NYC GREEN INFRASTRUCTURE PLAN

A SUSTAINABLE STRATEGY FOR CLEAN WATERWAYS

planYC

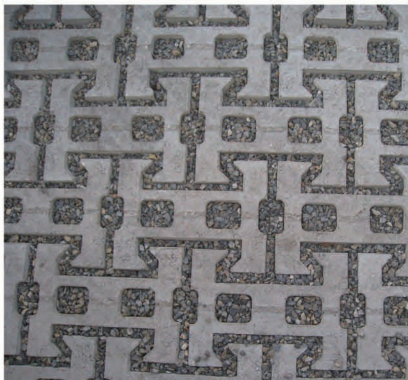
NYC Environmental Protection

Michael R. Bloomberg, Mayor
Cas Holloway, Commissioner







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Green infrastructure photographs (clockwise, starting from the top-left): rain barrel, enhanced tree pit, Staten Island Bluebelt, porous concrete sidewalk, porous pavers, restored wetland, green roof, blue roof

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THE CITY OF NEW YORK
OFFICE OF THE MAYOR
NEW YORK, NY 10007

Dear Friends:

Cleaning up New York City's rivers, creeks, and coastal waters has been a top priority for our Administration, and the pace of progress has increased dramatically over the past several years. Since 2002, the City has invested more than $6 billion in water quality, and key indicators show that New York Harbor is the cleanest and healthiest it's been in more than a century. But to open as much of our waterfront as possible to recreation and development, we need a long-term plan to manage the stormwater that can overwhelm our combined sewer system when it rains, impairing water quality in the harbor and its tributaries.

To succeed, any plan must be effective and affordable, and the 8.4 million New Yorkers who will pay for it must see and feel its benefits. The NYC Green Infrastructure Plan will achieve that goal. Based on years of study and our experience with new technologies, we know that green infrastructure—advanced street-tree pits, porous pavements and streets, green and blue roofs, and many other stormwater controls—can improve water and air quality, help to cool the City, reduce energy bills and greenhouse gas emissions, increase property values, and beautify our communities. And we can achieve all of these benefits for billions of dollars less than the cost of the traditional tanks and tunnels that are useful only when it rains.

The NYC Green Infrastructure Plan continues the implementation of PlaNYC, not only by improving water quality, but by helping the City achieve cleaner air and greener streets, and we look forward to working with the New York State Department of Environmental Conservation and the U.S. Environmental Protection Agency to make our plan a reality. The unprecedented scale of this plan and our commitment to implement it will put the City at the forefront of stormwater management, and ensure our progress toward a greener, greater New York.

Sincerely,

Michael R. Bloomberg
Mayor

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ACRONYMS

AMR	Automated Meter Reading
ARRA	American Recovery and Reinvestment Act
BID	Business Improvement District
BMP	Best Management Practice
CAC	Citizens Advisory Committee
CAPA	City Administrative Procedure Act
CSO	combined sewer overflow
DCP	New York City Department of City Planning
DEC	New York State Department of Environmental Conservation
DEP	New York City Department of Environmental Protection
DDC	New York City Department of Design & Construction
DOB	New York City Department of Buildings
DOE	New York City Department of Education
DOT	New York City Department of Transportation
DPR	New York City Department of Parks & Recreation
EPA	United States Environmental Protection Agency
FOG	fat, oil, and grease
HPD	New York City Department of Housing Preservation & Department
LTCP	Long Term Control Plan
MTA	New York City Metropolitan Transit Authority
NYCHA	New York City Housing Authority
OMB	New York City Office of Management and Budget
SCADA	Supervisor Control and Data Acquisition
RCNY	Rules of the City of New York
ROW	Right-of-Way
WWFP	Waterbody Watershed Facility Plan
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

New York City's efforts to improve water quality are a critical part of PlaNYC, Mayor Bloomberg's blueprint for a greener, greater city. Already the Harbor is cleaner than it has been in over 100 years, and millions of people enjoy the City's waterfront and waterways every year, thanks in part to the New York City Department of Environmental Protection's (DEP's) investment of billions of dollars in sewer and wastewater treatment plant upgrades. But in those waterbodies that do not yet meet water quality standards for pathogens, the biggest remaining challenge is to further reduce combined sewer overflows (CSOs) that discharge a mixture of untreated sewage and stormwater runoff when it rains. Traditional approaches to reduce CSOs further would include the construction of additional, large infrastructure, but the remaining opportunities for such construction are very expensive, and do not provide the sustainability benefits that New Yorkers rightly expect from multi-billion dollar investments of public funds.

This Green Infrastructure Plan presents an alternative approach to improving water quality that integrates "green infrastructure," such as swales and green roofs, with investments to optimize the existing system and to build targeted, smaller-scale "grey" or traditional infrastructure. This is a multi-pronged, modular, and adaptive approach to a complicated problem that will provide widespread, immediate benefits at a lower cost. The green infrastructure component of this strategy builds upon and reinforces the strong public and government support that will be necessary to make additional water quality investments. A critical goal of the green infrastructure component is to manage runoff from 10% of the impervious surfaces in combined sewer watersheds through detention and infiltration source controls.

New York City's "Green Strategy" is nimble enough to incorporate new technologies and approaches as they emerge during the implementation of our plan. DEP will preserve its ability to pursue larger grey infrastructure if necessary and appropriate in the event that the Green Strategy cannot achieve water quality objectives in a particular drainage area. Promoting green infrastructure has been endorsed by the U.S. Environmental Protection Agency (EPA) and the New York State Department of Environmental Conservation (DEC). Under Administrator Lisa Jackson, EPA has testified that green infrastructure is an "effective response to a variety of environmental challenges that is cost-effective, sustainable, and provides multiple desirable environmental outcomes." (Testimony before the U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Water Resources and Environment, March 19, 2009)

In fact, this approach is not so new — the City and its partners have a long track record of successfully meeting water quality standards with natural solutions that have substantial, quantifiable co-benefits. For example, in our Catskill and Delaware watersheds, the City, EPA, New York State, and community and environmental groups came together and agreed that preserving forested areas and natural buffers was a better way to keep our drinking water clean than relying upon end-of-the-pipe, energy-intensive filtration systems. Since the City first applied for a waiver from filtration requirements for the Catskill and Delaware system in 1991, DEP has committed more than $1.5 billion and dedicated staff to sustain the pristine quality of source waters, and so far has eliminated the need for a filtration plant that would cost $10 billion or more. These commitments are included in the Filtration Avoidance Determinations issued by EPA and implemented by DEP and its watershed partners, including New York State, watershed towns, and civic organizations. Similarly, since the early 1990s DEP has relied upon wetlands and natural areas in our Bluebelt system in Staten Island to absorb stormwater runoff from streets, thereby eliminating the need for costly sewer systems.

In 2007, PlaNYC committed the City to build more Bluebelts and Greenstreets, to require green parking lots, to incentivize green roofs, and to form an Inter-agency Best Management Practices Task Force. The *Sustainable Stormwater Management Plan* issued by that Task Force in 2008 concluded that green infrastructure was feasible in many areas in the city and could be more cost-effective than certain large infrastructure projects such as CSO storage tunnels. This Green Infrastructure Plan builds on the *Sustainable Stormwater Management Plan* and proposes to continue coordination among City agencies to build green infrastructure projects. This effort will be led by the Mayor's Office and DEP, and will include collaboration with many City agencies, including the Department of Transportation (DOT), the Department of Parks and Recreation (DPR), the Department of Design and Construction (DDC), the Department of City Planning (DCP), the Department of Education (DOE), the Department of Sanitation (DSNY), the Department of Citywide Administrative Services (DCAS), the Department of Housing and Preservation and Development (HPD), the New York City Economic Development Corporation (EDC), and the New York City Housing Authority (NYCHA).

This Green Infrastructure Plan builds upon and extends the commitments made in PlaNYC and the *Sustainable Stormwater Management Plan*. This plan provides a detailed framework and implementation plan to meet the twin goals of better water quality in New York Harbor and a livable and sustainable New York City. The analysis in this Green Infrastructure Plan is based upon the predicted impacts of the strategy on CSO volumes in individual watersheds and upon the City's estimates of capital and operating costs. Further analysis, which is substantially under way, will refine the modeling and projections in this report by using more updated geospatial impervious data, incorporating detention technologies, and assessing the impact of CSO reductions on water quality. It will also present data about the operating costs, maintenance, and performance of the green infrastructure projects currently underway. This Green Infrastructure Plan forms a framework for CSO reduction strategies and investments over the next 20 years and will lead to both clean waterways and a greener, more sustainable city.

The importance of the choice we face as a city and the urgent need for collaborative partnerships with our state and federal regulators cannot be overemphasized. The City is facing tremendous economic challenges and tightly constrained resources while the cost of grey investments such as 50-million gallon underground storage tanks is significantly increasing and the marginal contribution of such investments to the achievement of overall water quality objectives is diminishing. At the same time, PlaNYC and the many studies that guided it made clear that New Yorkers need and want sustainability benefits such as more open space, improved air quality, more shade, and increased property values. In this new reality, the City must strive to get the most water quality and sustainability benefits out of every dollar it invests.

The Green Infrastructure Plan

The Green Infrastructure Plan will achieve better water quality and sustainability benefits than the all-Grey Strategy that is mandated or is currently under consideration by:

- Reducing CSO volume by an additional 3.8 billion gallons per year (bgy), or approximately 2 bgy more than the all-Grey Strategy;
- Capturing rainfall from 10% of impervious surfaces in CSO areas through green infrastructure and other source controls; and
- Providing substantial, quantifiable sustainability benefits – cooling the city, reducing energy use, increasing property values, and cleaning the air – that the current all Grey Strategy does not provide.

Ultimately the success of this program will be measured by water quality objectives, not by CSO reductions alone.

The Green Infrastructure Plan has five key components:

1. Build cost-effective grey infrastructure

DEP has already built or is planning to build over $2.9 billion in targeted grey infrastructure to reduce CSO volumes (the Cost-Effective Grey Infrastructure Investments). These projects were set out in Waterbody Watershed Facility Plans (Facility Plans) submitted to the New York State Department of Environmental Conservation (DEC) pursuant to a consent order.[1] For the most part, these projects are the most cost-effective among a number of alternatives considered. The cost-effective projects will reduce CSOs by approximately 8.3 bgy compared to the projected baseline for the year 2045 that was used in the 2007 Facility Plans. The grey investments planned or underway reduce CSOs at a cost of $0.36 per gallon. These investments are five times more cost-effective than certain other alternatives that DEP seeks to avoid or defer.[2] The Cost-Effective Grey Infrastructure Investments are presented in greater detail in the chapter on *The Green Infrastructure Plan*, especially Tables 6 and 8.

2. Optimize the existing wastewater system

DEP will optimize the existing wastewater system through both targeted and system-wide capacity enhancements to ensure that it can store as much combined flow as is possible. DEP has already started a comprehensive assessment of the existing system and its hydraulic capacity to assess further cost-effective improvements. In the meantime, we are already improving existing programs by inspecting tide gates, surveying and rehabilitating interceptor sewers, preventing obstructions and cleaning lateral collection sewers, and identifying inflow and infiltration. These initiatives include the purchase of two new Vactor trucks and a commitment to rehabilitate 136 miles of interceptor sewers within two years. By these additional measures, DEP can reduce CSOs by approximately 586 million gallons per year (mgy), and will achieve greater re-

[1] Under a 2005 Administrative Consent Order, DEC file no. CO2-20000107-8, as modified by a 2008 Order on Consent, DEC file no. CO2-2007-0101-1 (the CSO Order or the Consent Order).

[2] These are the CSO detention tunnels in the Newtown Creek and Flushing Bay drainage areas, the CSO detention tanks in the Hutchinson River and Westchester Creek drainage areas, and the wet weather expansions at the 26th Ward and Jamaica WWTPs (Potential Tanks, Tunnels, and Expansions).

ductions from the additional system improvements that will occur as additional areas are surveyed. The Green Infrastructure Plan is DEP's first attempt to integrate those particular elements into a comprehensive CSO reduction program.

A critical element of wet weather overflows is the base flow of sanitary waste from household and other uses, which can take up sewer system storage and wastewater treatment plant (WWTP) capacity that could otherwise be used to convey and treat stormwater. Lower sanitary flows maximize plant capacity during wet weather. Sanitary flows vary with the overall consumption of water, which has constantly and significantly declined in recent years and will continue to decline. DEP estimates that continued declines will reduce CSO volumes by approximately 1.7 bgy, or 8% of overall city CSOs, by 2030. This is nearly equivalent to the CSO reductions estimated for large grey infrastructure investments that are currently contemplated under the CSO Order or in future Long Term Control Plans (LTCPs).

Encouraging prudent water use also benefits DEP's water supply and wastewater treatment system by reducing wear on infrastructure, chemical costs, energy costs for pumping and treating flow, and greenhouse gas emissions. These are important considerations because in just a few years DEP's energy demand will be 30% greater than today as the ultraviolet disinfection plant for the Catskill and Delaware systems, and the Croton filtration plant come on line. DEP will undertake or continue conservation initiatives to ensure reduced flow in future years, including completing installation of the Automated Meter Reading (AMR) network and, if feasible, low flow fixture rebates and other initiatives.

3. Control runoff from 10% of impervious surfaces through green infrastructure

Green infrastructure is at the core of this plan. The City's goal is to capture the first inch of rainfall on 10% of the impervious areas in combined sewer watersheds through detention or infiltration techniques over 20 years. By preventing one inch of precipitation from becoming runoff that surges into the sewers over 10% of each combined sewer watershed's impervious area, DEP estimates that CSOs will be reduced by approximately 1.5 bgy. DEP proposes to meet this goal by achieving 1.5% impervious area capture by 2015, an additional 2.5% by 2020, an additional 3% by 2025, and the remaining 3% by 2030.

The strategies to achieve the 10% goal vary depending on the type of land use (see Table 1, following page). DEP's initial analysis shows that there are significant opportunities to incorporate green infrastructure in 52% of the land in CSO areas of the City, well more than needed to meet the 10% capture goal over 20 years**.** The remaining 48% of the City's land area consists of existing development, where stormwater retrofits may also be appropriate but are more difficult and expensive to build. For a highly urbanized city, the goal of 10% capture over 20 years is ambitious but achievable.

To reach this goal the City will create a Green Infrastructure Task Force to design and build stormwater controls into planned roadway reconstructions and other public infrastructure projects. The City is prepared to create a Green Infrastructure Fund and to immediately commit substantial capital and operating resources to this effort.

The Green Infrastructure Task Force will target investments on a watershed-by-watershed basis. Already, DEP has completed an unprecedented, detailed analysis of roadway projects and

Table 1: Green Infrastructure Opportunities, Strategies, and Technologies (citywide)

Land Use	% of Combined Sewer Watershed	Potential Strategies and Technologies
New development and redevelopment	5.0%	Stormwater performance standard for new and expanded development
		Rooftop detention; green roofs; subsurface detention and infiltration
Streets and sidewalks	26.6%	Integrate stormwater management into capital program in partnership with DOT, DDC, and DPR
		Enlist Business Improvement Districts and other community partners
		Create performance standard for sidewalk reconstruction
		Swales; street trees; Greenstreets; permeable pavement
Multi-family residential complexes	3.4%	Integrate stormwater management into capital program in partnership with NYCHA and HPD
		Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels or cisterns; rain gardens; swales; street trees; Greenstreets; permeable pavement
Parking lots	0.5%	Sewer charge for stormwater
		DCP zoning amendments
		Continue demonstration projects in partnership with MTA and DOT
		Swales; permeable pavement; engineered wetlands
Parks	11.6%	Partner with DPR to integrate green infrastructure into capital program
		Continue demonstration projects in partnership with DPR
		Swales; permeable pavement; engineered wetlands
Schools	1.9%	Integrate stormwater management into capital program in partnership with DOE
		Rooftop detention; green roofs; subsurface detention and infiltration
Vacant lots	1.9%	Grant programs
		Potential sewer charge for stormwater
		Rain gardens; green gardens
Other public properties	1.1%	Integrate stormwater management into capital programs
		Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels; permeable pavement
Other existing development	48.0%	Green roof tax credit
		Sewer charges for stormwater
		Continue demonstration projects and data collection
		Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels or cisterns; rain gardens; swales; street trees; Greenstreets; permeable pavement

development trends to create a preliminary assessment of the specific opportunities, volume reductions, and costs for each of the 13 combined sewer watersheds that are the subject of the CSO Order. For example, in the Bronx River watershed, the goal of 10% capture over 20 years could be met through a combination of:

- Three percent (3%) impervious area capture by street trees, swales, and sidewalks that are rebuilt or retrofitted with additional controls;
- Three percent (3%) impervious area capture by performance standards on new and expanded developments that would include bioinfiltration, blue and green roofs, subsurface detention/infiltration, or other source controls;
- Three percent (3%) impervious area capture by existing schools, residences, and other development; and
- One percent (1%) impervious area capture by additional planted areas in open spaces and waterfront areas.

