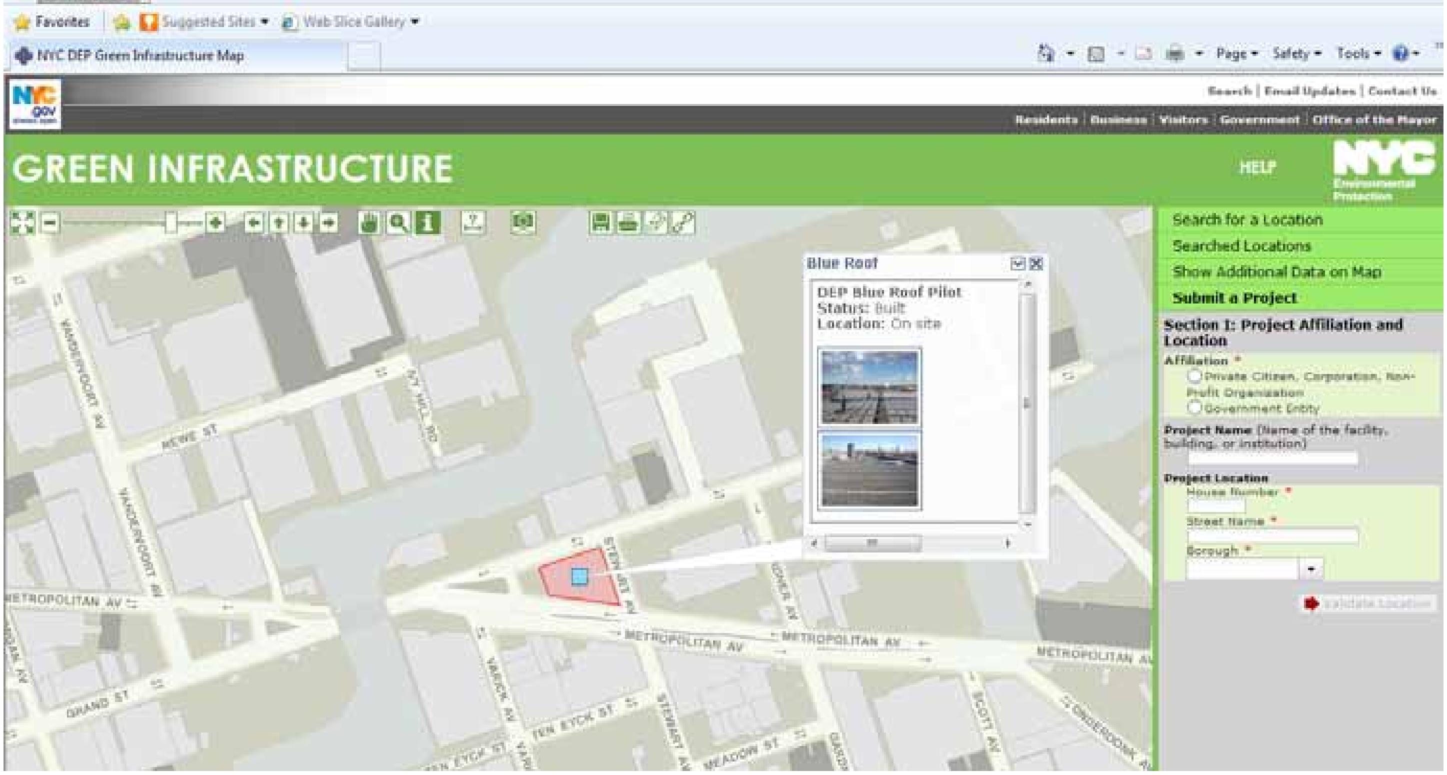
Moving forward, DEP will continue to partner with other City agencies to increase opportunities for stewardship. These partnerships include:

- Collaborating with other City agencies to create a signs and marketing campaign geared to increase the visibility of green infrastructure systems;
- Encouraging community groups and neighborhoods to get involved with existing New York City Steward programming such as the Adopt-a-Bluebelt program in Staten Island or the MillionTrees Stewardship Corps; and
- Working with DOE to create a resource for teachers who want to create lesson plans related to green infrastructure, featuring slide shows, photos, and videos on policy and best management practices.

In 2011, DEP created a website devoted to the green infrastructure program where the agency regularly posts and updates information that may be useful to the public. DEP keeps and maintains a Citizens Group/Stakeholder List made up of individuals, businesses, institutions, and anyone else who wants to receive periodic updates from the Office of Green Infrastructure such as public meetings, grant program information/updates, press releases, and other relevant news. DEP is also creating a Green Infrastructure Vendor Directory that will include information on contractors, architects, landscape architects, designers, green roof professionals, and firms that offer stormwater management and green infrastructure services. This database will be accessible through the agency's website and will serve as a resource for New Yorkers who want to build green infrastructure projects.

Last year, DEP launched an interactive Green Infrastructure Webmap which offered users the ability to see where green infrastructure projects have been constructed across the city. In addition to being able to search for a project by address, this webmap allowed users to plot particular types of green infrastructure technology. Users could choose to plot blue roofs, cisterms, constructed wetlands (part of the award-winning Bluebelt system), green roofs, pervious pavement installations, rain barrels, rain gardens, rainwater reuse systems, swales, and enhanced tree pits.

In January 2012, DEP released an updated version of the webmap. This update increases user functionality, and offer enhanced features, such as the ability to "Submit a Project." That option permits users, including government agencies, not for profit organizations, private citizens, and



The updated webmap offers users the ability to submit their own projects and post images.

green infrastructure grant awardees, to submit information on their own green infrastructure projects, including location, technology, specifications, and images. These projects will be then be searchable on the webmap. These upgrades will offer a more comprehensive view of the investment in green infrastructure across the city and will allow DEP to track progress towards our 10% reduction in impervious surface goal.

Long Term Control Plans

As part of the Long Term Control Plan (LTCP) for CSOs, DEP will establish and document public participation and outreach programs that will actively involve stakeholders in the decision making process. By providing a conduit for the evaluation and incorporation of stakeholder's recommendations, DEP shall work with communities from all the CSO impacted waterbodies to share information, receive input, and develop and build support for the proposed plans.

DEP will use a mix of traditional outreach and public education methods and a modern web-based approach in order to reach as wide an audience as possible.

During the formation of the LTCPs, DEP will meet with representatives from community boards as well as local elected officials and their offices. DEP will also produce educational materials, which will be available in Community Board offices as well as elected officials' offices and via 311. As part of the LTCP Public Participation Process, DEP will launch a specific CSO LTCP webpage to provide information on upcoming Steering Committee meetings and links to other related programs and regulatory sites. DEP will also post audio/visual presentations for each watershed/waterbody, CSO Quarterly Reports, annual GI reports, educational materials, and pamphlets on this site.

LTCP Submission Schedule

Watershed	Date Due to DEC
Alley Creek	June 2013
Coney Island	June 2014
Hutchinson River	September 2014
Flushing Creek	December 2014
Gowanus Canal	June 2015
Bronx River	June 2015
Jamaica Bay and Tributaries	June 2016
Flushing Bay	June 2016
Westchester Creek	June 2017
Newtown Creek	June 2017
Citywide LTCP	December 2017

GREEN INFRASTRUCTURE CASE STUDIES

DEP has been actively installing and monitoring various green infrastructure demonstration studies as part of its 2007 Jamaica Bay Watershed Protection Plan, the Nitrogen and Combined Sewer Overflow Environmental Benefit Projects with the New York State Department of Environmental Conservation and other green infrastructure initiatives. These demonstration studies provide DEP opportunities to test different designs and monitoring techniques to then determine the most cost-effective, adaptable, and efficient green infrastructure strategies that can be implemented citywide.

Since the release of the Plan, DEP has continued to construct several different green infrastructure systems and has analyzed their performance over the course of a growing season. Already, these systems have provided information that has influenced siting procedures and the designs of future green infrastructure systems. The ability to evaluate performance, modify designs, and improve upon existing green infrastructure is one of the greatest strengths of our adaptive management approach to managing stormwater.

The following four case studies demonstrate the innovative work DEP is performing in partnership with other City agencies, academic institutions, and consultants to discover new ways to manage stormwater using green infrastructure. The information presented in the following four case studies is preliminary and should not be used to make assumptions about the construction or performance of green infrastructure systems in New York City. DEP will write more extensive studies for each of the following green infrastructure systems and will post the studies on the agency's website.

First Generation Bioswales in the Right of Way: Enhanced Tree Pits and Streetside Infiltration Swales

Background

Streets and sidewalks make up 26.6% of land in combined sewer drainages areas, are generally impervious, and represent a significant opportunity for green infrastructure. Most New York City streets are bowed with the high point in the center so that stormwater drains away to the curb. In sewered parts of the city, stormwater runs off impervious surfaces, along the gutter and into catch basins connected to the sewer system. Over the past two years, DEP has designed, built, and tested the first generation of bioswales that were designed to fit into tight spaces within the right of way and to capture stormwater from the curb before it enters the sewer, reducing the volume of stormwater directed to WWTPs during wet weather. DEP constructed these bioswales in a variety of locations using different design types to evaluate their performance, maintenance requirements, public reception, and costs. DEP will monitor each of these pilots for three years and will use these studies to inform future designs.

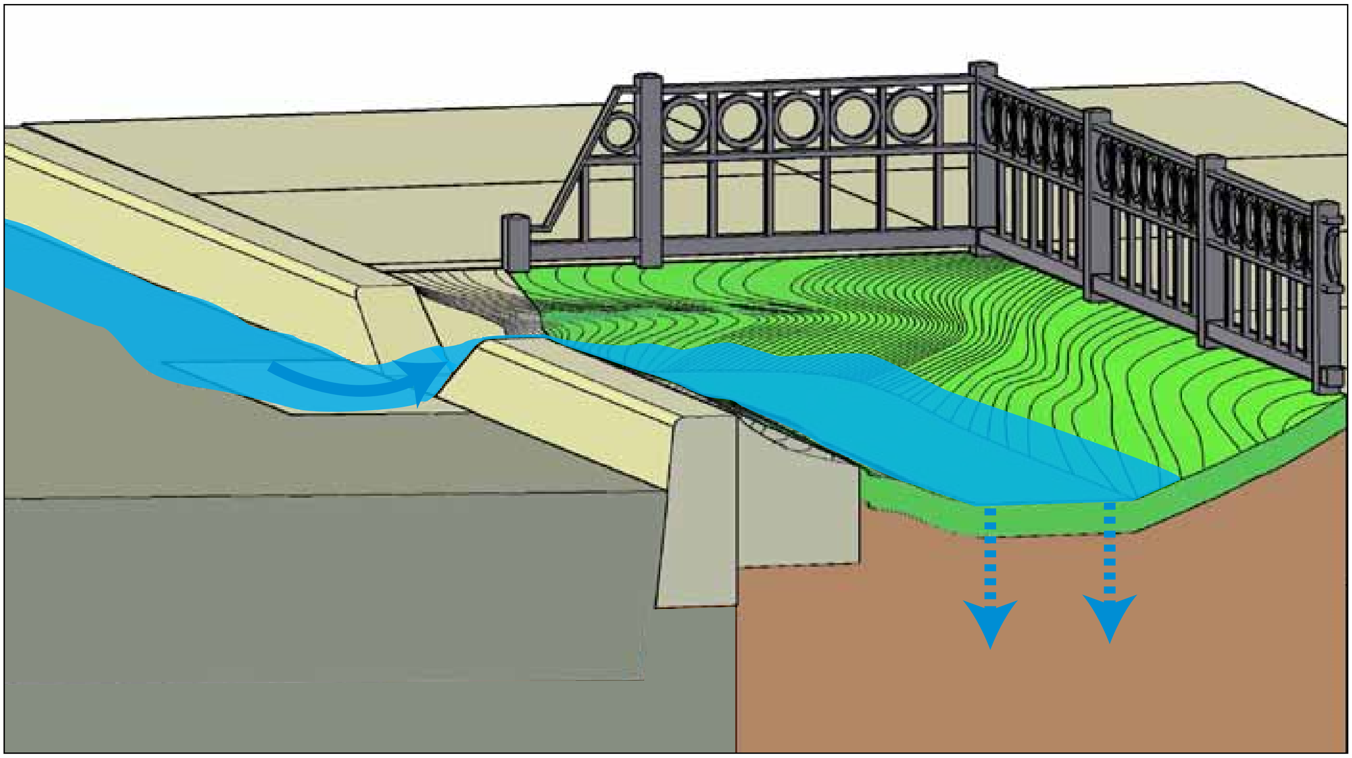
Design

DEP piloted two different designs of first generation bioswales, Enhanced Tree Pits (ETPs) and Streetside Infiltration Swales (SSISs). Both designs, which look similar to standard tree pits, are built on sidewalks upstream from catch basins to divert the stormwater out of the gutter through an inlet. Water pools in the system and infiltrates through the top layer of soil and vegetation. In instances where the system cannot contain all of the stormwater, excess water flows through an outlet and into the gutter.

The ETPs and SSISs differ significantly from each other in both size—SSISs are larger than ETPS, and subsurface design—SSISs have one layer of soil while ETPs have a top layer of soil and either gravel, glass, or storage chambers beneath. The soil used in both systems has a high sand content, ranging from 70%-85%. DEP is evaluating these sand and soil variations to determine the soil that serves the vegetation's needs while maintaining the highest rates of infiltration.

ETPS are 20 feet long, five feet wide, and 4.5 feet deep. ETPs have two subsurface layers: the top layer is made up of two feet of engineered soil, while the bottom layer contains 2.5 feet of gravel, recycled glass or storage chambers.

SSISs are 40 feet long, five feet wide, and 4.5 feet deep, and have only one subsurface layer made of engineered soil.



When it rains, stormwater runs down the street, into the curb cut, and infiltrates into the soil.

To determine the design storage volume of the different types of technology, DEP assumed that the soil has 20% void space, the glass and gravel have 35% void space, and the storage chambers have 100% void space. DEP calculated that ETPs with a subsurface layer of glass or gravel can store up to 954 gallons of stormwater, while those with storage chambers can store up to 1,626 gallons of stormwater. SSISs can store between 935 and 1,346 gallons of stormwater.

DEP worked with DPR and selected indigenous plant species known to tolerate varying soil moisture conditions throughout the growing season, such as *Liquidambar styraciflua* (Sweetgum), *Acer rubrum* (Red Maple), *Nyssa sylvatica* (Black Gum), and *Quercus bicolor* (Swamp White Oak). These plants have performed well during wet periods (Summer 2011) and dry periods (Summer 2010).

Original designs of both the first generation bioswales used a cast iron curb plate at the inlet. The cast iron plate is sturdy, preserves the line of the curb, and can bear the weight of cars and trucks without damage to the curb or the bioswale. However, it is expensive and has created some challenges that will be addressed in "Lessons Learned and Future Research."

Monitoring

DEP installed a variety of monitoring devices including pressure transducers to monitor flow into the system, flow turbines to measure flow rates inside the inflow/outflow pipes, and piezometers to monitor water level. In order to measure local precipitation, DEP mounted a rain gauge at each site. DEP also installed two sets of soil moisture sensors at each SSIS and one set at each ETP. The additional soil moisture sensors and loggers monitor and measure stormwater capture volume, evaluate water movement within the soil profile, and help DEP understand the overall water balance throughout the systems. Data loggers continuously record information from the various monitoring devices and store data for up to 30 days.

At the beginning and end of each growing season, DEP performs hydrant tests at the first generation bioswales to compare design and actual storage, calibrate the monitoring devices, and ensure that the systems function in the proper manner. To conduct a hydrant test, the project team opens a hydrant above the bioswale and runs the hydrant for a specific period of time at a predetermined flow. DEP then evaluates the performance of monitoring equipment and the bioswale based on the amount of water directed into the site.