To accelerate the implementation of green infrastructure, DEP is building more than 20 demonstration projects in collaboration with other city agencies and local authorities, including DPR, DOT, DOE, NYCHA, and MTA. These demonstration projects are testing techniques that are appropriate for a variety of land uses:

- Blue roofs and green roofs for rooftop stormwater detention and retention;
- Porous pavement for parking lots;
- Tree pits, streetside swales, and porous pavement for roadways;
- Greenstreets, medians, and curbside extensions for roads;
- Constructed wetlands and swales for parks;
- A variety of these techniques for high density multi-family housing; and
- Rain barrels for low density single family housing.

4. Institutionalize adaptive management, model impacts, measure CSOs, and monitor water quality

This Green Infrastructure Plan is an adaptive management strategy – an iterative, flexible decision-making process where incremental measures are continually evaluated and rejected or improved. This process produces better decisions about investments and overall resource allocation to achieve water quality objectives. Already, DEP has adjusted its approach to incorporate conservation strategies. An adaptive management approach is essential given the magnitude of investment required to manage stormwater and the wide range of uncertainties about future conditions, including climate, rainfall, population, water demand, land use, technology, and regulatory requirements. The effectiveness of adaptive management depends upon DEP's ability to measure performance. Accordingly, DEP will recalibrate its sewer system model using new and better impervious data and recently updated wastewater flow projections and will model the effects of a combination of detention and infiltration strategies on water quality. DEP will also assess the hydraulic capacities of the sewer system in key drainage areas.

DEP will monitor CSO events by three methods – water elevation monitoring at Tier 1, 2, and 3 CSO outfalls, flows measured at DEP wastewater treatment plants, and flows measured from CSO detention facilities – that will enable us to monitor up to 90% of CSO flow volume citywide. DEP is also seeking to develop the technology necessary to measure actual flows at CSO outfalls. Finally, DEP will gauge improvements in pathogen concentrations resulting from implementation of the Green Infrastructure Plan by building upon its network of 57 monitoring stations across the harbor increasing the number of sampling sites at the mouths of key tributaries.

5. Engage and enlist stakeholders

DEP will also take immediate steps to reduce exposure to potentially harmful waters by replacing the signs at all 422 CSO outfalls to reach non-English speakers, and by improving its website notifications about the risks in recreation after wet weather.

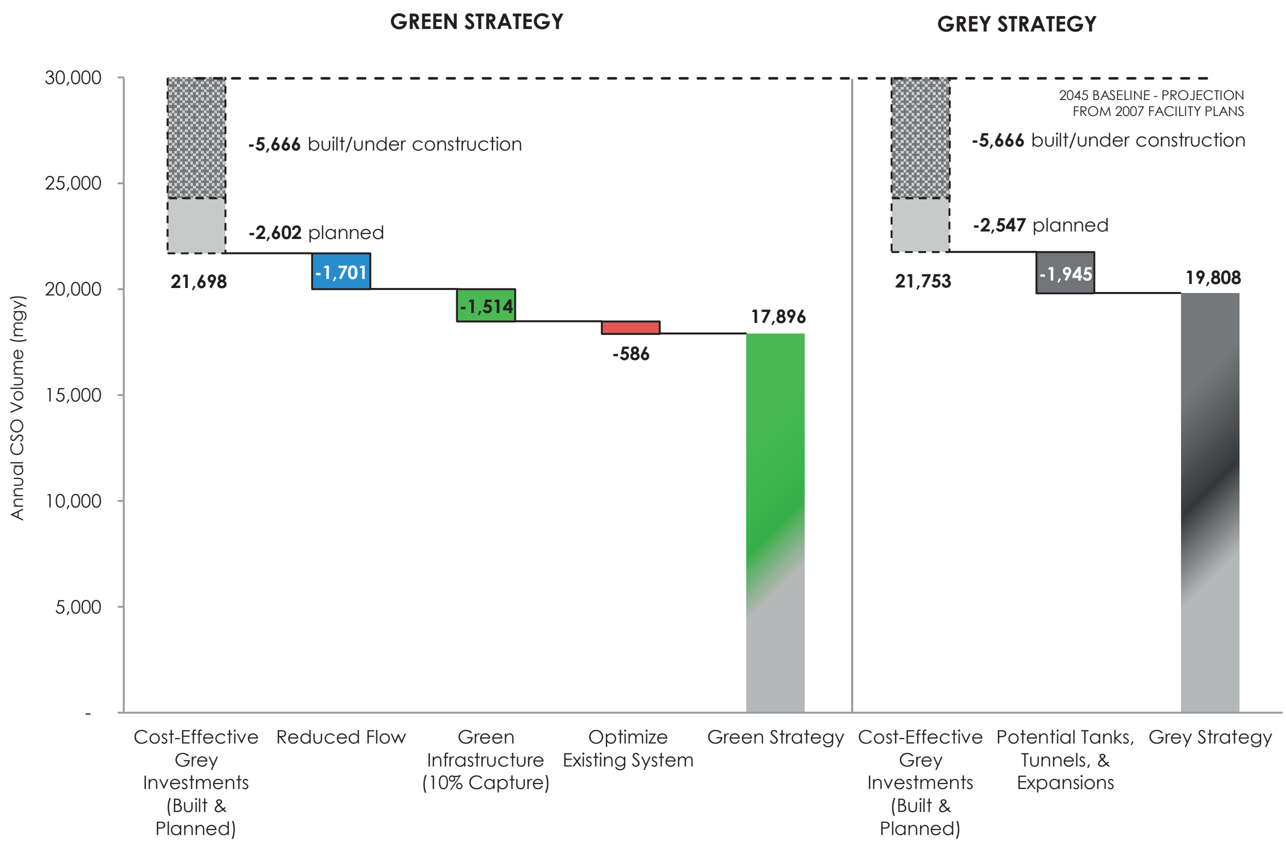
Partnerships with numerous community and civic groups and other stakeholders will be necessary to build and maintain green infrastructure. As part of the development of this plan, DEP had several meetings with environmental groups, city agencies, and other potential partners, and held a general public meeting to explain its vision for the Green Infrastructure Plan. DEP will provide resources and technical support so that communities can propose, build, and maintain green infrastructure. This is particularly important in environmental justice communities that need the additional public health and other sustainability benefits of green infrastructure.

Cities around the world are developing innovative ways to meet the needs of growing populations. To incubate the practical application of advanced techniques and designs, DEP will sponsor an international forum about green infrastructure.

Overall Performance and Costs

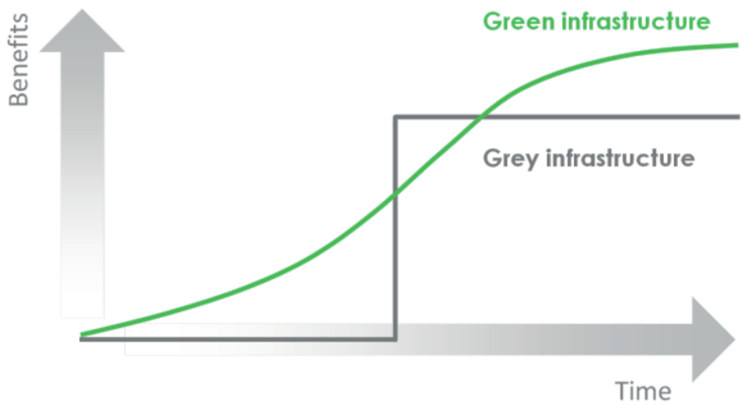
DEP modeling shows that the Green Strategy will reduce more CSO volumes at significantly less cost to New Yorkers than the all-Grey Strategy currently contemplated under the CSO Order and Facility Plans submitted to DEC. The Green Infrastructure Plan builds on DEP's Cost-Effective Grey Infrastructure with investments that will provide both water quality and other public sustainability benefits. Over 20 years, DEP projects that the Green Infrastructure Plan will reduce CSO volumes from approximately 30 billion gallons a year to approximately 17.9 bgy (Figure 1). This is nearly 2 billion gallons lower CSO volume per year than would be achieved by the Grey Strategy (Figure 1).

Figure 1: Predicted CSO Volume*



* Notes for Figure 1: (1) Volume is calculated over a 20-year implementation timeline, based on a 2045 CSO volume projection as a starting point. (2) While DEP is pursuing many efforts to optimize the existing system today, its additional efforts concerning interceptor rehabilitation, tide gate rehabilitation, and reduced flows are all included as part of the Green Strategy and not the Grey Strategy. That is because those elements were not considered or credited as part of the Facility Plans that are currently before DEC. (3) The Cost-Effective Grey Investments under the Grey Strategy do not include certain interceptor and bending weir projects for the 26th Ward wastewater treatment plant since they would not be necessary if the 26th Ward wastewater treatment plant wet weather expansion has to be built. The interceptor and bending weir projects are included in the Green Strategy that would defer expansion. This ac-

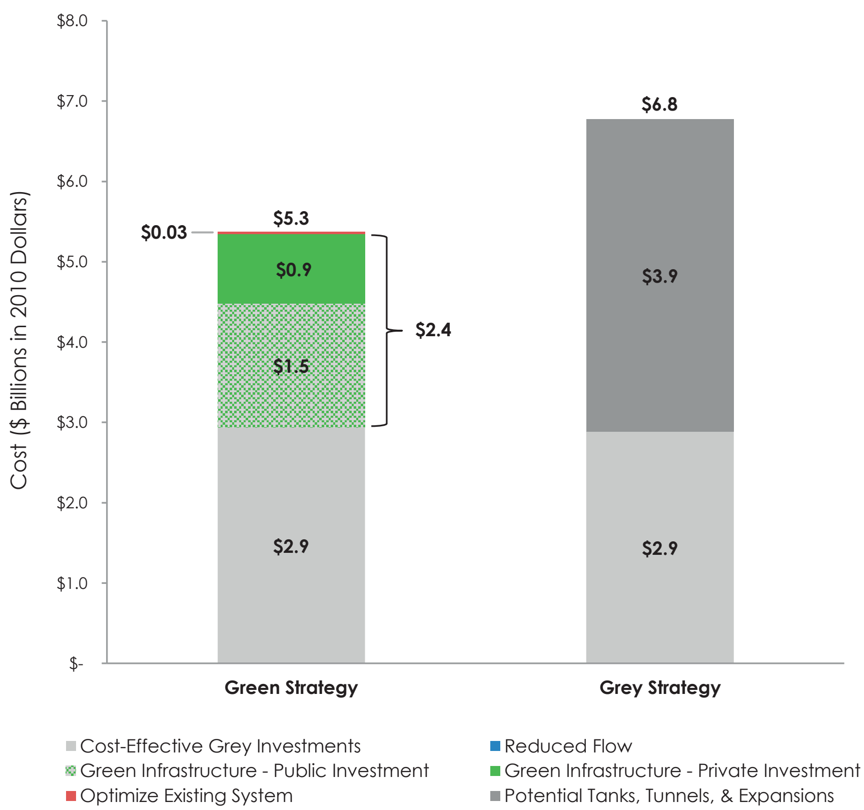
Figure 2: Phasing of Green Infrastructure and Grey Infrastructure Benefits



The significant sustainability benefits of the Green Strategy – which are not available through the Grey Strategy – would begin to accrue immediately and build over time, in contrast to tanks, tunnels, and expansions, which provide only water quality benefits at the end of a decades-long design and construction period (Figure 2).

The green infrastructure component – capturing 10% of the impervious area of combined sewer watersheds – would cost approximately $1.5 billion in public funds compared to $3.9 billion in public funds for additional grey investments (Figure 3). The overall cost of the Green

Figure 3: Citywide Costs of CSO Control Scenarios (after 20 years)



Infrastructure Plan would be approximately $5.3 billion, $1.5 billion less than the $6.8 billion required for the Grey Strategy (Figure 3).[3]

The greater overall efficiency of the Green Strategy is critical for continued ratepayer and citizen support for additional water quality measures in light of competing social needs.

Green infrastructure will allow DEP to leverage opportunities to build cost-effective stormwater controls in new development at an incremental cost. DEP predicts that about 40% of green infrastructure investments over the next 20 years would be made in connection with new development if there were a rule to limit the release rate of runoff. That standard will provide for the capture of approximately two inches of precipitation. New development performance standards will provide a base level of green infrastructure across the city, in both combined sewer and non-combined sewer watersheds.

Green infrastructure costs vary widely across watersheds, but in general are approximately $1 to $2 per gallon of CSO avoided. The average cost is less than Potential Tanks, Tunnels, and Expansions. DEP will invest in those areas where green infrastructure is the most cost-effective and will ensure that private sector green infrastructure investments throughout the city are reasonable.

Green infrastructure, moreover, would be spread throughout the city and would provide many additional sustainability benefits. After a 20-year period, DEP estimates that New Yorkers would receive between $139 million and $418 million in additional benefits through reduced energy bills, increased property values, and improved health. A citywide policy to support green infrastructure would also help to address future regulatory requirements to manage stormwater in the separately sewered areas.

None of these benefits accrue through an all-Grey Strategy. Tanks, tunnels, and expansions are single-function items and lay dormant unless there is a storm of sufficient size. These large investments have long lead times for design and construction and are subject to intervening risks from changes in climate, labor, and economic conditions as well as regulatory requirements. Tanks, tunnels, and expansions also contain a significant amount of embedded energy – i.e., the greenhouse gas emissions and materials in their construction – involve significant amounts of construction-related air and other emissions, will require energy for pumping when in use, and are labor-intensive. For example, it costs approximately $3.1 million every year to operate the newly-built Flushing Creek CSO detention facility.

Given these factors, the Green Infrastructure Plan presents more balanced benefits and fewer risks to the City. By pursuing a basket of different pollution control strategies with smaller footprints that can be adjusted, supplanted, and changed over the 20-year investment timeline of the plan, the City will gain knowledge through experience, improve effectiveness, and reduce costs.

[3] A CSO detention tunnel for the Newtown Creek drainage area, for example, is estimated to cost $1.3 billion. (See Tables 7 and 9, in *The Green Infrastructure Plan* section.)

Next steps

To implement this Green Infrastructure Plan, the City is prepared to spend up to $1.5 billion over 20 years, including approximately $187 million in capital funds over the next four years, to build green infrastructure. These commitments depend upon acceptance by DEC and EPA of the Green Infrastructure Plan as an alternative to the current all-Grey Strategy that costs billions more, reduces less CSO volume, and foregoes sustainability co-benefits. Additional grey infrastructure should be pursued only if more effective and beneficial green infrastructure investments fail. The City seeks to immediately engage with DEC to incorporate the Green Infrastructure Plan into the existing CSO Order and the 14 separate LTCPs required by 2017. DEP will also work with the EPA, community leaders, environmental groups, and other stakeholders to seek consensus on the scope and duration of our green infrastructure commitments.

Over the next year, the City will take a number of concrete steps to begin early implementation of the Green Infrastructure Plan. These actions include:

1. Preparing a Green Infrastructure Fund;
2. Creating 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;
3. Building green infrastructure demonstration projects on a variety of land uses;
4. Partnering with community groups to develop programs for the construction and maintenance of green infrastructure;
5. Launching a comprehensive program to increase optimization of the existing system, including drainage plans, hydraulic studies, the survey and rehabilitation of 136 miles of interceptor sewers in two years, the inspection and repair of tide gates, and programs to prevent grease from obstructing the sewers;
6. Developing a stormwater management standard for new construction and redevelopment that expands existing development;
7. Piloting sewer charges for stormwater for stand-alone parking lots;
8. Refining DEP models by including new impervious cover data and extending predictions to ambient water quality;
9. Identifying other funding for additional elements of the Green Infrastructure Plan; and
10. Replacing all CSO outfall signs to reduce potential exposure.

INTRODUCTION

Water quality in New York Harbor: past, present, and future

The New York Harbor is cleaner than it has been in 100 years as the City has steadily eliminated public health threats. The first sewer systems conveyed untreated sewage out of crowded neighborhoods and directly into the Harbor, based on the need at that time to prevent epidemics caused by sewage in streets and contamination in shallow groundwater wells. As the near-shore waters became too polluted to use, except for industrial and maritime commerce, and rising income and awareness led to public demands for both clean land and a clean harbor, the City built the first wastewater treatment plants (WWTPs) in the 1890s and a network of large pipes to intercept sewers at their former discharge points and to convey wastewater to the plants. By the late 1980s, with the end of most raw sewage discharges, pathogen levels dropped in many areas of the Harbor by 99 percent, and most open waters in the Harbor achieved a level of quality that makes boating and other recreational activities possible.

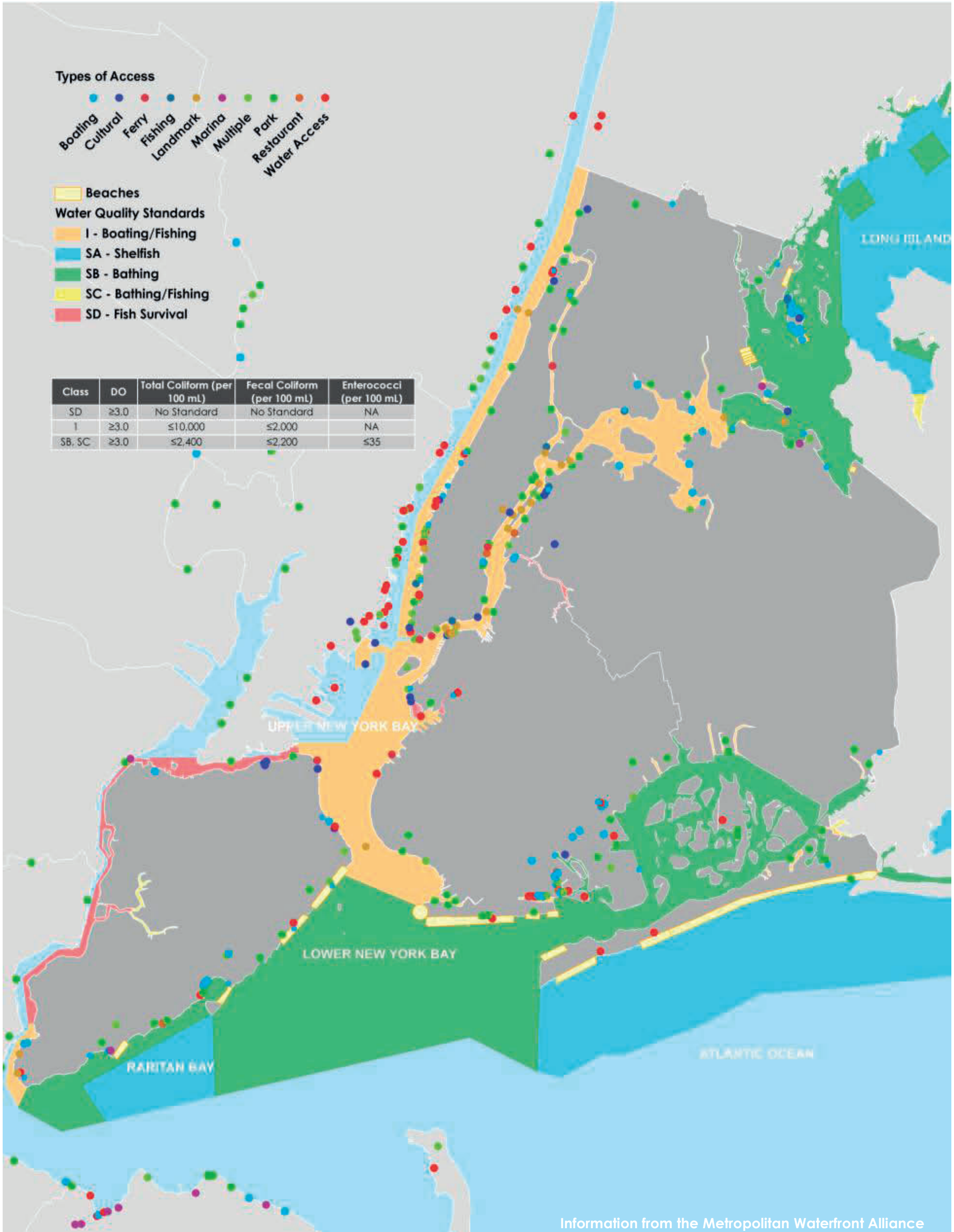
Today, DEP treats an average of 1.3 billion gallons of wastewater a day over the course of a year, inclusive of all dry and wet weather flows. This tremendous flow is conveyed by 7,400 miles of lateral sewers, 149 miles of interceptor sewers, and 113 pump stations, and is treated at 14 WWTPs. DEP plants have plenty of capacity to handle New York City's wastewater in dry weather and during most storms; 13 are designed with a capacity of double dry weather flows (the Oakwood Beach WWTP accepts sanitary flow only and its drainage area is a separated sewer area). After billions of dollars of past and current investments in upgrades at the WWTPs, harborwide pathogen and dissolved oxygen levels are now consistently better than state standards.

As a result, most areas in the Harbor are safe for recreational activities year-round, giving the public meaningful access to water (Figure 4, following page). In addition, the City is building or rehabilitating waterfront parks, esplanades, housing, and other areas to accommodate water-related uses. Of the 156 square miles on the New York side of the harbor, 116 square miles or 75% of the area meets state pathogen standards, the limiting factor for primary contact recreation. That water quality supports over 14 miles of public bathing beaches that were able to accommodate 7.7 million visitors in 2009.

A significant portion of the Harbor is also available for fishing and boating. This area represents 29.4 square miles or 19% of the New York side of the Harbor that is classified for secondary contact recreation where the water quality meets applicable pathogen standards (Figure 4). This is in addition to Raritan Bay and the Atlantic Ocean, where commercial harvesting of shellfish is allowed. While recreational fishing is widely available, in many areas New York State has adopted advisories not to consume fish because of contaminated sediments from historic industrial pollution and current air deposition of mercury and other contaminants that are unrelated to ongoing CSOs.

The City's smallest, most impaired tributaries comprise less than 7% of the water area in the Harbor; much of those areas support manufacturing and shipping, including the largest tugboat fleet and maritime services industry on the East Coast, the largest commuter ferry system

Figure 4: Current Water Quality Standards and Public Access Points



Class	DO	Total Coliform (per 100 mL)	Fecal Coliform (per 100 mL)	Enterococci (per 100 mL)
SD	≥3.0	No Standard	No Standard	NA
1	≥3.0	≤10,000	≤2,000	NA
SB, SC	≥3.0	≤2,400	≤2,200	≤35

in the country, distribution and warehouse districts, and the remnants of New York City's manufacturing sector. Achieving recreational water quality standards in these tributaries will require billions of dollars in public and private investments.

As DEP looks to the future, it is critical that its investments be made based on scientific assessment of their overall impact on water quality, consensus about the value of additional recreational areas, and key sustainability measures such as PlaNYC's goal of reducing greenhouse gas emissions by 30%. Over the past ten years, the City has invested more capital funds in environmental protection than on other critical municipal functions, including education, transportation, and housing (Table 2). These relative levels of spending are not sustainable unless there are compelling reasons for further spending on water quality measures that have broad support.

Table 2: Water Quality and Other New York City Capital Investments (FY 2002-2009)*

Category	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	Total	Share
Environmental Protection	1,871	1,380	1,714	2,339	1,741	3,689	3,050	2,174	17,958	28%
Education	1,350	984	612	2,208	2,030	3,238	3,337	2,866	16,625	26%
Transportation	359	1,155	877	692	579	650	1,183	918	6,413	10%
Parks & Public Buildings	336	328	319	303	389	571	710	692	3,648	6%
Technology & Equipment	225	213	180	297	410	706	864	664	3,559	6%
Housing	438	313	283	423	356	299	453	358	2,923	5%
Economic Development	193	255	221	215	168	175	398	373	1,998	3%
Public Protection	300	290	164	186	289	250	260	257	1,996	3%
Hospitals	121	104	90	451	307	230	231	281	1,815	3%
Sanitation	216	159	140	137	77	189	173	171	1,262	2%
All Other	804	618	434	519	470	547	1,046	777	5,215	8%
Total Commitments	6,213	5,799	5,034	7,770	6,816	10,544	11,705	9,531	63,412	100%

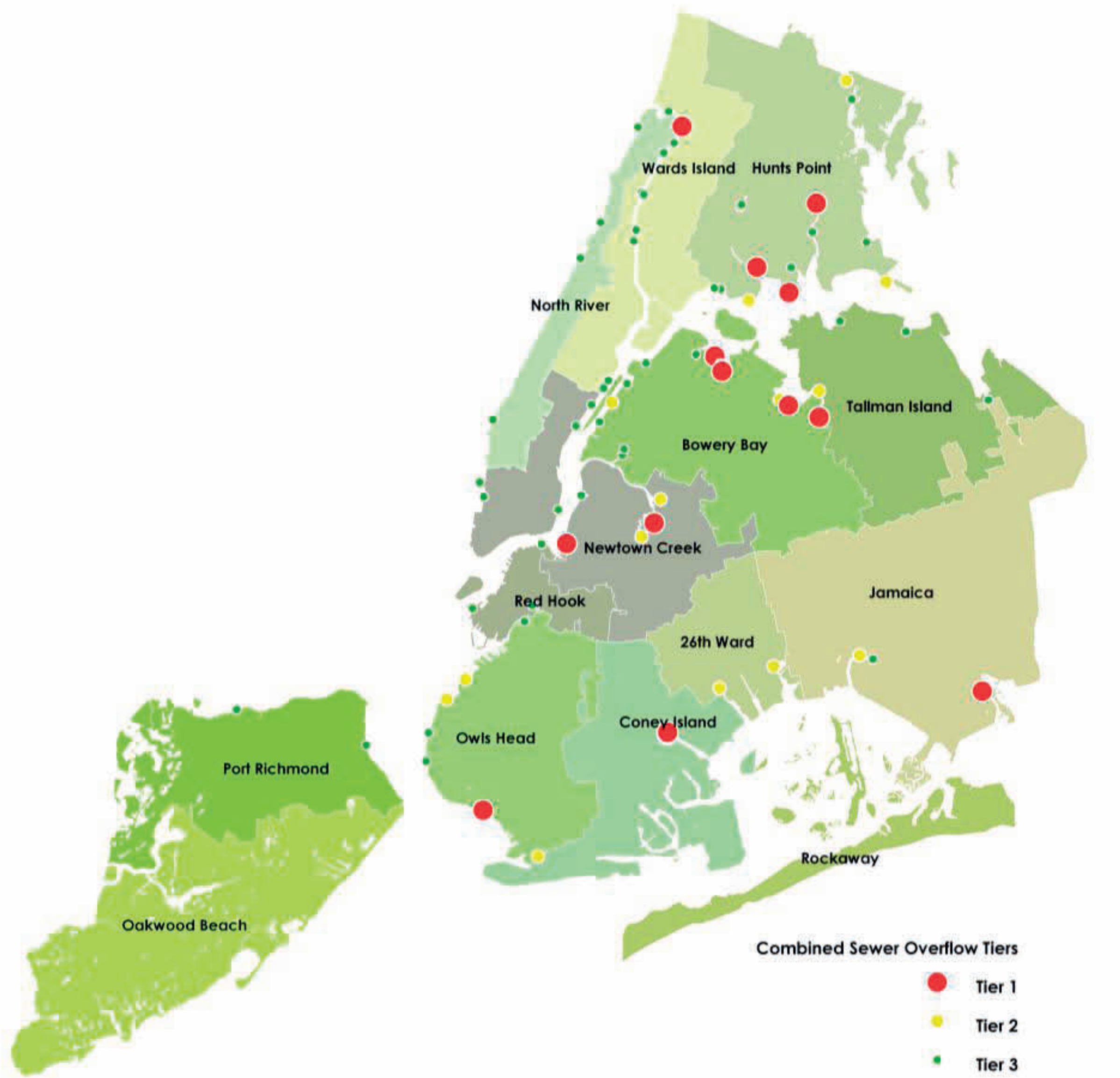
Source: New York City Office of the Comptroller, *Comprehensive Annual Financial Report*, *Fiscal Years 2002-2009.*

*All values in millions of dollars except for "Share" column.

The Clean Water Act's regulatory structure directs municipalities to meet water quality standards where attainable, not to reduce discharges for the sake of reduction. DEP has examined those areas of the Harbor where water quality standards are not yet met and has analyzed the sources of impairment. The biggest remaining challenges within New York City's control are to reduce discharges of nitrogen from DEP's WWTPs and to limit combined sewer overflows (CSOs) to levels that do not affect water quality.

Almost two-thirds of New York City's sewered system is a combined sewer that collects wastewater and stormwater runoff from properties and streets. During heavy rainfall or snowmelt, excess flows through the plant can wash out the biological unit's organisms that break down and treat waste. To protect the treatment plants and to prevent upstream flooding during high rainfall, New York City's 149 miles of interceptor sewers are designed with "regulators" that have overflow weirs to divert combined stormwater and wastewater into New York City's surrounding waterways when storm flows exceed the capacity of the system. These are combined sewer overflows or CSOs. New York City's combined sewer system has 422 sewer regulators that can discharge CSOs. These CSO outfalls are classified by tiers depending on the volume of annual discharge: Tier 1 outfalls discharge over 500 million gallons per year (mgy) and comprise roughly 50% of all CSO volumes, Tier 2 outfalls discharge between 250 to 500 mgy and make-up an additional 20% of CSO volume, and Tier 3 outfalls discharge between 50.7 to 250 mgy and make-up an additional 10% of CSO volume (See Figure 5).

Figure 5: Combined Sewer Overflow Outfalls and Wastewater Treatment Plant Drainage Areas



The CSO outfalls cannot be simply "plugged up;" if they were, the combined flow would destroy elements of the system and would cause even greater discharges over time. Over the past 20 years, DEP's upgrades to its plants and sewers and its construction of storage tanks have allowed the capture of an ever greater amount of overall CSO volume, from approximately 30% annually in the 1980s to over 72% today. New York City's CSOs were approximately 30% sanitary waste; today that percentage has dropped to 12%. The reduction of CSO volume varies by watershed, as does the impact of CSOs on water quality. That is because water quality also depends upon other sources of pollution, the strength of tidal flows, and historic dredging, filling, or other alterations to the waterbed (topographically speaking, "bathymetry"), that affect flows and the mixing of surface and deep waters. In many of NYC's tributaries, water quality standards would not be attained even if the wastewater plants could stop discharging altogether or if all CSOs were eliminated.

DEP's program to control combined sewer overflows

To further reduce CSOs, New York City is in the midst of an unprecedented period of capital investment. These projects have been agreed to by DEP in a 2005 Administrative Consent Order with the New York State Department of Environmental Conservation (DEC), DEC file no. CO2-20000107-8, as modified in 2008 by Order on Consent DEC file no. CO2-2007-0101-1 (the CSO Order or the Consent Order). On CSOs alone, the City has spent over $1.5 billion on sewer, regulator, and pumping station improvements as well as an upgrade of the CSO storage facility at Spring Creek and the construction of new CSO storage tanks at Flushing Creek, Alley Creek, and Paerdegat Basin. The planned investments include approximately $2 billion for additional CSO control measures. Through these measures, the City is projected to reduce its CSOs by over 8.3 billion gallons per year compared to the baseline case. DEP is investing billions more in WWTP and sewer upgrades unrelated to CSOs (See *The Green Infrastructure Plan*, Tables 6 and 8).

Many of these CSO-related programs were recommended by DEP in June 2007, when it submitted Waterbody Watershed CSO Facility Plans (Facility Plans) to DEC pursuant to the CSO Order. The 2007 Facility Plans analyzed the efficacy of ongoing and possible infrastructure upgrades towards improving pathogens and dissolved oxygen, the applicable water quality standards, cost, and constructability. Some of the ongoing infrastructure upgrades, such as the CSO detention tanks built or underway in Flushing Creek, Alley Creek, and Paerdegat Basin, scored well on the cost-benefit curve, and these are included in the Cost-Effective Grey Infrastructure Investments. Other alternatives would have cost more to improve water quality. The Cost-Effective Grey Infrastructure Investments in the CSO program results in significant CSO reductions and are projected to enable many of the waterbodies to achieve substantial compliance with existing water quality standards for pathogens. The full benefits of many of these projects will not be realized for a decade or more, but some will provide near-term benefits.

DEP must prepare watershed-specific Long Term Control Plans (LTCPs) for 13 waterbodies with the final citywide LTCP due to be submitted by the end of 2017. The LTCPs will assess the need for and recommend the implementation of measures to further improve water quality, including Potential Tanks, Tunnels, and Expansions and any alternatives.

There are several significant items that are included in the Facility Plans that DEP now believes are not cost-effective or provide limited benefits. These are CSO storage tanks in the Westchester Creek and Hutchinson River watersheds, large CSO storage tunnels in the Flushing Bay and Newtown Creek watersheds, and certain expansions of the Jamaica and 26th Ward wastewater treatment plants (collectively, these are referred to as Potential Tanks, Tunnels, and Expansions).

Sustainability and DEP's water quality initiatives

While water quality is and must remain the touchstone for DEP's investments, the alternatives it considers must also meet the City's sustainability goals. PlaNYC provides a holistic framework for meeting the City's housing, open space, energy, transportation, and environmental infrastructure needs over the next 20 years. PlaNYC initiatives typically make progress towards several goals at the same time. The MillionTreesNYC initiative, for example, improves open space and reduces greenhouse gas emissions and energy use. Congestion pricing and other traffic mitigation measures are designed to improve transportation infrastructure and financing, and to reduce air pollution. The PlaNYC framework gives greater weight to those CSO reduction alternatives that make the City more sustainable.