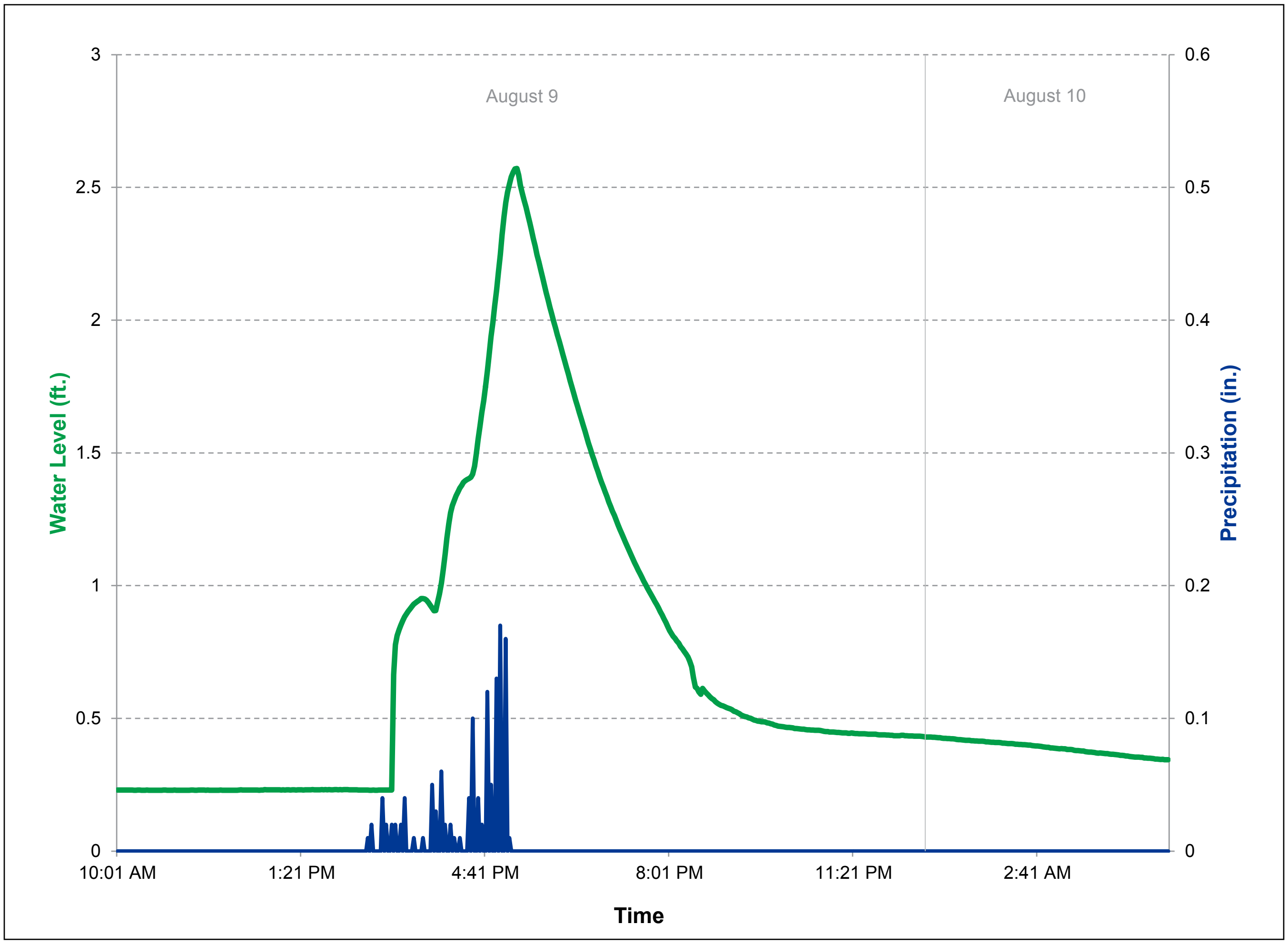


Chart 1 - Performance of the Union Street enhanced tree pit before, during, and after a rain event on August 9, 2011.

Performance

DEP observed the first generation bioswales for one growing season to allow the vegetation to establish before installing the monitoring equipment. The performance of each system is specific to its design, the size of the contributing drainage area, and conditions of the surrounding site such as height of the water table and surrounding soils and geology. The size of the drainage area is determined by the area of impervious surfaces that channel rain into the system because of elevation gradients and direct precipitation onto the site. In general, sites that have larger drainage areas have lower capture rates than sites with smaller drainage areas. The project team purposefully varied the location and size of the drainage areas, to understand the effect on drainage area on capture rates. For example, the drainage area of the Union ETP is only one eighth the size of the drainage area of the Eastern Parkway ETP. This process provides DEP with data on the performance of particular designs relative to the drainage area. In the future, DEP will use this information to maximize the efficiency of siting and designing new green infrastructure systems across the city.

Chart 1 illustrates piezometer readings at the Union ETP from 10:00am on August 9th, 2011 until 4:00am on August 10th and illustrates how these systems can perform in ideal conditions. Precipitation (blue line) is measured in inches on the right vertical axis and piezometer readings of water level in the system (green line) are measured in feet on the left vertical axis. As the blue bars show, the day was relatively dry until the storm from 2:30pm until 5:08pm created a total of 1.25 inches of rain– a short but relatively intense storm. Water level in the ETP was stable at 0.23 feet from 10:00am on August 9th until approximately thirty minutes after the rain started. At that point the water level in the ETP rose quickly to a maximum of 2.57 feet at 5:17pm, just 15 minutes after the peak rainfall. Once the rain stopped the water continued to infiltrate into the surrounding soils and by midnight the water level was down to 0.44 feet; not far from the dry weather baseline.

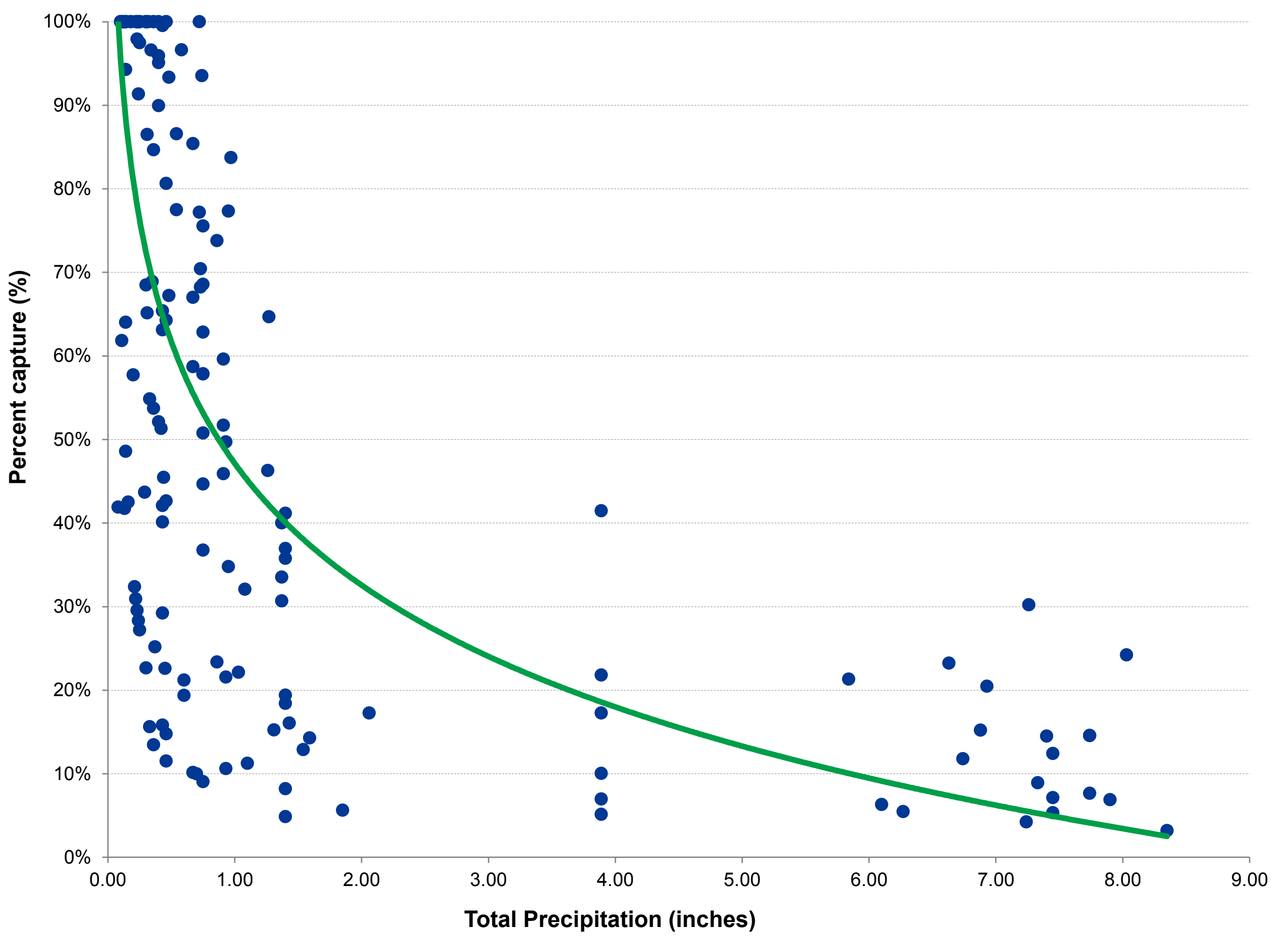


Chart 2 - The preliminary performance of 10 enhanced tree pits and streetside infiltration swales over the course of 185 rain events.

The dry weather baseline does not reach zero because a small amount of water can be trapped in the monitoring device even after all of the stormwater has infiltrated into the soil.

Data from this event is preliminary and unique to the design of the ETP and is dependent upon event-specific conditions such as storm duration and intensity, prior saturation, and inlet clogging. It is also important to remember that green infrastructure should be evaluated as a system and not in isolation. As the city builds more green infrastructure across the five boroughs, DEP anticipates that the total percent capture of the system will increase and as a result less stormwater will enter the sewers.

Percent Capture of 10 ETPs and SSISs		
Rainfall (in.)	**Mean**	**Median**
Below 1.00	73%	85%
1.00-2.00	25%	21%
Above 2.00	14%	12%
Total	59%	60%

Table 1 - Preliminary percent capture of ten ETPs and SSISs.

Though not all systems will perform as exceptionally as the Union St. site did from August 9 to August 10, DEP has seen encouraging results across all of the first generation bioswales. Chart 2 shows percent capture of five ETPs and five SSISs for 185 rain events from Spring 2011 through Summer 2011. Preliminary results are positive showing mean stormwater capture of 59% and median stormwater capture of 60%. For precipitation less than one inch, the systems captured an average of 73% of the rainfall and a median of 85% of the rainfall. The data also suggests that the systems perform better than anticipated for storms with total precipitation less than two inches, capturing an average of 67% of the rain and a median of 69% of the rain. As with Chart 1, this data is preliminary and should not be used to make final conclusions about the performance of pilot and future green infrastructure systems.