A sustainable approach leads to management of stormwater at its source through the creation of vegetated areas and other green infrastructure. PlaNYC committed the City to build more Bluebelts and Greenstreets, to require green parking lots, to incentivize green roofs, and to form an Inter-agency Best Management Practices Task Force. The *Sustainable Stormwater Management Plan* issued by that Task Force concluded that green infrastructure was feasible in some areas and could be more cost-effective than certain large infrastructure projects such as CSO storage tunnels. This Green Infrastructure Plan builds upon and extends the commitments made in the *Sustainable Stormwater Management Plan*.

While municipalities such as Seattle, Portland, Chicago, and Philadelphia have experimented with efforts to manage stormwater through sidewalk planters, swales, porous alleys, and planted roofs, such measures have not been widely credited towards meeting obligations under the Clean Water Act's regulatory system. In 2007, however, the EPA and four national environmental groups jointly issued a statement encouraging the use of green infrastructure by cities and wastewater treatment plants as a prominent component of CSO programs. The EPA has since adopted guidance that encourages reliance upon green infrastructure as a preferred alternative to meeting regulatory obligations. (See *Memorandum on Using Green Infrastructure to Improve Water Quality in Stormwater, CSO, Nonpoint Source, and other Water Programs* (March 5, 2007); *Memorandum on the Use of Green Infrastructure in NPDES Permits and Enforcement* (August 16, 2007)). DEC has also published a *Stormwater Management Design Manual* that contains green infrastructure designs for controlling stormwater at its source, and has inventoried examples in the Hudson Valley. In Fall 2009, Philadelphia submitted a proposed LTCP update to the EPA that would rely exclusively on green infrastructure to control CSOs over a 20-year planning horizon; as of the date of this plan the EPA had not made a decision about whether to accept this approach in an LTCP.

DEP had prepared its 2007 Facility Plans before the EPA had adopted relevant guidance or PlaNYC was published, and consequently did not include a full analysis of green infrastructure alternatives for controlling CSOs. In comments on DEP's 2007 Facility Plans, community and environmental groups voiced widespread support for green infrastructure and urged that DEP place greater reliance upon that sustainable strategy. In a June 2010 public meeting on elements of this Green Infrastructure Plan, DEP also received overwhelming endorsement of the green infrastructure approach.

This Green Infrastructure Plan incorporates EPA's, DEC's, and the public's comments about using green approaches to meet regulatory commitments. This report specifies the expected reductions of CSOs in each of the in-city combined sewer watersheds that would follow from various on-site stormwater controls and efforts to make the existing system function more efficiently. As demonstrated by our modeling, the use of green infrastructure in combination with other strategies will be more effective at controlling CSOs than former proposals to use all grey strategy and will also help meet key sustainability goals such as, cooling the city, reducing energy costs, and increasing property values.

This Green Infrastructure Plan proposes a hybrid approach that includes certain Cost-Effective Grey Infrastructure projects, conservation, green infrastructure, and measures to optimize the existing system to control CSOs. DEP will seek DEC's partnership in this effort to implement the Green Infrastructure Plan, to evaluate its success and make mid-course adjustments, and to evaluate attainment of water quality standards in LTCPs.

PREDICTED PERFORMANCE AND ESTIMATED COSTS

Overview of Grey and Green Strategies and modeling methods

For this plan, DEP evaluated the impact of two different infrastructure investment strategies for reducing CSOs – a Green Strategy and a Grey Strategy. To assess the future performance of capital projects, DEP used a sophisticated computer model that has been tested and calibrated against past rainfall events to develop the best possible estimate of future CSO flows. The use of models is a state-of-the-art industry practice and is well accepted by regulators and utilities. The model used by DEP is based on the commercially-available InfoWorks mathematical modeling software for urban hydrology and has been customized for well over a decade to account for the unique flow characteristics of New York City's sewer system. It uses information for 25,000 catchments, 7,500 pipes, 6,000 manholes, regulators, and other features, and predicts overland runoff routing in New York City's topography. The general model is described in the *Appendix*.

The InfoWorks model was used in the preparation of 2007 Facility Plans and its essential characteristics were kept intact in this report. DEP made minor adjustments to the model to reflect the elements of Grey and Green Strategies, including the Cost-Effective Grey Infrastructure Investments, Potential Tanks, Tunnels, and Expansions, green infrastructure, reduced wastewater flows, and optimization of the existing sewer network. These elements are described in greater detail below and in the *Appendix*. Using InfoWorks to simulate sanitary and stormwater flow through the City's sewer system, DEP modeled CSO discharges to each waterbody under each strategy, using rainfall from 1988 – a year used in past regulatory filings. Further details about the assumptions and modeling methodology are provided in the *Appendix*.

The CSO volume projections that are presented in this Green Infrastructure Plan are preliminary. As described in *Next Steps*, DEP is recalibrating the InfoWorks model using updated geospatial data about the extent and distribution of impervious surfaces in the City and 2030 dry weather flow projections. DEP will then model combined detention-infiltration scenarios to estimate CSO volumes and the projected impact on ambient water quality conditions.

Grey Strategy modeling assumptions

The Grey Strategy that DEP modeled includes two main elements: **Cost-Effective Grey Infrastructure Investments** and **Potential Tanks, Tunnels, and Expansions**.

Cost-Effective Grey Infrastructure Investments are the infrastructure elements included in the Facility Plans submitted to DEC under the CSO Order, with the exception of the Newtown Creek and Flushing Bay Tunnels and expansion of the wet weather capacity at the Jamaica and 26th Ward WWTPs. The Westchester and Hutchinson CSO Detention Tanks were not part of DEP's proposals in the Facility Plans but have been the subject of discussions with DEC and may be required to be analyzed in LTCPs; these tanks are also excluded from the category of Cost-Effective Grey Infrastructure Investments in this plan. DEP has since concluded that these very expensive projects are not cost-effective and will not have a meaningful impact on CSO volume or water quality. Those projects are not recommended for construction in the Green Infrastructure Plan.

The ***Potential Tanks, Tunnels, and Expansions*** are the Newtown Creek and Flushing Bay CSO Detention Tunnels, the Hutchinson and Westchester CSO Detention Tanks, and the Jamaica and 26th Ward WWTP wet weather expansions. These projects are evaluated because they are either required by the CSO Order, are currently proposed in Facility Plans, or will be under consideration as part of the City's LTCPs.

The Facility Plans included modeling predictions for 2045 following the construction of these projects. In this report, the CSO reductions have been slightly modified from the Facility Plan submissions based on updates to the underlying InfoWorks model. Most aspects of the model runs for the Grey Strategy are consistent with previous submissions, including the highly conservative 2045 flow projections that were used in the 2007 Facility Plans, which projected future consumption using 161 gallons per capita per day for new development.

Green Strategy modeling assumptions

The Green Strategy includes three main elements: **Cost-Effective Grey Infrastructure Investments**, **System Optimization and Reduced Flow**, and **Green Infrastructure**.

Cost-Effective Grey Infrastructure Investments are the infrastructure elements included in the Facility Plans submitted to DEC under the CSO Order, with the exception of the Newtown Creek and Flushing Bay Tunnels, the Westchester and Hutchinson CSO Detention Tanks, and the wet weather expansion projects at the Jamaica and 26th Ward WWTPs. This category is identical to that analyzed under the Grey Strategy.

System Optimization reduces CSOs by increasing the capacity of the system to handle wet weather flows. DEP's entire program will institutionalize a higher level of system optimization than we have been able to achieve in the past, and will complement the major capital improvements that will be analyzed as part of the LTCPs. DEP seeks to improve on its best management system for operations and maintenance through a comprehensive series of management initiatives that are memorialized in the Green Infrastructure Plan. The modeling in this report quantifies only a few of these initiatives – the programs to survey and rehabilitate interceptors and tide gates – and these programs alone are estimated to reduce CSOs by at least 586 mgy.

This estimate is extremely conservative because it is not yet possible to model the impacts of surveying and rehabilitating all the interceptors or the impacts of various DEP initiatives to prevent pollution from reaching our lateral collection sewers, to proactively clean sewers, and to pilot adjustments to weir elevations in sewer regulator chambers, inflatable dams and bending weirs. For example, interceptors convey and store combined flow before the elevation of the tipping weirs is exceeded. DEP's modeling reflected sediment removed from three interceptors leading to the 26th Ward, Jamaica, and Tallman Island WWTPs. Once data becomes available for interceptors in the other 11 CSO watersheds, DEP will model the effects of rehabilitation in those locations as well. Accordingly, DEP's predictions about overall CSO capture will likely increase and predicted CSO volumes will decrease.

In addition, DEP modeled the impact of tide gate repairs in the Coney Island, Newtown Creek, and Wards Island WWTP drainage areas. In other WWTP drainage areas where the plants operate at or below the permit influent limits of 400 mg/l in chlorides concentrations, DEP assumed that tidal water is not a major contributor to flows. But our tide gate inspection and rehabilitation program may find other areas in need of repair, and future modeling will reflect that information.

The ***Reduced Flow*** element reflects recent declines in water consumption, which DEP expects to be able to maintain in the future. Water consumption for all uses – drinking, cooking, cleaning, and flushing – increases sanitary flows, which take up sewer and plant capacity that could otherwise be used to convey and treat wet weather flows. The 2045 baseline used in the Facility Plan submissions did not reflect the City's conservation initiatives and water use trends. Since submitting those plans, DEP has revised its projections of sanitary flows over the 20-year implementation horizon for the Green Infrastructure Plan. Specifically, for purposes of modeling under this plan, DEP assumed that 2030 flows would be similar to the highest measured flows in recent years – i.e., 2005 flows for all watersheds except Newtown Creek, where 2008 flows were used because they were higher than 2005 flows. These assumptions are conservative because water consumption and wastewater flows have already declined considerably from 2005 levels; in 2009 wastewater flows were 62 mgd below 2005 levels. Since modeling the Reduced Flow scenario, DEP has prepared new projections of future wastewater flows that confirm the 2005 flows used in this report's modeling provide a reasonable estimate of future flows through the year 2030 for most wastewater treatment plants. In future modeling, DEP will use predicted 2030 flows for all plants. (See *Modeling Methodology* in the *Appendix* for more information on flow assumptions.)

DEP's modeling of ***Green Infrastructure*** assumed the capture and infiltration of the first inch of rainfall on 10% of existing impervious surfaces in each combined sewer watershed. DEP expects that green infrastructure will be implemented as a combination of infiltration and detention technologies. Detention is more realistic in the many areas of New York City that have low percolating soils, high bedrock, high groundwater table, underground utilities, and other characteristics that make infiltration infeasible. Therefore, DEP is developing an approach to model detention scenarios, a more complex undertaking than modeling infiltration scenarios. For example, based on one catchment area modeled to date, DEP projects that detention of one inch of rain is 60% less effective than infiltration of one inch of rain. As DEP is considering a stormwater management performance standard for new development that will effectively require the detention of two inches of rain, CSO capture predicted by the detention and infiltration model in the near future should be roughly equivalent to the CSO capture predicted by the infiltration model alone in this report. (See *Impervious area assumptions* below.)

Cost estimation methodology

Public Grey Infrastructure costs (**Cost-Effective Grey Infrastructure Investments** and **Potential Tanks, Tunnels, and Expansions**) were based on construction costs developed for the Facility Plan submitted to DEC, adjusted to 2010 dollars. The underlying costs were conservative because they were developed in 2007 during a construction boom in the City. Future years may or may not reflect the tight labor and material markets of 2007.

Green Infrastructure costs were derived separately for right-of-way projects and on-site projects. (See *Appendix* for additional details.) These costs are conservative because as the industry matures some green infrastructure costs, other than labor and material costs, are likely to decrease. Costs per acre were developed in 2010 dollars, allocated to ROW and on-site parcels based on the proportion of each opportunity area in each watershed. On average, 27% of the watersheds' land area consists of ROW and 73% of the area is on-site development; overall costs were developed based on this ratio of opportunities and the different costs of building in those areas, as explained below. The Green Infrastructure Plan contemplates that in the East River and Open Waters watershed, where we already meet current water quality standards, green infrastructure investment will principally come from the private sector as public funds are spent on higher priority areas.

Costs of green infrastructure for the right-of-way: The costs of green infrastructure to be built on sidewalks and streets are based on actual demonstration projects that are built or bid out by DEP. DEP's estimates included actual line item costs for New York City materials and labor, less the line items that are unique to demonstration projects, such as soil moisture meters, rain gauges, and other monitoring devices and associated labor. Costs depend on design and type of green infrastructure; DEP chose a sidewalk swale as a typical right-of-way technology. Our estimates were based upon the lower end of the range of costs, in anticipation of maturation in the industry and future economies of scale. Swales are expected to cost $30,000 each to construct and twenty 200-square-foot swales with trees are needed to capture the first inch on one acre of impervious runoff. Accordingly, the total cost to capture the first inch of rain on 1 acre of impervious surfaces in the right-of-way is $600,000 for construction costs plus $120,000 for design and construction management. (See the *Appendix* for cost details.)

Costs of green infrastructure for on-site development, including new development: There are a wide range of practices that can be used to control runoff from existing and new development. On the low end of the range is rooftop detention (or "blue roofs"); in the middle range are subsurface infiltration/detention techniques such as stormchambers, gravel beds, and perforated pipes; and on the high end, due in part to the cost of vegetation, are bioinfiltration and green roof technologies. Even though we expect that blue roofs will be the technology of choice on new construction due to their low cost, there are inherent limitations for retrofitting existing development with blue roofs, including roof slope and structural integrity. To be conservative, therefore, DEP's estimate is based upon the costs of perforated pipes, a mid-level technology. Based on the costs of New York City labor and materials, it would cost $200,000 to install these systems. (See the *Appendix* for cost details.)

Impervious area assumptions: While the goal of the Green Strategy is to capture runoff from 10% of impervious areas in combined sewer watersheds, DEP conservatively assumed that 15% of the impervious area of each watershed would be needed to meet the 10% capture goal, because it is more likely that a combination of detention and infiltration technologies will actually be used to manage stormwater. Combined detention and infiltration scenarios will be evaluated in the next phase of modeling described in *Next Steps*.

Reduced Flow strategies are expected to require little incremental expenditure as water consumption and wastewater flows have been on the decline in recent years. The combination of Automated Meter Reading, the ability of customers to track water usage, and national water efficient fixture standards is expected to keep flows stable. Should flows begin to increase over the next 20 years beyond levels modeled here, DEP is prepared to implement additional conservation measures, such as toilet and other fixture rebate programs, but these costs are expected to be nominal.

Interceptor and Tide Gate Rehabilitation costs. Interceptor rehabilitation costs were calculated using the amount of sediment in each interceptor (based on sonar surveys) and DEP's actual costs of $280 for each cubic yard of sediment and other material that has been or will be removed. Tide gate rehabilitation costs were calculated based on the identification of three WWTP drainage areas where tidal inflow is contributing appreciably to plant flows, the number of tide gates in each of the three identified WWTP drainage areas, and $5,000 per tide gate repair.

Predicted performance and estimated costs of each strategy

Predicted citywide CSO reductions

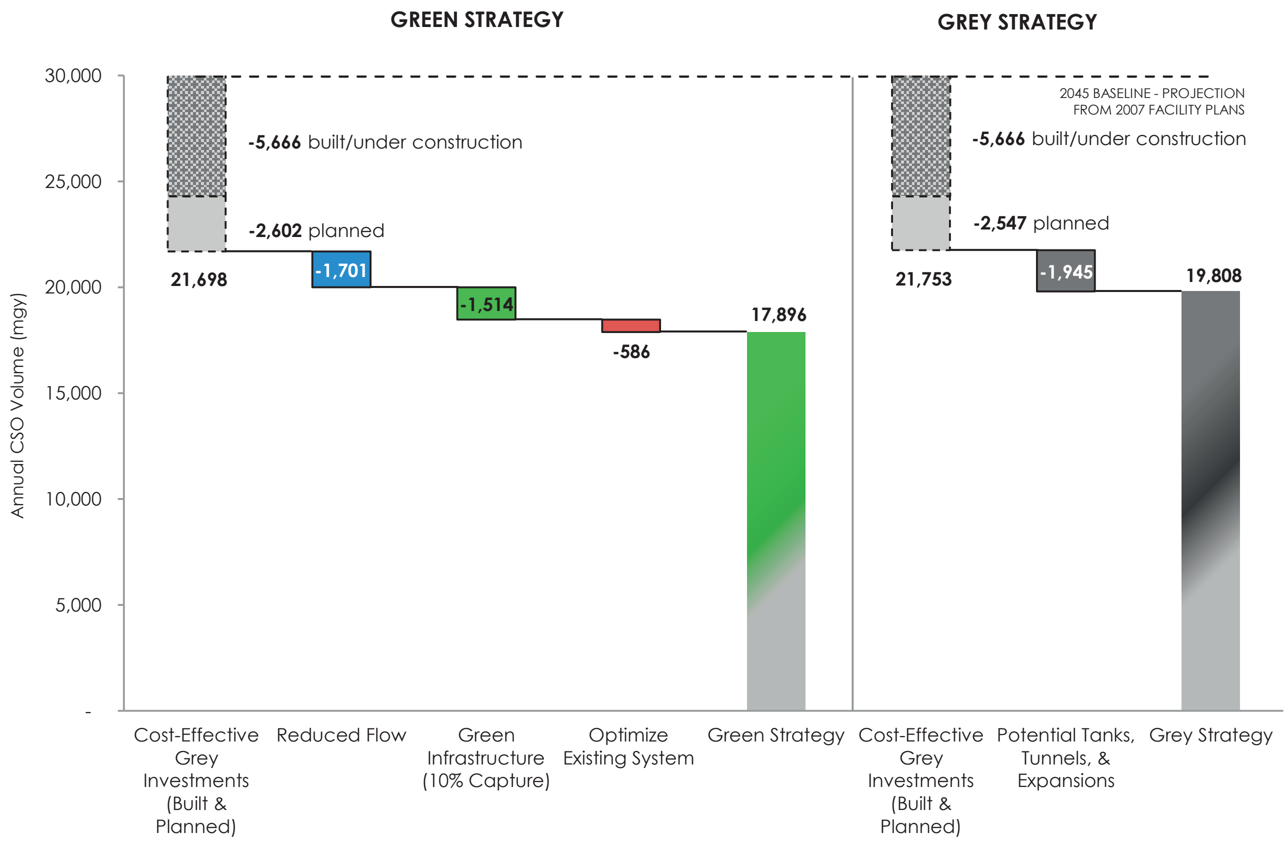
Under the Grey Strategy, DEP predicts that there would be approximately 19.8 bgy in CSO volume after full implementation (Figure 6, following page), 10 bgy less than the approximately 30 bgy baseline in 2045 used in the Facility Plans.

Under the Green Strategy, DEP predicts that there would be approximately 17.9 bgy in CSO volume in 2030 (Figure 6, following page), nearly 2 bgy less than the Grey Strategy. Green infrastructure alone would reduce CSOs by approximately 1.5 bgy and reduced water consumption would reduce CSO volumes by approximately 1.7 bgy (the equivalent CSO reduction predicted for the Potential Tanks, Tunnels, and Expansions currently under consideration).

While DEP is pursuing many efforts to optimize the existing system today, interceptor rehabilitation, tide gate rehabilitation, and reduced flows are all included as part of the Green Strategy and not the Grey Strategy. That is because those elements were not considered or credited as part of the CSO reduction plan proposed in the Facility Plans submitted to DEC. The Green Infrastructure Plan is DEP's first effort to integrate all of these elements into a comprehensive CSO reduction program.

Detailed information about CSO volume reduction for each component is available in Table 5: *Predicted Performance and Estimated Costs for Grey and Green Strategies*. These model predictions lead to the conclusion that a Green Strategy can, over a 20-year period, reduce CSO volumes more than future tanks, tunnels, and expansions, and provide substantial, quantifiable sustainability benefits.

Figure 6: Predicted CSO Volume*



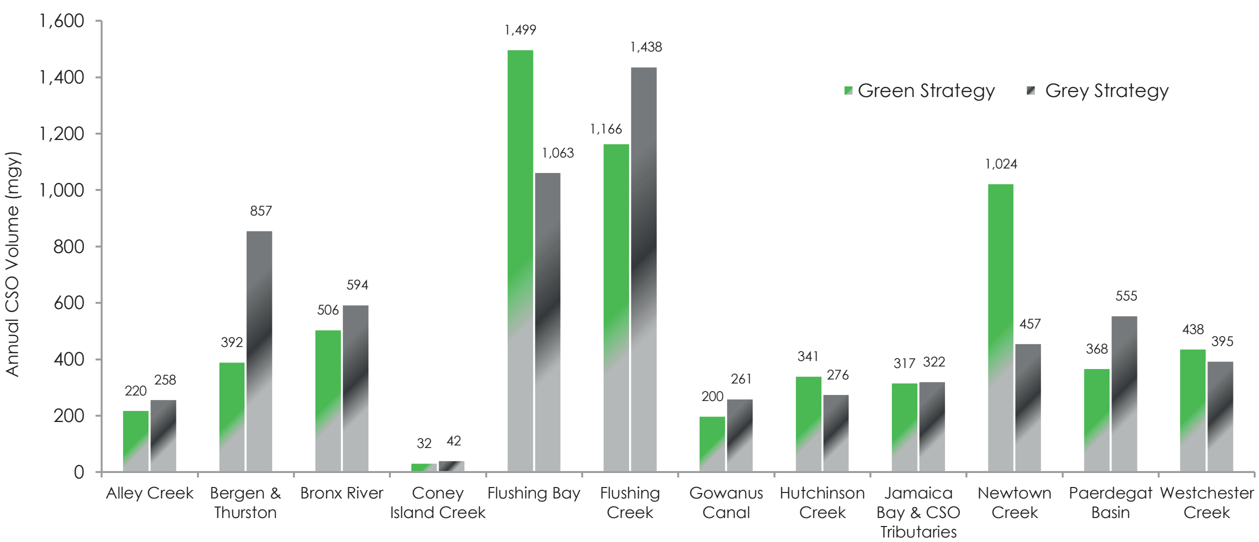
* Notes for Figure 6: (1) Volume is calculated over a 20-year implementation timeline, based on a 2045 CSO volume projection as a starting point. (2) While DEP is pursuing many efforts to optimize the existing system today, its additional efforts concerning interceptor rehabilitation, tide gate rehabilitation, and reduced flows are all included as part of the Green Strategy and not the Grey Strategy. That is because those elements were not considered or credited as part of the Facility Plans that are currently before DEC. (3) The Cost-Effective Grey Investments under the Grey Strategy do not include certain interceptor and bending weir projects for the 26th Ward wastewater treatment plant since they would not be necessary if the 26th Ward wastewater treatment plant wet weather expansion has to be built. The interceptor and bending weir projects are included in the Green Strategy that would defer expansion. This accounts for the projected 55 million gallon per year difference in planned Cost-Effective Grey Infrastructure Investments between the two scenarios.

Predicted CSO reductions by watershed

DEP's modeling predicts greater overall CSO reductions from the Green Strategy compared to the Grey Strategy. This trend holds in most CSO watersheds; specifically, the Green Strategy is predicted to provide greater CSO reductions than the Grey Strategy in the nine watersheds where a tank or tunnel is not under consideration (Figure 7).

In only four CSO watersheds, the Green Strategy is not predicted to match the CSO volume reduction of Potential Tanks, Tunnels, and Expansions. DEP's preliminary analysis shows this to be true in Flushing Bay, Hutchinson Creek, Newtown Creek, and Westchester Creek, where the Grey Strategy includes enormous CSO storage tunnels or tanks. For these watersheds, it is necessary to assess whether the gap in CSO reduction will translate to a significant impact on water quality. In addition to water quality, the strategies need to be considered in the context of relevant legal standards, the appropriate uses of waterways, overall public benefits, and costs.

Figure 7: CSO Volume by Watershed (after full implementation)*



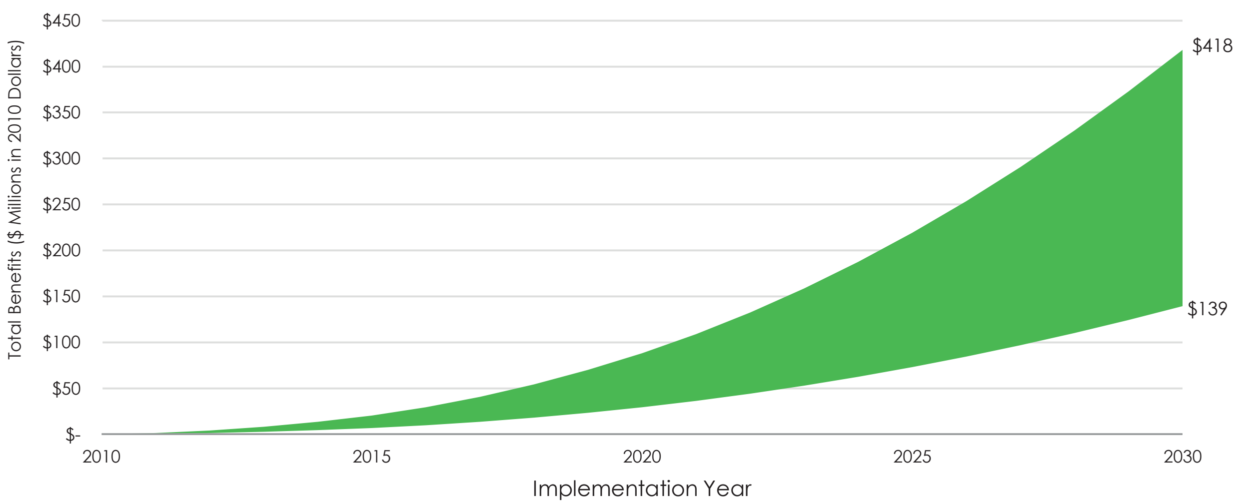
* Notes for Figure 7: (1) This preliminary analysis is for CSO volume only; DEP's second report will show the impact of the Green Strategy and the Grey Strategy on water quality by watershed. (2) Figure 7 does not include the large East River and Open Waters watershed because of limitations of scale; the annual CSO volume for the Grey Strategy in the East River and Open Waters is 13,289 mgy and the annual CSO volume for the Green Strategy is 11,394 mgy. Here, water quality standards are or will be attained through investments that have already been completed or are underway.

The value of sustainability benefits of the Green Infrastructure Plan

The Green Infrastructure Plan will also substantially advance Mayor Bloomberg's PlaNYC, a multi-pronged sustainability effort that will reduce the urban heat island effect, enhance recreational opportunities, improve quality-of-life, restore ecosystems, improve air quality, save energy, and mitigate and adapt to climate change. These goals, as well as improved water quality, are substantially advanced by green infrastructure in ways that traditional grey infrastructure cannot match. EPA has stated that the use of green infrastructure is an "effective response to a variety of environmental challenges that is cost-effective, sustainable, and provides multiple desirable environmental outcomes."[1]

Based upon currently available information, DEP estimates that accumulated sustainability benefits at full implementation will range from $139 million to $418 million, depending upon the amount of vegetation in the source controls used to meet the goals (Figure 8). These benefits will accumulate over the 20-year implementation period as green infrastructure is adopted according to interim milestones: 1.5% of impervious surfaces by 2015, an additional 2.5% by 2020, an additional 3% by 2025, and the remaining 3% by 2030 (Figure 8).

Figure 8: Accumulated Benefits Over 20 Years



To develop this working model, DEP first estimated the amount of land that would be converted from impervious surfaces to planted areas. Our estimates include a low-end estimate (25% of the acreage required for the 10% capture strategy would be planted areas rather than other, non-planted source controls) and a high-end estimate (75% of acreage required for 10% capture strategy would consist of planted areas). The scenarios that were used to estimate costs ranged from 1,085 acres of vegetated surface area to 3,255 acres (Table 3, facing page).

DEP assumed that half of all planted green infrastructure would be fully vegetated – as is the case for green roofs – and the other half would be considered partially vegetated to account for the lower ratio of surface area required to drain impervious surfaces in the right-of-way. In the right-of-way – and similar areas – it is likely that every acre of planted green infrastructure

[1] Testimony of EPA before the U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Water Resources and Environment, March 19, 2009.

will accept stormwater from 11 acres of existing impervious area. No incremental costs were assumed for the additional sustainability benefits to reduce the green infrastructure costs modeled and presented in the previous section of this report.

Table 3: Total Vegetated Acres in 2030

	Low	High
Combined sewer watershed area potentially addressed by vegetated source controls	1,985	5,956
Fully vegetated (e.g., green roofs)	993	2,978
Partially vegetated (e.g., right-of-way)	92	277
Total vegetation	1,085	3,255

We next estimated the total benefits provided by those planted areas using the best available data about New York City to derive dollar per acre benefits for the mix of green infrastructure at full implementation. For this report DEP found that the best proxy for green infrastructure benefits were the values for street trees found in the *New York Municipal Forest Resource Analysis* (MFRA) prepared by the U.S. Department of Agriculture, which used data collected in 2006 for the New York City Street Tree Census. The MFRA applies a U.S. Forest Service ecosystem services model to estimate the environmental benefits provided by New York City street trees.

All vegetated areas were assumed to have the same benefits as street trees as a starting point, but the fully vegetated area was assumed to have additional benefits from green roofs. DEP divided the total energy, carbon dioxide, air quality, and property value benefits found in the MFRA by the total area of street trees (11,110 acres) to find the average per acre value of these individual benefits. For green roofs, energy benefits were based proportionately on the assumption made in *Green Roofs in the New York Metropolitan Region* roofing manual that estimated that greening half of New York City's roofs (7,698 acres) would reduce temperature 0.8°F and that every 1°F temperature reduction represents energy savings of approximately $82 million per year, per estimates from the *New York City Department of Design & Construction Cool & Green Roofing Manual* of 2007. The energy savings also increase the carbon dioxide and air quality benefits of green roofs beyond the baseline numbers for street trees on the assumption – in the MFRA report – that approximately 60% of CO_2 and 50% of air pollution reductions occur at the power plant.

The results of this analysis predict that every fully vegetated acre of green infrastructure would provide total annual benefits of $8,522 in reduced energy demand, $166 in reduced CO_2 emissions, $1,044 in improved air quality, and $4,725 in increased property value, with lesser amounts for partially vegetated acres (Table 4).

Table 4: Annual Benefits of Vegetated Source Controls in 2030 ($/acre)

	Fully vegetated	Partially vegetated
Energy	8,522	2,504
CO2	166	68
Air quality	1,044	474
Property value	4,725	4,725
Total	14,457	7,771

Finally, DEP calculated benefits by multiplying those amounts by the value of the corresponding amount of new green infrastructure (993 fully vegetated and 92 partially vegetated acres in the low estimate to 2,978 acres of fully vegetated and 277 partially vegetated acres in the high estimate) to derive the total benefits; accumulated over 20 years, this produced benefits of $139 million to $418 million in 2030 (Figure 8). These benefits would continue to accumulate beyond 2030.[2]

Explanations of the sustainability benefits of green infrastructure

Reduced Urban Heat Island Effect: The urban heat island (UHI) effect occurs when built-up urban areas become warmer than nearby areas because of changes in surface coverage over time. The UHI effect can be detected throughout the year, but it is of particular concern during the summer, when higher surface air temperature is associated with increases in electricity demand for air conditioning, air pollution, and heat stress–related mortality and illness. Vegetated source controls would mitigate the UHI effect through added shade and evapotranspiration in areas otherwise covered by buildings, streets and sidewalks, and other paved surfaces. Computer models used in the 2009 study *Mitigating New York City's Heat Island* of widespread implementation of street trees and green roofs showed reductions in simulated air temperature of 0.7°F on average, and up to 2°F in some neighborhoods in Manhattan and Brooklyn at 3 pm, a time of day that corresponds to the peak commercial electricity load. A 2010 Columbia University study, *A Temperature and Seasonal Energy Analysis of Green, White, and Black Roofs* of a green roof in Queens, New York, found that green roof membrane temperature peaks are on average 60°F cooler than black roofs in summer. In addition, the average winter heat loss rate on the green roof was 34% lower than under the black roof, and the summer heat gain rate was 84% lower than under the black roof.

Energy Conservation and Climate Change Offsets: Green infrastructure reduces the energy needed for heating and cooling, and eliminates carbon dioxide emissions through direct removal from the air and avoided emissions from power plants. The shading and climate effects of New York City's street trees already provide approximately $27.8 million in energy actual savings per year and reduce atmospheric carbon dioxide by 113,016 tons according to the MFRA. The same study mentioned earlier by the Department of Design & Construction calculated an energy benefit of at least $82 million a year for every reduction of 1°F.

Improved Air Quality: Vegetated source controls offset air pollution by directly removing pollutants from the air, reducing power plant emissions, and reducing the high temperatures and sunlight that contributes to ozone formation. Existing New York City street trees are estimated to remove or avoid 129 tons of ozone, 63 tons of particulate matter, and 193 tons of nitrous dioxide every year according to the MFRA.

Higher Property Values, Enhanced Recreation, and Improved Quality of Life: The aesthetic benefits provided by vegetated source controls can enhance the livability of New York City neighborhoods. For example, real estate advertisements in Staten Island cite proximity to the Bluebelts as a selling point. A useful proxy to demonstrate this benefit is provided by New York City parks and community gardens, which increase adjacent property value as found in a 2008 study entitled *The Effect of Community Gardens on Neighboring Property Values*. A garden can raise neighboring property values by as much as 9.4% within five years of opening and values of

[2] DEP recognizes that there might be a minimum adoption threshold for some of these additional benefits, such as the overall energy savings that would occur if green infrastructure can reduce the City's ambient temperature is reduced. Other sustainability benefits such as improved property values, aesthetics, and habitat are likely to accrue without thresholds. The overall sustainability benefits are likely to further reduce the costs of green compared to grey infrastructure.

single-family homes located near parks in Brooklyn, Queens and Staten Island were 8% to 30% higher than values of homes farther from the parks. This can lead to increases in tax revenues of about half a million dollars per garden or park over a 20-year period. GrowNYC's 60 community gardens citywide would represent a $30 million increase in tax revenues over a 20-year period. Approximately 20% of the value of properties within the first two blocks of the Greenwich Village section can be attributed to the park according to a 2008 study by Friends of Hudson River Park entitled *The Impact of Hudson River Park on Property Values*. The same study found that, projected over the entire area within two blocks of the new section of the Park, the value attributable to the Park would approach $200 million.