Lessons Learned and Future Research

Design: Throughout the monitoring period, DEP focused on increasing the volume of stormwater entering the first generation bioswales by modifying the inlet structure. For example, a significant source of under-performance throughout the monitoring period was attributed to inlet clogging from litter. To solve this, DEP retrofitted the inlets so that now they are either a depressed curb or have had the back-plate on the cast iron curb pieces modified to allow a minimum of 3" clearance. These modifications have increased the overall conveyance of stormwater to the underground storage areas while not adversely affecting vegetation.

At the Eastern Parkway ETP, DEP incorporated some new ideas and avoided some pitfalls that were learned from other sites. Specifically, the modified design moves the inlet catch basin three feet upstream, deepens the swale to allow more stormwater to enter, and incorporates a one-foot diameter spill zone near the end of the system. This spill zone allows excess water to infiltrate through stones directly to the subsurface stone layer prior to exiting the system. This modification allows more stormwater to infiltrate during periods of intense rainfall.

Monitoring: In addition to the piezometers used to measure water level, DEP installed inlet and outlet boxes fitted with pressure transducers and pipes at six sites in June 2011 to measure flow in and out of each system during storm events. The hydrant test revealed that the pressure transducers greatly overestimated the true water capture volume, while the piezometer water level readings were much closer to predictions. DEP believes that the large variance from predictions is due to soil flow restrictions and back pressure within the pipes that led to false flow measurements. Based on the outcome of the calibration tests, DEP decided to use piezometers as the standard instrument for all water level monitoring in the first generation bioswales. DEP will continue to monitor and regularly calibrate the system through hydrant tests. At the beginning and end of each monitoring season, we intend to perform hydrant flow tests at each site to ensure that the equipment is working properly and calibrated to validate and raise confidence in our monitoring.

Litter often clogged the original inlet design, causing stormwater to bypass the ETP or SSIS completely.

After evaluation of the first generation of inlets, DEP replaced some of the inlets with depressed curbs to increase stormwater conveyance into the ETP or SSIS.

At the Eastern Parkway ETP, DEP moved the inlet catch basin three feet upstream.

In May 2011, DEP constructed a pilot mini-wetland and bioswale system in the parking lot of an MTA bus depot in Brooklyn.

MINI-WETLAND & BIOSWALE STUDY IN THE SPRING CREEK BUS DEPOT PARKING LOT

Background

DEP estimates that stand-alone parking lots comprise 0.5% of all land in combined sewer drainage areas. In addition, most parking lots are completely impervious and present an opportunity to capture all of the rain that falls on them with only minor modifications to the lot. In May 2011, DEP constructed a pilot mini-wetland and bioswale system in the parking lot of a Metropolitan Transit Authority (MTA) bus depot on Flatlands Avenue in Brooklyn. Mini-wetlands are significantly larger than most right of way green infrastructure systems but they offer unique advantages such as the ability to store high volumes of water, absorb nutrients, and provide ecological benefits such as greater local biodiversity.

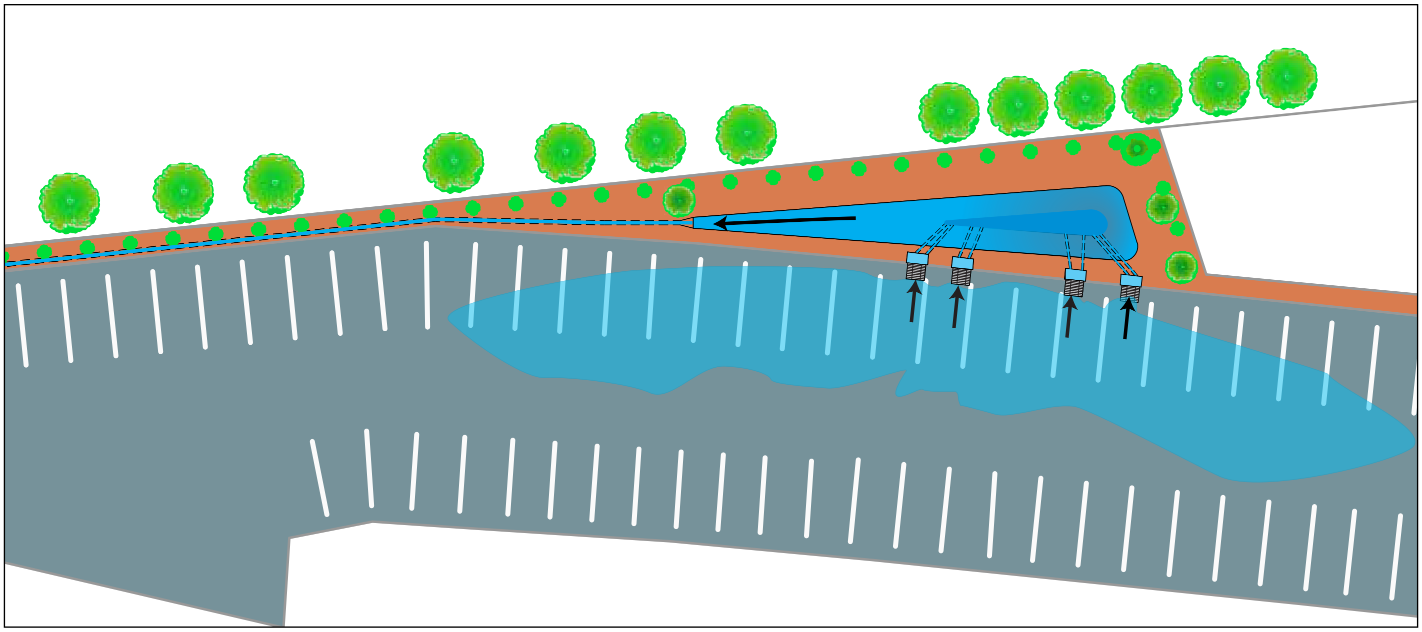
Design

When it rains, runoff from the parking lot flows through catch basins at the perimeter of the lot directly into the bottom of the wet meadow. Once the wet meadow reaches full capacity, the excess water flows through a perforated pipe and into the swale, eventually infiltrating into the soil. This green infrastructure installation is designed to collect and treat up to 21,000 gallons of rainwater.

The project is separated into two components: a 1,700 square foot wet meadow in the northern section and a 900 square foot linear swale on the southern edge. The total drainage area is 28,950 square feet and can generate up to 18,045 gallons of stormwater per one inch rainfall. To sustain the wet meadow vegetation, the northern section has an impermeable liner to maintain a water level of at least one foot. The pond can capture and store stormwater during a rain event. When the water level reaches the top of the impermeable liner, excess water infiltrates through the soil. The site also has a solar powered groundwater pump that continuously pumps water into the pond to maintain base-flow for the wetland plants.

During heavy rains, the system is designed to overflow into the linear swale at the southern end running parallel to the street. The overflow swale is a shallow basin with three distinct layers. The upper layer is a high sand content soil similar to that used in the other right of way green infrastructure systems. The bottom two layers of the overflow swale contain a mix of sand and recycled glass that provide temporary storage space for stormwater before the water is naturally absorbed by the underlying soil.

Unlike the soils used in the right of way green infrastructure pilots, the sand content used here is slightly higher and is in the range of 85% to 90%. Using similar ecological principles for soil development, the plants used in the wet meadow must



Stormwater runoff from the parking lot flows through catch basins at the perimeter of the lot directly into the bottom of the wet meadow. Once the wet meadow reaches full capacity the excess water flows through a perforated pipe and into the swale, eventually infiltrating into the soil.

be able to withstand fully saturated soil conditions for most of the growing season, while the southern portion must be adapted to occasional saturated soil conditions and drier soil conditions that may occur during periods of drought. Within the saturated zone, DEP selected indigenous wetland plant species known to tolerate varying water levels throughout the growing season. Within the drier upland areas, DEP chose species that are tolerant of occasional saturation and drought.

Monitoring

DEP installed a variety of monitoring devices to measure the flow of water into, and the capacity of, the wet meadow as well as the infiltration of stormwater into the surrounding soil and swale. The project team installed pressure transducers using v-notch flow weirs to determine accurate flow under various conditions. The pressure transducer is calibrated to the density of water, and records the height of the water above it. The team then determines the volume and flow rate by measuring the heights of the water and the corresponding width of the V-notch in the weir. Because of the persistently high water level in the pond (due to well water continuously being pumped into the pond), the V-notch has been under water since installation and has not been useful for measuring flow. For that reason, DEP used piezometers to determine how much stormwater was stored by the wet meadow and swale. The project team also used rain gauges on-site to measure local precipitation.