Restored Ecosystems: Vegetated source controls can provide valuable habitat. The Bluebelt program is a leading example of using ecosystem services to manage stormwater and improve wildlife habitat. On a smaller scale, street trees and green roofs can provide nesting, migratory, and feeding habitat for a variety of birds, butterflies, bees, and other insects.

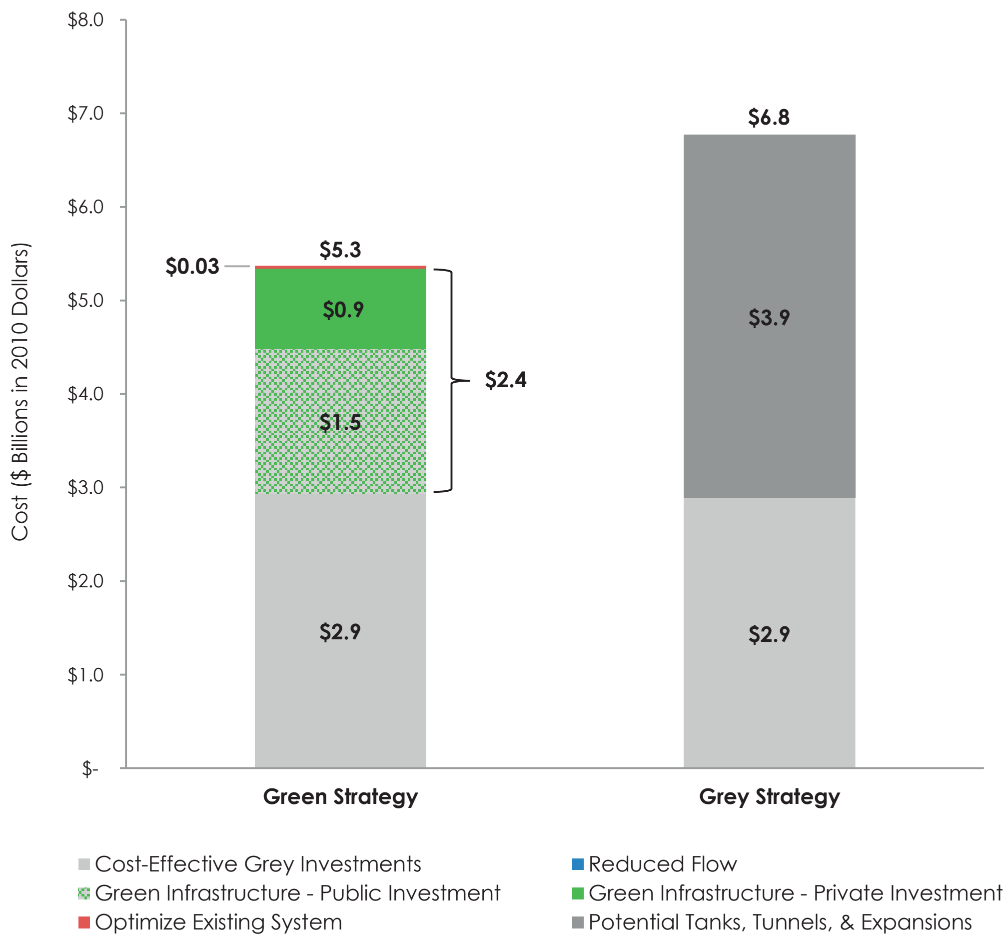
Operational Benefits of Reduced Flow: Encouraging prudent water use provides benefits to DEP's water supply and wastewater treatment system by reducing wear on infrastructure, chemical costs at our water supply and wastewater treatment plants, and energy costs for pumping and treating flow.

Estimated citywide costs

The total cost of the Grey Strategy – which includes construction of the Cost-Effective Grey Infrastructure Investments and the less efficient Potential Tanks, Tunnels, and Expansions – would cost approximately $6.8 billion. These estimates were derived from the 2007 Facility Plans and have been escalated to 2010 dollars to be comparable with the cost estimates for the Green Strategy that were developed for this report (Figure 9 and Table 5).

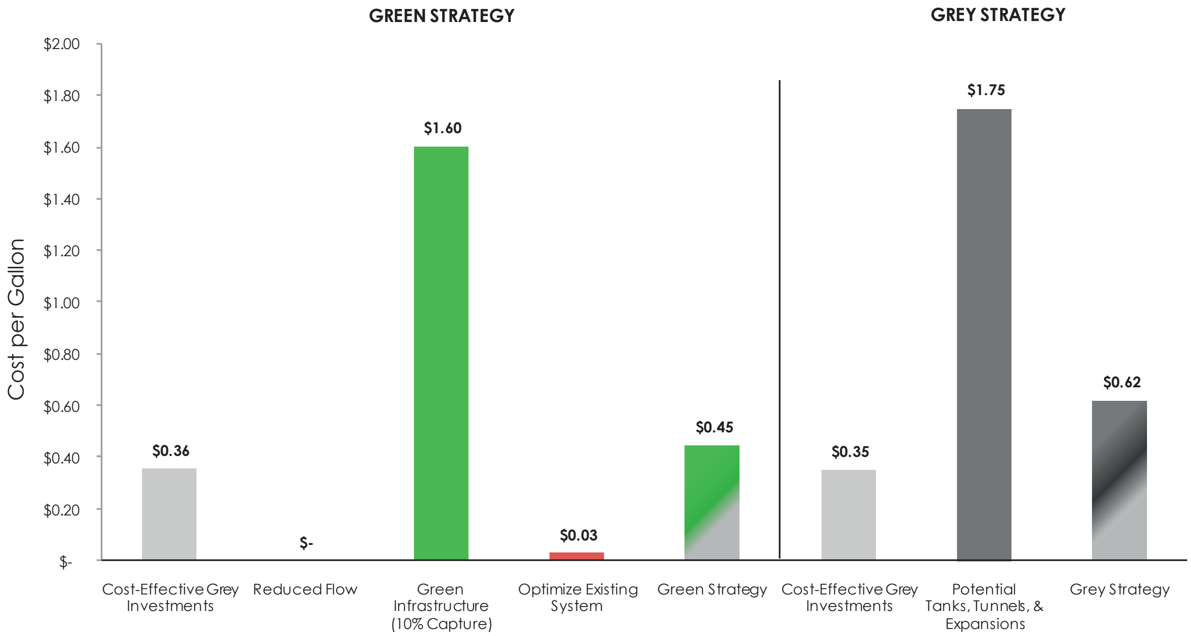
Based on the costs of demonstration projects and the other green elements, as described above and in greater detail in the *Appendix*, DEP estimates that the cost of a citywide Green Strategy would be approximately $5.3 billion, compared to $6.8 billion for the Grey Strategy (Figure 9). Of this total, a green infrastructure program to capture stormwater on 10% of the combined sewer watersheds' impervious areas would cost approximately $2.4 billion, far less than the $3.9 billion for Potential Tanks, Tunnels, and Expansions, which provide few if any sustainability benefits. Detailed cost information for each strategy element is included in Table 5: *Predicted Performance and Estimated Costs for Grey and Green Strategies*.

Figure 9: Citywide Costs of CSO Control Scenarios (after 20 years)



On a unit cost basis the overall Green Strategy is estimated to cost $0.45 per gallon of CSO reduction and the overall Grey Strategy is estimated to cost $0.62 per gallon (Figure 10). Both strategies include Cost-Effective Grey Infrastructure Investments, which are the most cost-effective grey investments to reduce CSO volume, at an average cost of approximately $0.36 per gallon of CSO reduction. The Grey Strategy includes Potential Tanks, Tunnels, and Expansions that are significantly more expensive per unit cost, at approximately $1.75 per gallon of CSO captured (Figure 10). At five times the cost per gallon of CSO of Cost-Effective Grey Infrastructure, Potential Tanks, Tunnels, and Expansions are much more difficult to justify.

Figure 10: Estimated Citywide Costs per Gallon of CSO Reduced

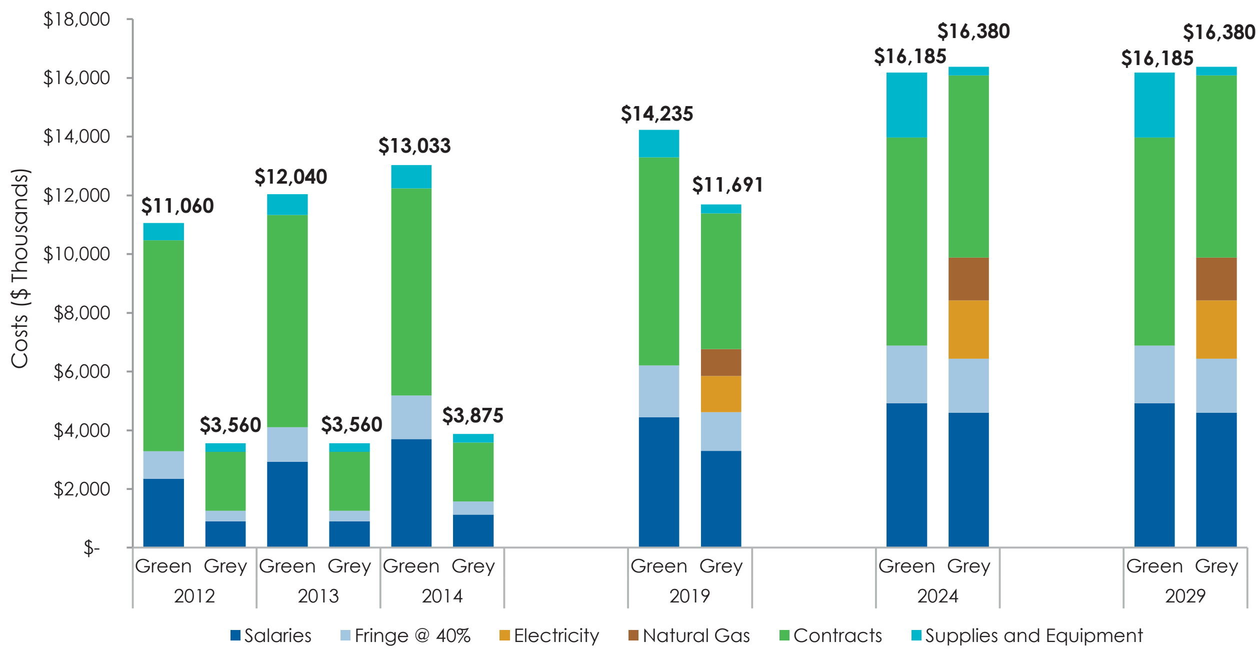


The Green Strategy includes green infrastructure, which is estimated to cost approximately $1.60 per gallon of CSO reduced (Figure 10). This cost per unit is considerably lower than tanks, tunnels, and expansions despite the economies of scale associated with large grey infrastructure. The overall costs of the Green Strategy – $0.45 per gallon – are low in part because optimizing the existing system is by far the most cost-effective option, with estimated average costs of $0.03 per gallon of CSO captured.

Operations and maintenance for the Green Strategy is higher in the initial years as source controls are built quickly, while operations and maintenance for grey infrastructure is higher in the long run as the large tanks, tunnels and expansion costs come online (Figure 11, following page). Significantly, the Grey Strategy requires energy costs that are not required for green infrastructure.

Moreover, green infrastructure provides an opportunity to leverage investment in new development. DEP estimates that about 40% of green infrastructure investments over the next 20 years will be made in connection with a substantially more stringent stormwater runoff standard for new development.

Figure 11: O&M Costs to the City of CSO Control Scenarios



Estimated costs by watershed

The additional costs for Cost-Effective Grey Infrastructure Investments range from approximately $3 to $5 million in the Flushing Bay and Hutchinson River watersheds to approximately $912 million in Bergen and Thurston Basins (Table 5). Potential Tanks, Tunnels, and Expansions range in cost from approximately $340 million in Hutchinson River to approximately $1.3 billion in Newtown Creek (Table 5).

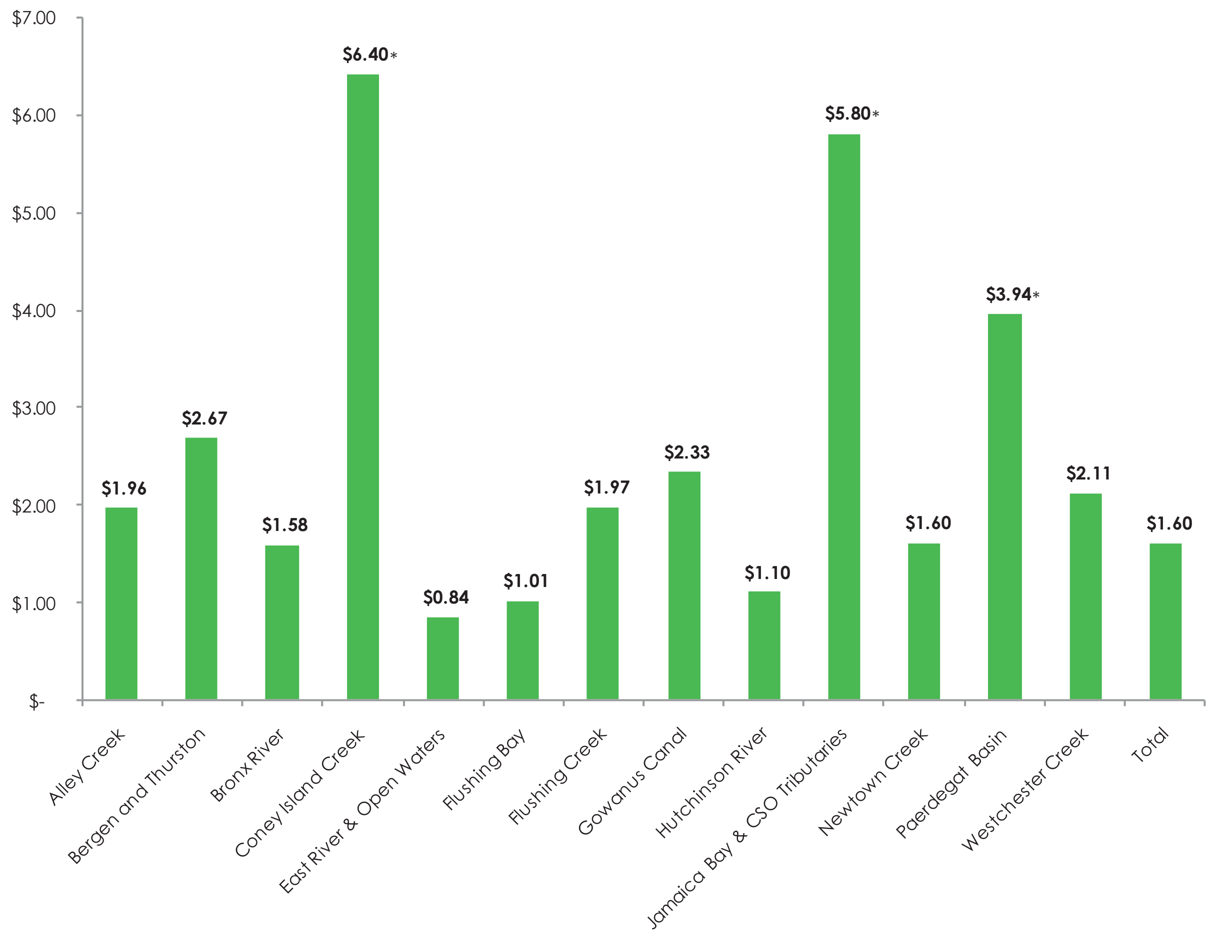
Green infrastructure costs per gallon of CSO reduction vary widely across watersheds from approximately $0.84 per gallon to approximately $6.40 per gallon (Figure 12, following page, and Table 5). In many watersheds, costs per gallon are in the $1 to $2 range and are therefore competitive with Potential Tanks, Tunnels, and Expansions. In the Coney Island Creek and Paerdegat Basin watersheds where DEP has or will be investing heavily in grey infrastructure, costs tend to be higher per gallon captured (approximately $3.94 to $6.40 per gallon). There, green infrastructure can provide additional CSO reductions, but at a higher cost, because the incremental benefit is provided only after the tank, weirs, or other improvements have exceeded their capacity. Detailed cost information for each waterbody is available in Table 5: *Predicted Performance and Estimated Costs for Grey and Green Strategies*.