Hydrangea arborescens (Smooth Hydrangea)

Performance

Early data from the wet meadow and swale indicate that the system is functioning well and, unlike the smaller green infrastructure systems in the right of way, has a larger buffering capacity for larger and more intense storms. Over the course of eight different rain events in Summer 2011, the system retained a total of 70% of the rainfall. If we exclude the anomalous 7.33 inches of rainfall caused by Hurricane Irene (August 27-28, 2011), the system captured approximately 77% of all

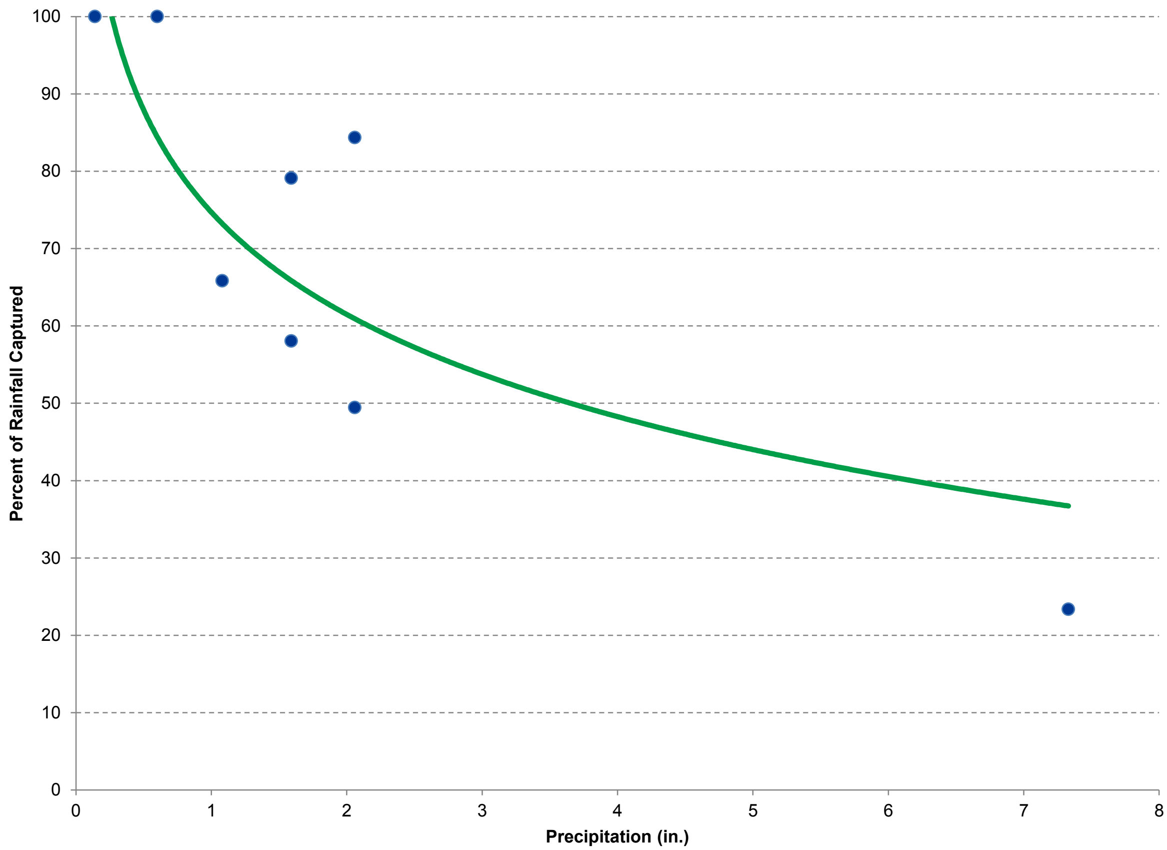


Chart 3 depicts the performance of the wet meadow and swale over the course of eight storms in Summer 2011.

rainfall from the other seven events during the summer. In general, the wet meadow and swale are most efficient during prolonged rains with a total precipitation of two inches or less because the stormwater has ample opportunity to infiltrate into the surrounding soil. Yet, it is also better equipped to handle short bursts of heavy rain than a right of way green infrastructure system because the first line of stormwater capture funnels the water directly into the wet meadow. For example, exactly 2.06 inches of rain fell on both August 3 and September 6. On August 3, the rain was relatively intense and lasted for 2.6 hours and the wet meadow and swale captured 2,699 gallons of stormwater, approximately 49% of the total stormwater from the parking lot. On September 6, the rain was less intense and lasted for 11.5 hours, and the wet meadow and swale captured 4,605 gallons, or 84% of the total stormwater from the parking lot.

Performance of the Wet Meadow and Swale				
Date	Precipitation (in)	Duration (hrs)	Stormwater Captured (gal)	Percent Rainfall Captured
August 8	2.06	2.6	2,699	49
August 18	1.08	0.4	1,884	66
August 19	1.59	0.4	2,446	58
August 21	0.60	4.9	1,590	100
August 25	0.14	9.2	371	100
August 27	7.33	22.0	4,536	23
September 6	2.06	11.5	4,605	84
September 22	1.59	5.3	3,333	79

Table 2

While both the site and the system design are unique, the data is encouraging and suggests that mini-wetland systems are a viable tool for stormwater management in sites that are adjacent to large impervious areas and meet other constraints like soil characteristics.

Lessons Learned and Future Research

Design: Despite a topographic survey of the parking lot drainage area, the very subtle grade changes within the parking lot presented a challenge in defining the actual drainage area. DEP will continue to visit the site during rain events and will perform hydrant tests to observe actual flow patterns to refine the current drainage area.

The site has a solar-powered groundwater pump that continuously pumps water into the pond to maintain base water level for the wetland plants. The extra well water pumped into the pond is designed to keep the plants and animals alive during extended period of drought, but it also decreases capacity to hold stormwater. Continuous pumping also reduces the capacity of the pond and diminishes its ability to accept more stormwater. Prior to the start of the 2012 growing season, DEP will install a float sensor on the solar pump that will automatically turn-off the pump when the water height in the pond reaches one foot high. This will maintain the wetland plant community while increasing the maximum capacity available for stormwater capture.

Monitoring: DEP has recently installed an innovative sap flow meter that will help measure average transpiration rates for the various tree species used in swale systems. The instrument records the time of the temperature change between two, non-destructive needle points inserted into the tree whichmonitor the movement of water. The device continuously records water-use through the plant under varying environmental conditions, compensating and re-calculating changes in cloud cover, wind speed, humidity, and temperature. Data from the sap flow meter will allow DEP to select vegetation that processes the most amount of stormwater through transpiration.

Solar-powered ground water pump

Sap flow meter

BLUE ROOF COMPARISON STUDY ON 1201 METROPOLITAN AVENUE

Background

In December 2010, DEP constructed a blue roof demonstration pilot at one of our general storehouse facilities in the Newtown Creek Watershed. Blue roofs can vary in form, but all are designed to capture rainwater and regulate the flow of runoff to the sewer system. Rooftops comprise more than half of the impervious surfaces in New York City. Blue roofs can be an effective way to manage stormwater on many of these rooftops because they are easy to install, lightweight, relatively inexpensive, easy to maintain, and can be tailored to meet the rooftop requirements of various City agencies.

DEP believes that blue roofs will prove to be an effective component of the city's green infrastructure portfolio. However, more research must be conducted to better understand how these systems perform. DEP and a project team of consultants and academics selected 1201 Metropolitan Avenue in Brooklyn, which has a large rooftop with a nearly flat slope across the entire facility. The large, flat roof allows DEP to compare different technologies in separate quadrants. By reducing variability caused by site specific differences and geographical variations in rainfall, this pilot will help DEP verify replicable concepts that maximize stormwater storage as well as the constructability of various blue roof technologies on existing buildings. Throughout the pilot, DEP will identify maximum feasible ponding depths and the corresponding release rates in each of the quadrants. Additionally, DEP will use this pilot to verify the actual performance compared to the designed or theoretical performance of various technologies.

DEP piloted three different blue roof technologies on the rootfop of one of our general storehouse facilities in Brooklyn. The design includes a tray and ballast system, on the left side of the above image, and an intermediate check dams system, on the right side of the image.

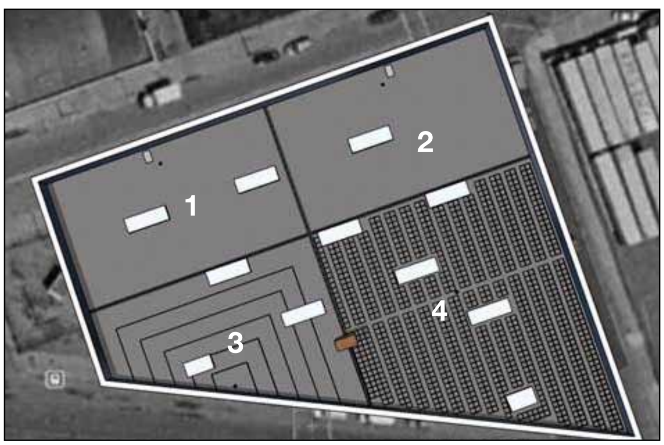
Design

The 27,500 square foot roof is divided into four drainage areas, or quadrants, to measure storage volumes and flow rates of three different types of blue roof detention technologies. In each of the three modified quadrants, DEP removed the existing drain cover and replaced it with a new cover and gravel stop. The first quadrant (5,300 SF) is the control and was left unmodified to provide comparison data.