As green infrastructure costs vary across watersheds, there are many opportunities to direct funds towards lower cost green infrastructure areas and away from higher cost areas. DEP will work with stakeholders to determine how to prioritize its discretionary spending. This will depend in significant part on future water quality modeling and estimated costs per incremental water quality benefit.

In the meantime, estimated costs per gallon of CSO volume reduced lead to the preliminary conclusion that discretionary green infrastructure funds should be spent in priority watersheds. Based on current information, potential priority watersheds could be:

- The Hutchinson River, Westchester Creek, Flushing Bay, and Jamaica Bay and CSO Tributaries watersheds, where DEP is seeking to preclude the need for tanks, tunnels, and expansions. (In Newtown Creek, green infrastructure strategies need to be synchronized with the proposed Superfund designation and other water quality improvements that are currently planned.)
- The Bronx River watershed, where DEP has not invested heavily in hard infrastructure, where the costs of green infrastructure are expected to be $1.58 per gallon, and where there is widespread community support for green infrastructure.
- The Gowanus Canal watershed.

Figure 12: Estimated Costs of Green Infrastructure per Gallon of CSO Reduced, by Watershed



* Watersheds where unit cost is high because the modeled impacts of green infrastructure consider only the marginal benefit of reducing CSOs that are not captured by planned or built Cost-Effective Grey Infrastructure, These projects include the Avenue V force main and pumping station (Coney Island Creek watershed), the 50 million gallon detention facility at Paerdegat Basin, and the 20 million gallon Spring Creek CSO detention facility (Jamaica Bay & CSO Tributaries watershed).

Table 5: Predicted Performance and Estimated Costs for Grey and Green Strategies

ALL NUMBERS ARE IN MILLIONS (EXCEPT FOR COST / GALLON)	Green Strategy																				
Waterbody	Cost-Effective Grey Infrastructure Investments				PLUS Reduced Flow				PLUS Green Infrastructure (10% Capture)				PLUS Tide Gate Repair and Interceptor Cleaning				Green Strategy				Waterbody
	CSO (Volume)	Incremental Reduction from 2045 (Vol)	Total Cost	Cost/ gallon	CSO (Volume)	Incremental Reduction from Prior (Vol)	Total Cost	Cost/ gallon	CSO (Volume)	Incremental Reduction from Prior (Vol)	Total Cost	Cost/ gallon	CSO (Volume)	Incremental Reduction from Prior (Vol)	Total Cost	Cost/ gallon	CSO (Volume)	Incremental Reduction from 2045 (Vol)	Total Cost	Cost/ gallon	
Alley Creek	258	244	$ 142	$ 0.58	257	1	$ -	$ -	220	37	$ 72	$ 1.96	220	0	$ -	$ -	220	282	$ 214	$ 0.76	Alley Creek
Bergen and Thurston	859	1,125	$ 912	$ 0.81	848	11	$ -	$ -	803	45	$ 121	$ 2.67	392	411	$ 12.33	$ 0.03	392	1,592	$ 1,046	$ 0.66	Bergen and Thurston
Bronx River	594	346	$ 20	$ 0.06	581	13	$ -	$ -	506	75	$ 119	$ 1.58	506	0	$ -	$ -	506	434	$ 140	$ 0.32	Bronx River
Coney Island Creek	42	259	$ 199	$ 0.77	38	4	$ -	$ -	32	6	$ 37	$ 6.40	32	0	$ -	$ -	32	269	$ 236	$ 0.88	Coney Island Creek
East River & Open Waters	13,289	2,865	$ 345	$ 0.12	12,007	1,282	$ -	$ -	11,459	548	$ 463	$ 0.84	11,394	65	$ 1	$ 0.02	11,394	4,760	$ 808	$ 0.17	East River & Open Waters
Flushing Bay	1,824	363	$ 5	$ 0.01	1,713	111	$ -	$ -	1,499	214	$ 216	$ 1.01	1,499	0	$ -	$ -	1,499	688	$ 221	$ 0.32	Flushing Bay
Flushing Creek	1,438	957	$ 356	$ 0.37	1,402	36	$ -	$ -	1,251	151	$ 298	$ 1.97	1,166	85	$ 3	$ 0.03	1,166	1,229	$ 656	$ 0.53	Flushing Creek
Gowanus Canal	261	143	$ 115	$ 0.81	232	29	$ -	$ -	200	32	$ 75	$ 2.33	200	0	$ -	$ -	200	204	$ 190	$ 0.93	Gowanus Canal
Hutchinson River	400	36	$ 3	$ 0.08	393	7	$ -	$ -	341	52	$ 58	$ 1.10	341	0	$ -	$ -	341	95	$ 61	$ 0.64	Hutchinson River
Jamaica Bay & CSO Tributaries	399	207	$ 169	$ 0.82	370	29	$ -	$ -	321	49	$ 284	$ 5.80	317	4	$ 0.12	$ 0.03	317	289	$ 454	$ 1.57	Jamaica Bay & CSO Tributaries
Newtown Creek	1,243	229	$ 236	$ 1.03	1,194	49	$ -	$ -	1,039	155	$ 249	$ 1.60	1,024	15	$ 0.05	$ 0.003	1,024	448	$ 485	$ 1.08	Newtown Creek
Paerdegat Basin	555	1,278	$ 387	$ 0.30	439	116	$ -	$ -	374	65	$ 256	$ 3.94	368	6	$ 0.03	$ 0.01	368	1,465	$ 643	$ 0.44	Paerdegat Basin
Westchester Creek	535	216	$ 46	$ 0.21	522	13	$ -	$ -	438	84	$ 178	$ 2.11	438	0	$ -	$ -	438	313	$ 223	$ 0.71	Westchester Creek
Total	**21,698**	**8,267**	**$ 2,936**	**$ 0.36**	**19,997**	**1,701**	**$ -**	**$ -**	**18,482**	**1,514**	**$ 2,426**	**$ 1.60**	**17,896**	**586**	**$ 16.13**	**$ 0.03**	**17,896**	**12,069**	**$ 5,377**	**$ 0.45**	**Total**

reductions in CSO associated with interceptor

reductions in CSO associated with tide gate

ALL NUMBERS ARE IN MILLIONS (EXCEPT FOR COST / GALLON)	Grey Strategy											
Waterbody	Cost-Effective Grey Infrastructure Investments				PLUS Potential Tanks, Tunnels & Expansions				Grey Strategy			
	CSO (Volume)	Incremental Reduction from 2045 (Vol)	Total Cost	Cost/ gallon	CSO (Volume)	Incremental Reduction from Prior (Vol)	Total Cost	Cost/ gallon	CSO (Volume)	Incremental Reduction from 2045 (Vol)	Total Cost	Cost/ gallon
Alley Creek	258	244	$ 142	$ 0.58	258	-	$ -	$ -	258	244	$ 142	$ 0.58
Bergen and Thurston	859	1,125	$ 912	$ 0.81	857	2	$ 490	$ 245.00	857	1,127	$ 1,402	$ 1.24
Bronx River	594	346	$ 20	$ 0.06	594	-	$ -	$ -	594	346	$ 20	$ 0.06
Coney Island Creek	42	259	$ 199	$ 0.77	42	-	$ -	$ -	42	259	$ 199	$ 0.77
East River & Open Waters	13,289	2,865	$ 345	$ 0.12	13,289	-	$ -	$ -	13,289	2,865	$ 345	$ 0.12
Flushing Bay	1,824	363	$ 5	$ 0.01	1,063	761	$ 800	$ 1.05	1,063	1,124	$ 805	$ 0.72
Flushing Creek	1,438	957	$ 356	$ 0.37	1,438	-	$ -	$ -	1,438	957	$ 356	$ 0.37
Gowanus Canal	261	143	$ 115	$ 0.81	261	-	$ -	$ -	261	143	$ 115	$ 0.81
Hutchinson River	400	36	$ 3	$ 0.08	276	124	$ 341	$ 2.75	276	160	$ 344	$ 2.15
Jamaica Bay & CSO Tributaries*	454	152	$ 119	$ 0.78	322	132	$ 546	$ 4.14	322	284	$ 665	$ 2.34
Newtown Creek	1,243	229	$ 236	$ 1.03	457	786	$ 1,300	$ 1.65	457	1,015	$ 1,536	$ 1.51
Paerdegat Basin	555	1,278	$ 387	$ 0.30	555	-	$ -	$ -	555	1,278	$ 387	$ 0.30
Westchester Creek	535	216	$ 46	$ 0.21	395	140	$ 409	$ 2.92	395	356	$ 455	$ 1.28
Total**	**21,753**	**8,212**	**$ 2,885**	**$ 0.35**	**19,808**	**1,945**	**$ 3,886**	**$ 1.75**	**19,808**	**10,157**	**$ 6,771**	**$ 0.62**

*** Cost-Effective Grey Investments under the Grey Strategy do not include the interceptor and bending weir option (55 mg reduction) that are included under the Green Strategy since they are not necessary with the 26th Ward WWTP wet weather expansion.**

**** Since the cost per gallon is out of scale for the Potential Tanks, Tunnels and Expansions for Bergen and Thurston Basins ($245/gallon), this estimate has not been included in the Total Cost per Gallon estimate for either the Potential Tanks, Tunnels and Expansions section or the Total Grey Strategy section.**

All results are preliminary; subject to model calibration in future analyses.

THE GREEN INFRASTRUCTURE PLAN

1.BUILD COST-EFFECTIVE GREY INFRASTRUCTURE

DEP will construct $2.9 billion of cost-effective grey infrastructure investments over the next 20 years. These projects were set forth in the 2007 Facility Plans for reducing CSOs in each watershed in the City; DEP is seeking certain modifications to be incorporated in the final DEC approved Facility Plans. There are two categories of investments: CSO volume reduction projects and other CSO-related projects including floatables controls, aeration, and dredging. For the purposes of this Green Infrastructure Plan, the cost-effective CSO volume reduction projects are the following (Table 6):

Table 6: Cost-Effective Grey Infrastructure - CSO Volume Reduction Projects

Waterbody	Projects Constructed/Under Construction	Future Projects
Alley Creek	Phase I: Outfall and Sewer System Improvements	
	Phase 2: CSO Facility	
Bergen and Thurston Basins	Meadowmere & Warnerville DWO Abatement	Sewer System Improvements
		Regulator Automation
		High Level Sewer Separation in Southeast Queens
Bronx River	Hunts Point WWTP Headworks Improvements - BR allocation	
Coney Island Creek	Avenue V Pump Station Upgrade & Force Main	
East River & Open Waters	Bowery Bay WPCP Headworks Improvements	East River Plan Regulator Improvements
	Regulator Fixed Orifices	Wards Island WWTP Flow Maximization
	Regulator Automation	Gravity Diversion at Hannah Street Pumping Station
	Port Richmond Throttling Facility	Divert Low-Lying Sewers
	In-Line Storage	Raise Regulator Weir
		Tallman Island WWTP Flow Maximization
Flushing Bay		Regulator Modifications
Flushing Creek	CSO Facility	
Gowanus Canal	Gowanus Pump Station Upgrade	
Hutchinson River	Hunts Point WWTP Headworks Improvements - HR allocation	
Jamaica Bay & CSO Tributaries	26th Ward Drainage Area Sewer Cleaning & Evaluation	Parallel Interceptor & Bending Weir
	Spring Creek 20 MG CSO Facility Upgrade	
Newtown Creek	Throttling Facility	Bending Weirs
	Increase Newtown Creek WWTP capacity to 700 MGD	Dutch Kills Relief Sewer
		Regulator Modifications
Paerdegat Basin	CSO Facility	
Westchester Creek	Hunts Point WWTP Headworks Improvements - WC allocation	Regulator Improvements

This list reflects all of the CSO reduction grey infrastructure investments in the Facility Plans or Consent Order with the exception of the Newtown Creek and Flushing Bay CSO Tunnels, Westchester Creek and Hutchinson River CSO Tanks, and the Jamaica and 26th Ward WWTP wet weather expansions. Under the Green Infrastructure Plan, those investments – or suitable alternatives – would be made only if green infrastructure investments in the relevant watersheds fail to achieve the CSO reductions projected through modeling.

CSO reduction projects completed or underway. DEP is already spending almost $1.7 billion to construct many of the CSO reduction projects set out in the Facility Plans. Completed projects include a rehabilitation of the Spring Creek 20 million gallon CSO detention facility, improvements to the headworks at the Hunts Point and Bowery Bay WWTPs, and construction of the Flushing Creek 43 million gallon CSO detention facility. Other noteworthy CSO reduction projects that are almost complete or under construction include the Paerdegat Basin 50 million gallon CSO Retention Facility that is projected to capture 1,278 mgy of CSO; increasing the Avenue V pumping station capacity from 30 mgd to 80 mgd; and increasing the capacity of the existing Gowanus Canal pumping station (Table 7). These projects will reduce CSO volumes by 5,666 bgy.

Table 7: Cost-Effective Grey Infrastructure - CSO Volume Reduction Projects Costs and CSO Volumes

Waterbody Name	2045 Projections	Cost-Effective Grey Investments (CSO Reduction)					Potential Tanks, Tunnels, and Expansions (CSO Reduction)			
ALL NUMBERS ARE IN MILLIONS (EXCEPT FOR COST PER GALLON)	CSO (Volume)	CSO (Volume)	Incremental Reduction from 2045 (Vol)	Cost of Projects Constructed/Under Construction	Total Cost (Current and Future)	Cost/ gallon	CSO (Volume)	Incremental Reduction from Preferred (Vol)	Cost	Cost/ gallon
Alley Creek	502	258	244	$ 142	$ 142	$ 0.58	258	-	-	$ -
Bergen and Thurston	1,984	859	1,125	$ 42	$ 912	$ 0.81	857	2	$ 490	$ 245.00
Bronx River	940	594	346	$ 20	$ 20	$ 0.06	594	-	$ -	$ -
Coney Island Creek	301	42	259	$ 199	$ 199	$ 0.77	42	-	$ -	$ -
East River & Open Waters	16,154	13,289	2,865	$ 155	$ 345	$ 0.12	13,289	-	$ -	$ -
Flushing Bay	2,187	1,824	363	$ -	$ 5	$ 0.01	1,063	761	$ 800	$ 1.05
Flushing Creek	2,395	1,438	957	$ 356	$ 356	$ 0.37	1,438	-	$ -	$ -
Gowanus Canal	404	261	143	$ 115	$ 115	$ 0.81	261	-	$ -	$ -
Hutchinson River	436	400	36	$ 3	$ 3	$ 0.08	276	124	$ 341	$ 2.75
Jamaica Bay & CSO Tributaries	606	399	207	$ 119	$ 169	$ 0.82	322	132	$ 546	$ 4.14
Newtown Creek	1,472	1,243	229	$ 149	$ 236	$ 1.03	457	786	$ 1,300	$ 1.65
Paerdegat Basin	1,833	555	1,278	$ 387	$ 387	$ 0.30	555	-	$ -	$ -
Westchester Creek	751	535	216	$ 8	$ 46	$ 0.21	395	140	$ 409	$ 2.92
Total	**29,965**	**21,698**	**8,267**	**$ 1,696**	**$ 2,936**	**$ 0.36**	**19,808**	**1945**	**$ 3,886**	**$ 1.75**

Planned CSO reduction projects. DEP will complete an additional $1.2 billion of grey infrastructure work to further reduce CSO discharges and improve water quality through lower pathogen levels (Tables 8 and 9). Noteworthy planned CSO reduction projects include Tallman Island WWTP flow modifications and regulator improvements. The built or planned CSO reduction projects will cost an average of $0.36 per gallon of CSOs reduced, compared to an average of $1.75 per gallon for Potential Tanks, Tunnels, and Expansions and will reduce CSO volumes by 2,602 bgy.

Other CSO related projects. Other CSO-related projects will directly improve water quality without reducing CSO volume: dredging the head end of certain tributaries, constructing floatables control at large CSO outfalls, reactivating the Gowanus Canal Flushing Tunnel, and installing in-stream aeration and destratification facilities in tributaries with low dissolved oxygen levels (Table 8). DEP will spend $750 million to construct these projects (Table 9, facing page).

Table 8: Other Projects Related to CSOs

Waterbody	Projects Constructed/Under Construction	Future Projects
Bergen and Thurston Basins	Shellbank Creek Destratification Facilities	Dredging & In-stream Aeration
Bronx River	Floatables Control	
Flushing Bay		Dredging
		Floatables Control
Flushing Creek		Dredging
Gowanus Canal	Gowanus Flushing Tunnel Modernization	Dredging at Head End of Canal
Hutchinson River		Floatables Control at Regulators
Jamaica Bay & CSO Tributaries	Hendrix Creek Dredging	Dredging, In-stream Aeration and Netting Facility Upgrate at Fresh Creek
Newtown Creek	Zone 1 Aeration Upper English Kills	Dredging & Floatables Control
		Enhancement of Zone I Aeration at Lower English Kills
		Enhancement of Zone II Aeration at East Branch, Dutch Kills and Portions of Newtown Creek
Paerdegat Basin		Dredging at Head End and at Mouth of Basin
Westchester Creek		Floatables Control

In addition to CSO-related improvements, DEP has spent almost $5 billion to upgrade the Newtown Creek WWTP alone and hundreds of millions more on ongoing upgrades to its Upper East River and Jamaica Bay plants to remove nitrogen, a natural byproduct of the wastewater treatment process that is not a threat to public health but can harm the ecosystem by reducing dissolved oxygen.