In the second quadrant (5,140 SF), DEP removed the drain cover and replaced it with a new cover and gravel stop. DEP also installed a six-inch diameter, two-inch tall PVC standpipe with a one inch orifice, sized to restrict flow rate to a maximum of five gallons per minute.

In the third quadrant (5,950 SF), DEP installed two-inch high by 3/8-inch thick aluminum "T" beam dams, each drilled with a series of orifices to achieve a design flow rate of five gallons per minute (two-inch ponding depth at the drain), along two-inch contours of the roof. The dams are spaced out eight feet along the parallel faces of the dams, and about 11 feet along the diagonal, to maximize storage area in the depressions between each check dam and to prevent backwater flow. One-inch diameter recycled concrete ballast abuts the upstream side of the dams to prevent debris from clogging the orifice openings.

In the fourth quadrant (10,500 SF), DEP installed a tray and ballast system composed of 1,600 20-inch by 20-inch aluminum trays, each with four quarter-inch orifices drilled in the bottom to allow stormwater to drain out. Each tray is filled with a layer of geotextile fabric, corrugated plastic, and approximately about 2.5 inches of one-inch recycled washed concrete ballast. In between the trays and the existing roof, DEP installed a layer of corrugated plastic and geotextile fabric to limit the flow to approximately 0.05 gallons per minute when the tray is full.



The rooftop was divided into four quadrants to study three different blue roof technologies in comparison to a control quadrant.


DEP installed a modified drain cover in the second quadrant to control the flow of stormwater off the roof.


In the third quadrant, DEP installed check dams that restrict the flow of stormwater to the drain by forcing the water to flow through small orifices drilled into each dam.


DEP installed a tray and ballast system in the fourth quadrant that detains stormwater in 1,600 trays before it eventually drains off the roof.

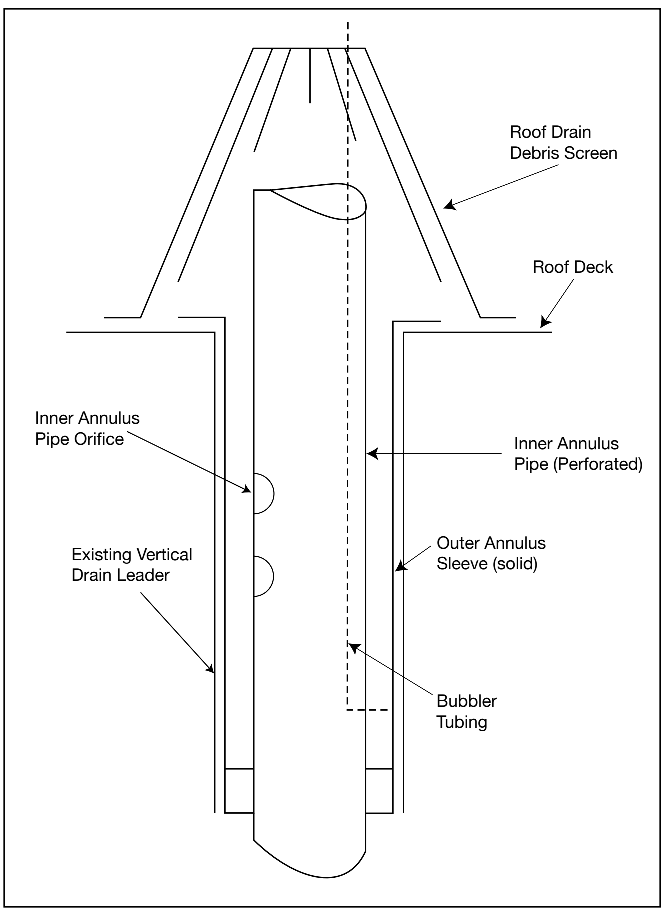
Monitoring

DEP installed monitoring equipment on April 1, 2011 and will monitor each quadrant for 24 months. The project team collects and reviews data for quality control from the monitoring devices on a monthly basis. DEP uses both camera recordings and visual observations during and after storms to provide visual confirmation of system performance during a variety of weather conditions and to alert the project team of possible malfunctions which may occur due to clogging or other circumstances.

To accurately monitor the flow rate from each section of the roof, DEP installed a monitoring device in each drain. The device includes a smaller pipe within the roof leader and a compression ring which fixes the device in place so it does not fall down the leader. Flow is directed into the area between the annulus and the inside of the leader, through orifices drilled in the annulus, and down the leader. A bubbler tube measures the depth of water in the space above the compression ring in 1-minute intervals and is used to calculate a total flow rate through the orifices.

DEP also measures runoff rates and water storage on three individual trays using weight scales. The project team records changes in the weight of the tray along with rainfall and evaporation data to determine average and peak flow rates, storage volumes, and average drawdown times. One of these three trays serves as an evaporation control and does not have drainage holes.

The area of New York City is more than 450 square miles and the three National Oceanic and Atmospheric Administration certified weather stations located in Central Park, and LaGuardia and John F. Kennedy airports often record different amounts of rainfall from the same rainstorm. For that reason, DEP installed a weather station in the center of the roof to record weather conditions at five-minute intervals, including rainfall intensity, wind speed and direction, temperature, relative humidity and barometric pressure. DEP uses this data in conjunction with the flow and storage data to analyze the performance of the blue roof.



In order to determine the efficiencies of the different blue roof technologies, DEP installed flow measurement devices in each of the roof drains.

DEP installed weight scales in three trays to determine evaporation rates, drawdown times, and average and peak flow rates.

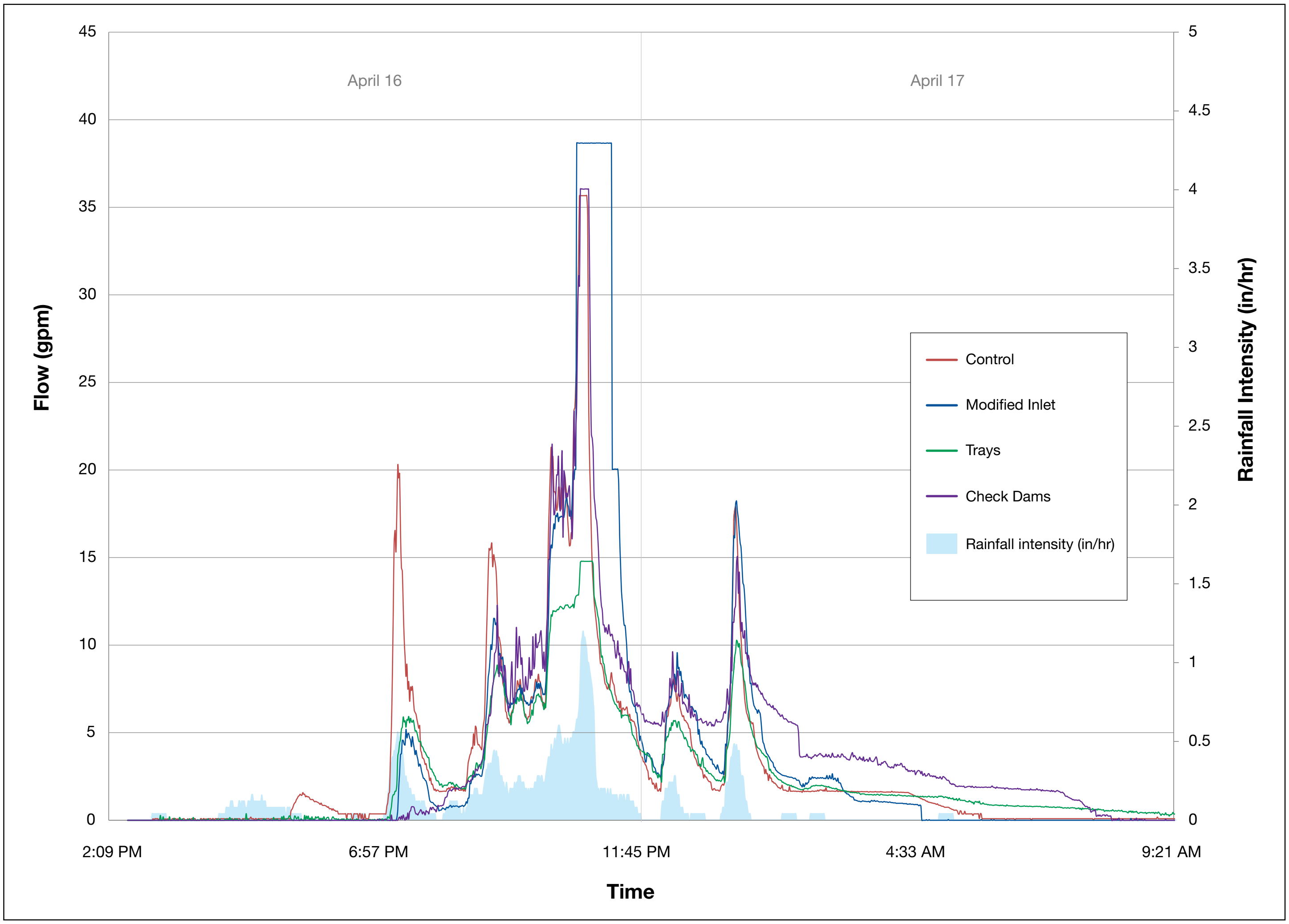


Chart 4 - Performance of the control, modified inlet, trays, and check dams quadrants during a storm on April 16, 2011.

Performance

Preliminary data show some encouraging results, especially in the tray and check dam quadrants. For example, both the check dams and tray quadrants reduce peak flow rates and create a delay in peak outflow rates relative to maximum precipitation intensity. During a storm on April 16, 2011, a total of 1.6 inches of rain fell over the course of 14.4 hours. Chart 4 illustrates the variation in performance of the different blue roof technologies during this storm. Performance is evaluated by the rate at which stormwater flows through the drain in a particular quadrant, as measured in gallons per minute.

As expected, the flow rate of stormwater runoff on the control quadrant mimicked the rainfall intensity during the storm. This is because the control quadrant, like most of the rooftops in New York City, has no design modifications that would detain the stormwater before running off the roof.

The modified inlet quadrant performed well at the onset of the storm during low intensity rainfall, but became less effective as the storm progressed and the intensity increased. For example, the modified inlet quadrant detained all of the stormwater for the first four hours of the storm, but after 7:00pm, the flow rate more closely resembled the fluctuations in rainfall intensity as runoff overtopped the modified inlet into the drain.

The check dam quadrant significantly reduced outflow at the onset of the storm, but became less effective as the duration and intensity of the storm increased. Check dams are particularly effective at the beginnings of storms and during small storms because the depressions between each of the check dams can store nearly all of the stormwater. The check dams become less effective at reducing flow when there is intense precipitation that forces the stormwater to crest over the dams and flow through the drains.

On the other hand, the tray system substantially reduced the runoff flow rates during peak rainfall intensities and created slow and steady outflow rates once the rain stopped. Unlike the modified inlet and check dams quadrants, the trays quadrant managed the flow of stormwater throughout the entire storm, first delaying the flow of stormwater off the roof and then maintaining a slow outflow even after the storm concluded. The performance of the trays quadrant can be attributed to runoff absorption within the geotextile fabric, detainment of the stormwater within the trays, and evaporation.

Perhaps the most interesting finding is that the volume of stormwater flowing out of the tray and check dam quadrants is significantly less than expected and less than measured in the other two quadrants. This volume reduction is comparable to reductions seen in vegetated rooftop technologies, such as green roofs, that use infiltration or vegetative uptake and evapotranspiration. DEP is currently analyzing the data and conducting visual observations to determine whether these volume reductions can be attributed to evaporation or to other conditions of the blue roofs—such as clogged trays, check dams, or drains from organic matter, the degradation of the blue roof materials, or damaged or malfunctioning equipment.

Lessons Learned and Future Research

Over the course of this past summer, DEP has learned valuable lessons about the design and performance of the different blue roof technologies. Moving forward, DEP will continue to monitor the existing systems and test new strategies to detain stormwater.

Construction: During the planning process, the project team took all efforts to procure and use locally sourced and recycled materials. Recycled concrete was selected as the ballast material in the tray system because it possesses the proper weight-to-volume ratio and its light color keeps the roof relatively cool. During construction, the project team washed the material on two separate occasions to prevent fine particles from degrading off the concrete and into the drain. The concrete seems to be performing well to date, but DEP will continue to monitor the material to ensure that it does not degrade over time and diminish performance of the blue roof.

Design: While this study only researched the performance of one blue roof technology at a time, in the future DEP will study the performance of a combination of blue roof technologies. For example, a controlled flow roof drain can be used in tandem with check dams and trays to enhance roof performance at a relatively low additional cost. Data from these additional configurations will be compared against data currently being collected to determine standard designs in the future.

DEP will also use pilot data to determine whether different layers or configurations of the geotextile fabric and protective plastic layers affect flow rates through the orifices, as these materials can be easy to modify based on differences in performance. DEP will assess additional observations and monitoring data from the weighing scales to determine if the tray system is more or less effective depending on the configuration of the geotextile fabric and protective plastic.

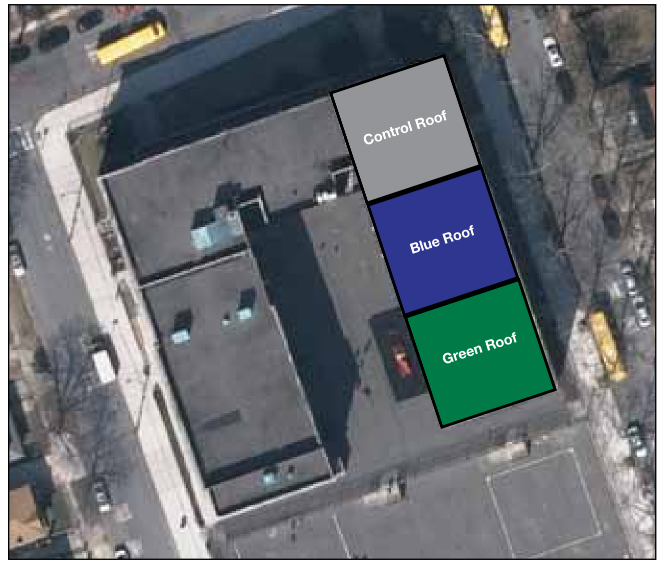
Weather Data: Future research will also analyze the performance of the blue roof technologies in regards to other variables such as temperature, relative humidity and barometric pressure, which may have an effect on evaporation rates and other performance metrics. DEP is uncertain about the roof's performance and operations and maintenance needs during the winter. Depending upon the outcome of winter site visits and monitoring data, the project team will re-design or modify equipment as necessary.

Future research at this site will measure the performance of the different blue roof technologies year round.

BLUE ROOF / GREEN ROOF STUDY ON P.S. 118

Background

Through a partnership with DOE and SCA, DEP constructed a blue and green roof comparison pilot project on P.S.118 in St. Albans, Queens in September 2010. DEP collaborated with Brooklyn College to develop a typical blue roof and a typical green roof adjacent to a control roof to compare the performance, cost, and maintenance of blue and green roofs during a three-year period. Blue roofs work primarily by slowing the flow of stormwater off the roof, delaying runoff and reducing peak flow to the sewers. Green roofs are designed to absorb rainwater in the soil until it can evaporate or be consumed by the vegetation. Both provide stormwater management benefits and can be built atop the city's roofs, which make up approximately 28% of the impervious surfaces in combined sewer areas. Rooftops present a significant opportunity for stormwater management, but there is little research showing the effectiveness of blue roofs in comparison to green roofs at the same location.



Design

The pilot at P.S. 118 has three distinct components: a blue roof, a green roof and a control area, each approximately 3,200 square feet. DEP designed the green roof to temporarily detain stormwater as it passes through the soil medium and to permanently retain stormwater through evapotranspiration. The design of the green roof is relatively simple and is meant to be easily replicable. Starting from the bottom up, the project team installed a root barrier atop the roof membrane to protect against root penetration that could cause leaking. Above the root barrier is a drainage mat which allows water that percolates through the soil to more easily flow to the roof drains. The green roof soil is four inches deep and is home to a mix of

Green roofs are designed to absorb rainwater until it can evaporate or be consumed by the vegetation through evapotranspiration.

DEP installed a weather station at P.S. 118.

sedum and native plants. DEP chose these plants for their hardiness and for their ability to tolerate droughts. Around the perimeter of the green roof, DEP installed aluminum edging to keep the medium from eroding and a two-foot wide egress of light weight pavers to allow access.

By building a blue roof and a green roof on the same building, DEP can determine which technology is most effective at managing stormwater.

The blue roof uses check dams similar to those constructed on the DEP pilot project at 1201 Metropolitan Avenue in Brooklyn. Check dams are designed to create ponds of stormwater on the roof that slow the flow of stormwater down the drain and into the sewer system. Atop the roof, DEP installed two-inch tall aluminum "T" beam dams, each drilled with a series of orifices, to slow the flow of stormwater towards the storm drains. DEP also installed one-inch diameter gravel on the upstream side of each dam to keep the orifices free from debris and a controlled flow roof drain to limit ponding at the drain to two inches. The control area was left unmodified to provide comparison data for the blue and green roofs.

Monitoring

DEP installed water level loggers at each of the drains on the roof that monitor the volume of water that flows through the drain. Data from these devices shows the comparative performance of each of the different types of technology used on the roof. Brooklyn College developed special drain insert tubes designed to monitor low flow rates that are typically a challenge to measure. At the shallow drain pipes on the control roof the monitoring team uses a custom V-notch weir to monitor flow.

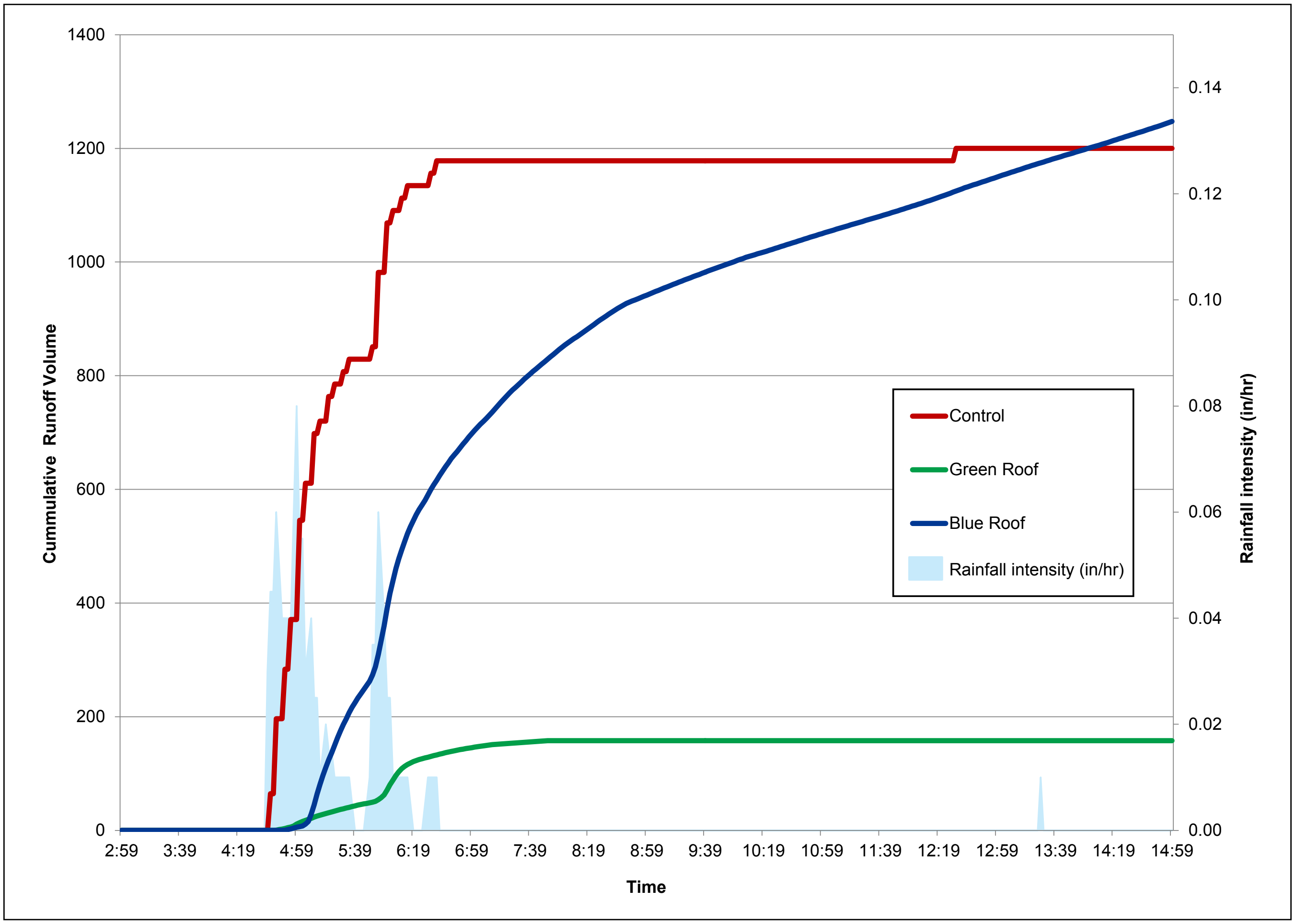


Chart 5 - Performance of the control, green and blue roofs during a rain storm on July 29, 2011.

For the same reasons that a weather station was installed at 1201 Metropolitan Avenue, DEP also installed a full weather station capable of measuring precipitation, temperature, wind speed and direction, barometric pressure, solar irradiance and humidity on the roof, and soil moisture and temperature. For comparative purposes, the project team placed multiple moisture sensors and temperature sensors at different locations and depths of the green roof and blue roof. To prevent vibrations and distortions in measurement, DEP installed the weather station on a 4'X4' wood base on top of an anti-vibration pad.

Performance

Preliminary data from the P.S. 118 pilot indicates that both the blue and green roof systems are performing as expected. The difference between the runoff volume for the two types of roofs is the result of two differing detention techniques employed by blue and green roofs.

Preliminary data collected for 12 rain events between July and November 2011, with precipitation totals of less than two inches, suggest that the green and blue roofs are performing well. Over the course of these 12 rain events the green roof captured 70% of all the rain that fell on it; an average of 1,047 gallons each rain event. Over the same 12 rain events, the blue roof detained the stormwater on the roof for an average of 3.7 hours.

Chart 5 shows the cumulative runoff from each of the three sections of the P.S. 118 pilot during a rainstorm on July 29, 2011. As expected, the flow of stormwater runoff through the control dam increased sharply when the rain began. The blue roof delayed the flow of stormwater for approximately 40 minutes after the rain began, but did not reduce the amount of stormwater that flowed through the drain. This is expected, as the blue roof is designed to detain, not retain, stormwater. The green roof, however, delayed the runoff of stormwater through the drain for nearly as long as the blue roof, and captured more than 1,000 gallons of stormwater during the rain event. The cumulative runoff from the blue roof was greater than the cumulative runoff from the control roof because it is slightly larger.

However well the green roof retains stormwater when dry, the data shows that it retains significantly less when wet. For example, the same amount of rain fell on both August 21 and September 23. On September 23 the green roof captured 1,960 gallons of stormwater, while on August 21 the green roof captured only 623 gallons of stormwater. Prior to the rainfall on September 23, no rain had fallen for 17 days, while it had rained only six days before the rain event on August 21. The difference in volume captured can likely be explained by the relative saturation of the green roof on August 21.

Green Roof Performance		
Date	Days Since Prior Rainfall	Gallons Captured
Aug21	6	623
Sept 23	17	1960

Lessons Learned and Future Research

Design: To optimize storage volume and retention benefits on rooftops, blue and green roofs require flat roofs. However, existing roofs are typically constructed with slopes that must be mitigated during the design. As a result, the depth of the green roof was designed to vary and average four inches across the roof surface. The blue roof was designed with intermediate check dams to slow flow across the roof's two percent slope. Various ponding depths are therefore anticipated on both roof surfaces.

Installation: DEP had to reroof the rooftops below both the blue and green roofs at P.S. 118. During this upgrade, DEP added the required insulation to the roof per SCA codes and requirements. The finished roof surface level was elevated a couple of inches above the existing elevation which created an unanticipated depression around the drains on the blue roof. To resolve this, DEP added dams around the edges of the depression to control that flow around the drains. Since then, both the blue and green roofs appear to be performing as designed and DEP anticipates no additional modifications. Similar to the blue roof pilot at 1201 Metropolitan Avenue, DEP will continue to monitor key components of the different roofs.

Maintenance: DEP is currently documenting the maintenance requirements of both roofs to better understand these costs when comparing the

Green roofs have higher maintenance costs because they require weeding, replanting, and irrigation.

effectiveness of blue and green roofs. Ongoing maintenance issues on the green roof include weeding, replanting, and irrigation. Likewise, the orifices distributed along the check dams have resulted in prolonged ponding on certain sections of the blue roof and have required DEP to frequently clean the trapped sediment and organic matter.

DEP will regularly visit P.S. 118 during the winter to determine operations and maintenance needs on both roofs as well as the differences between blue and green roof performance during freezing temperatures and different storm events. Depending on winter site visits and monitoring data, design or equipment modifications may be necessary.

Weather data: DEP would like to assess the performance data in comparison to other weather data in addition to precipitation volume and rate, such as wind speed and direction on outflow rates and temperature, relative humidity, and barometric pressure on evaporation on blue roofs and the function of soil media and vegetation on green roofs. The team will also assess climatic data to determine if there are any differences between blue and green roofs related to cooling and urban heat island.

Cost-benefit analysis: While preliminary data suggests greater benefits may be associated with green roofs given the retention function of soil media and vegetation, DEP must compare these benefits to the costs of design, construction, and maintenance. In particular, blue roofs may demonstrate consistent and effective release rates during multiple storms and at lesser costs compared to green roofs. Additional data will provide flow rates for different rainfall events to compare the cost-effectiveness of both blue and green roofs.

Environmental Protection

Michael R. Bloomberg, Mayor
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