In summary, DEP has built or will build $3.7 billion in CSO reduction and other CSO-related projects. These projects will reduce CSOs by 8.3 bgy and will result in less floatables and higher dissolved oxygen levels to improve water quality.

Table 9: Other Projects Related to CSOs - Costs

Waterbody Name	Other Projects Related to CSOs (e.g. Dredging, Aeration, Floatables)		Total Costs of Cost-Effective Grey Infrastructure PLUS Other Projects Related to CSOs	
ALL NUMBERS ARE IN MILLIONS (EXCEPT FOR COST PER GALLON)	Cost of Projects Constructed/Under Construction	Total Cost (Current and Future)	Cost of Projects Constructed/Under Construction	Total Cost (Current and Future)
Alley Creek	$ -	$ -	$ 142	$ 142
Bergen and Thurston	$ -	$ 144	$ 42	$ 1,056
Bronx River	$ 26	$ 26	$ 46	$ 46
Coney Island Creek	$ -	$ -	$ 199	$ 199
East River & Open Waters	$ -	$ -	$ 155	$ 345
Flushing Bay	$ -	$ 84	$ -	$ 89
Flushing Creek	$ -	$ 32	$ 356	$ 388
Gowanus Canal	$ 47	$ 71	$ 162	$ 186
Hutchinson River	$ -	$ 29	$ 3	$ 32
Jamaica Bay & CSO Tributaries	$ 15	$ 92	$ 134	$ 261
Newtown Creek	$ 9	$ 226	$ 158	$ 463
Paerdegat Basin	$ -	$ 36	$ 387	$ 423
Westchester Creek	$ -	$ 10	$ 8	$ 55
Total	$ 97	$ 750	$ 1,793	$ 3,686

2. OPTIMIZE THE EXISTING WASTEWATER SYSTEM

Wastewater system optimization

As part of the Green Infrastructure Plan, DEP will undertake a comprehensive series of management initiatives to improve its best management practices for operations and maintenance. More often than not, it is far more efficient to optimize existing infrastructure than to build new infrastructure. Many of the efforts to optimize our system through best management practices are set out in WWTP discharge permits under terms agreed upon between DEP and DEC. Progress on compliance with these requirements is regularly documented in DEP's annual reports about its best management practices. DEP's comprehensive program will institutionalize a higher level of system optimization than we have been able to achieve in the past, and will complement the major capital improvements that will be analyzed as part of the LTCPs.

The modeling in this report quantifies only a few of these initiatives – the programs to survey and rehabilitate interceptors and tide gates. Nevertheless, these programs alone are estimated to reduce CSOs by at least 586 mgy. This estimate is conservative because it is not yet possible to model the effects of surveying and rehabilitating all of the interceptors, the effects of various DEP initiatives to prevent pollution from reaching our lateral collection sewers and to proactively clean sewers, or the effects of pilots to adjust weir elevations in sewer regulator chambers, inflatable dams and bending weirs.

These programs represent a significant commitment of resources. DEP is already committed to improving its operational and maintenance program at a cost of at least $9.4 million, with recurring costs of approximately $4 million per year. Our sewer interceptor rehabilitation efforts alone will require approximately $2 million per year for labor, materials, and disposal costs. Tide gate repairs will be achieved through a re-allocation of personnel agreed to with DEC, which has allowed DEP to scale back certain regulator inspections from weekly to monthly. DEP is seeking further efficiencies in partnership with DEC.

Drainage plans, high-level storm sewers, system-wide hydraulic analysis, and research and development

DEP constructs its sewers according to detailed master drainage plans. These drainage plans incorporate information about the surrounding land uses and development trends to determine the amount of stormwater and sanitary sewage anticipated in the public sewer system. Drainage plans are updated as the zoning of a community changes. Under these plans, DEP has built 1,800 miles of separate storm sewers, primarily in southeast Queens and Staten Island.

Drainage plans also allow DEP to prioritize CSO "hotspots," low-lying areas, and areas shown to have high incidents of flooding or sewer backups for partial separation with high-level storm sewers, which divert up to 50% of stormwater from the combined flow. By removing this flow from the combined sewer, DEP adds significant capacity to the combined sewer, helping eliminate street flooding and sewer back-ups. To date, the City has completed amended drainage plans to incorporate high-level storm sewers in the Laurelton section of Queens, the Throggs Neck area of the Bronx, and the Gowanus area of Brooklyn. Over the next three years, DEP has committed capital funding to build high-level storm sewers in Fairfax Avenue, Commerce Avenue, Waterbury Avenue, and Hook Creek Boulevard.

DEP is also updating its evaluation of the hydraulic capacity of the sewer system in anticipation of the analysis required in LTCPs. The hydraulic capacity analysis includes an analysis of the impact of interceptor rehabilitation on CSO volumes. This will require that DEP update and recalibrate the InfoWorks models using updated impervious data based on a satellite flyover in 2009 using infrared imagery that captures the light spectrum emitted by vegetation, CSO post-construction monitoring data, recent Harbor Survey and Sentinel data, interceptor inspection and cleaning results, and all other available combined sewer system monitoring data. DEP will then complete InfoWorks modeling reports for each Facility Plan drainage basin and, ultimately, the entire New York City combined and sanitary sewer collection system. DEP expects to complete this update to the capacity evaluation by the end of 2012 after the conclusion of its initial inspection and rehabilitation program. In addition, as part of the LTCPs, DEP will prepare an updated hydraulic capacity evaluation of the sewers in each watershed, including an evaluation of regulators and weirs.

From 2010 to 2013, DEP will:

- Complete drainage plans for areas of the City where buildout is to occur.
- Build high-level storm sewers in Fairfax Avenue, Commerce Avenue, Waterbury Avenue and Hook Creek Boulevard.
- Prepare an updated baseline hydraulic capacity of the entire New York City combined and sanitary sewer collection system.

Interceptor surveys, rehabilitation, and improvements

New York City has 149 miles of large intercepting sewers that connect former outfalls of our lateral collection sewer system to the WWTPs. Most of our interceptor sewers were built at a low elevation and sometimes on a flatter slope than the lateral collection sewers that are designed to be self-cleaning by constantly maintaining a minimum flow velocity.

The combined sewer collection system also contains relief structures such as regulators and overflow weirs to protect the WWTPs from excessive flows during wet weather. This is necessary to ensure that the live cultures that process wastes are not washed out and lost, and that treatment performance is maintained during both wet and dry weather. During rainfalls where combined flows exceed the capacity of the sewer system and WWTPs, regulators divert combined flows into waterways, causing CSOs. Interceptor rehabilitation will restore the full design capacity to store and convey wastewater and stormwater, thereby reducing the amount of CSOs.

Using new technology, DEP is conducting sonar and video surveys of its entire interceptor system to identify the characteristics and extent of sediment and debris throughout the interceptor network. In June 2010, DEP announced a comprehensive plan to survey all interceptors within two years and to remove sediment and rehabilitate as necessary, depending upon the survey results. To do so, DEP purchased two additional Vactor trucks at a cost of $450,000 and will staff each with dedicated crews that will also be supplemented by contractors. The trucks contain a powerful vacuum system and custom attachments to suck waste out of the sewer system using a hose supported by a remotely controlled boom crane. The trucks also have a water jet to clear clogs in the sewer. A gauge on the 12-cubic-yard tank measures the amount of debris inside. The two trucks can collect up to 3 tons of sediment and debris each day. Training and road tests began in the summer of 2010, and the Vactor trucks will continue to clean interceptor and lateral sewers, pumping stations, regulators, and other elements in the collection system.

The trucks will clean the sewer interceptors first as sonar data becomes available. Experience with cleaning the system may show that those efforts should be coordinated with sonar inspection and cleaning of upstream lateral sewers to limit the new accumulation of sediment in interceptors from those upstream elements the City's sewer system (Figure 13).

Figure 13: DEP Crew and Vactor Truck in Operation

CSOs occur in heavy wet weather when the elevation of water in the system exceeds the height of a fixed-height weir – or dam – within a regulator chamber or overflow structure. By optimizing the elevations of these weirs with a chamber or a series of chambers, additional wet weather flow can be captured within the existing sewer system. This flow can then be sent to a treatment plant after the storm subsides.

Another optimization technique is to install bending weirs, which use counterweights to adjust weir height and store additional flow within the upstream sewer. These relatively inexpensive devices can be retrofitted within existing regulator chambers where hydraulic modeling shows that they can yield the greatest effect. Finally, inflatable dams can be installed in the existing sewer infrastructure to retain more flow during wet weather. Such devices are inflated with pneumatic pumps during storms, and can be adjusted under varying conditions to hold flow within a certain section of sewer. Because these technologies are not well established in New York City, DEP will undertake demonstration projects that will inform the capital commitments to be made in LTCPs.

From 2010 to 2013, DEP will:

- Complete video and sonar surveys of all interceptor sewers – by 2011 – and compile results in a report for each WWTP drainage area that will include the sediment depth and raw data from the surveys.
- Analyze the surveys and submit a schedule for necessary removal of debris and deposits, repairs, rehabilitations and replacement of the interceptor sewer system.

- Begin rehabilitating priority areas shown by sonar and video inspections to have significant accumulations of sediment and other debris. The Jamaica East and Rockaway East interceptors will be among the first interceptors to be cleaned. DEP will complete cleaning of 136 miles of interceptors within two years – the other 13 miles are deep sewers that cannot be reached with Vactor trucks and are expected to be clean without intervention.
- After the initial two-year period, DEP will continue to monitor its interceptor sewers with sonar profiling, and will rehabilitate interceptors that have new accumulation of sediment based on a system of prioritization.
- Build bending weirs in a Newtown Creek intercepting sewer.
- Build inflatable dams in the Newtown Creek and Red Hook intercepting sewers.
- Monitor and evaluate the demonstration projects as part of a comprehensive assessment of whether it is appropriate to install those technologies in other locations, and to analyze them as part of the LTCPs for each watershed.

Tide gate rehabilitation and inflow/infiltration surveys

At discharge points, tide gates prevent seawater from entering the sewer system. Tide gates can become obstructed by wooden debris and other material, and in extreme cases can become unhinged or lose their seal. If tide gates leak, seawater can reduce CSO storage in the system and, in extreme cases, can change the density of sanitary flows so that it is harder to remove solids at the treatment plants. To ensure the system does not have excessive seawater entering at high tides, chlorides are measured at the headworks of our WWTPs and are kept below 400 ppm on a 12-month rolling average under the terms of our SPDES permits. Inspecting, maintaining and, if necessary, repairing tide gates may be as simple as removing debris such as an old sneaker that is wedged into a hinge point and may be as complicated as removing the tide gate, taking it to DEP's repair shop, and performing welding and other repairs. DEP will increase the frequency with which it inspects and rehabilitates tide gates.

At the same time, DEP is assessing the inflow and infiltration of saline groundwater in coastal areas, which can consume capacity for storing CSOs. DEP's first assessment will be in the Coney Island watershed, as that plant has consistently high chlorides. DEP will then develop and submit an infiltration and inflow report summarizing the results of the investigation and identifying any necessary repairs, and determine whether other areas should undergo an infiltration and inflow assessment.

From 2010 to 2013, DEP will:

- Inspect 25 tide gates per month to ensure they operate and seal properly. Under the improved tide gate survey, inspection and rehabilitation program, DEP will prioritize sewersheds for WWTPs with high chloride levels.
- Within two years, inspect and, where necessary, repair all of the tide gates in the system. Continue tide gate inspections and will make repairs as needed.
- Complete an infiltration and inflow investigation of the combined and sanitary sewer system in the Coney Island WWTP drainage area (by 2012) to determine the cause of the consistently high chloride levels at the plant.

Pollution prevention and obstruction removal

Interceptors receive flow from 7,400 miles of lateral collection sewers that convey sanitary waste and stormwater from houses, buildings, and some of the City's 141,000 catch basins installed in streets and other areas (catch basins in separately sewered areas are connected to storm sewers that do not transmit flow to WWTPs). In combined sewer areas, obstructions in lateral sewers and catch basins can cause street flooding and, where houses do not contain required back-flow preventers, sewer backups into houses.

New York City has a vast lateral sewer system, which means that information about blockages is diffuse. A primary indicator of a blockage is its expression at the surface through flooding or sewer backups. Due to the City's creation and promotion of the 311 system for citizen complaints, DEP has been able to devolve some early warning functions to citizens; the 311 system receives nearly 500,000 calls per year related to DEP concerns. In addition, a team of DEP personnel walk different sections of our underground sewer system to inspect our largest lateral sewers. To maintain the City's lateral collection sewer system, DEP uses a fleet of 35 jet flusher trucks, 47 catch basin cleaning trucks, 12 regulator valve repair trucks, 7 pump trucks, 15 attenuator trucks for work zone safety, 47 construction trucks, and 7 boom trucks.

DEP also has a proactive maintenance program to prevent obstructions. To reduce the clogging of "upstream" areas, catch basins have a sump area to retain sediments and have hoods or other devices to block soda bottles and other "floatables" from entering the sewers. All 141,000 catch basins have these hoods or closed curb cuts to prevent floatables. DEP inspects each catch basin at least once every three years and cleans it if necessary. (However, contractors and other private citizens have been know to illegally open manholes and dump bricks, concrete, tarps, and other debris into the sewer, causing obstructions.)

To reduce obstructions from fats, oils and grease (FOG) from residential and commercial cooking that accumulate and harden in pipes, DEP requires that restaurants, nursing homes, fruit and vegetable stands, laundries, and dry cleaners use grease traps. These devices separate FOG from wastewater. DEP routinely sends inspectors to businesses to check grease traps and make sure they are correctly sized, properly installed, maintained, and operating effectively. In addition, DEP does not allow commercial establishments to use food waste disposals, which can create additional FOG.

From 2010 to 2013, DEP will:

- Use the new Vactor trucks to continue cleaning lateral collection sewers to remove sediment and debris.
- Launch an enhanced FOG enforcement and inspection program, in partnership with the Business Integrity Commission and other agency partners.
- Develop and enforce rules to meet the commitment of local legislation (Intro 194A) that was signed into law by Mayor Bloomberg on August 16, 2010. The law requires the use of two percent biodiesel blends in heating oil in New York City beginning in October 1, 2012. The local biodiesel mandate is large enough to use up all of the estimated waste yellow grease in the City, and will create a further incentive for businesses to recycle grease rather than dump it down the sewer.
- Work with its sister agencies and the City Council on brown and yellow grease recycling legislation to keep FOG out of the sewers.

Demand side management

Reducing water use is a cost-effective strategy for reducing CSOs, because lower sanitary flows create additional storage capacity in the interceptors and treatment capacity at the WWTPs. In the recent past, conveyance and water use in New York City has declined steadily; between 2002 and 2009 consumption declined on average 0.9% per year. In 2009, New Yorkers used 1.009 billion gallons per day (bgd), considerably less than the 1.108 bgd used in 2005, the 1.240 bgd used in 2000, or the 1.424 bgd used in 1990. A portion of that additional capacity is available to convey and store stormwater. DEP's analysis of population growth and usage trends predicts that the City's annual consumption is likely to remain at approximately 1.1 bgd over the next 10 to 20 years. DEP's CSO modeling shows that reduced flows will result in 1.7 bgy of less CSOs than the base case presented in the 2007 Facility Plans (Figure 1).

DEP is taking a number of steps to ensure that the flows projected for the future will remain at or below 2005 levels of 1.1 bgd even with population growth, potentially hotter temperatures from climate change, and other factors that tend to increase demand. These steps include DEP's investment in information management systems such as the Automated Meter Reading (AMR) network and improvements to customer service and billing. AMR consists of small, low-power radio transmitters connected to individual water meters that send daily readings to a network of rooftop receivers throughout the city. The new AMR technology can send accurate readings to a computerized billing system up to four times a day and lets customers track their daily water use. New York City's experience with the installation of meters in the early 1990s demonstrates that better information leads to reduced water usage.

These changes will make information about water usage more robust, accurate, and accessible. Improved information, in turn, will drive consumer behavior and will reduce usage.

From 2010 to 2013, DEP will:

- Complete the installation of AMR for 834,000 customers, conduct outreach to educate ratepayers about how to use the information, and use AMR data to identify leaks and, possibly, to target significant users for education about water conservation efforts, audits, and retrofits.
- Track water usage and future trends so that we know whether consumption is meeting or exceeding the CSO modeling projections on which the Green Infrastructure Plan is based.
- Work with city agencies and the City Council to create initiatives or legislation to lower consumption, including incentivizing low-use toilets and other fixtures in new construction and redevelopment, prohibiting new once-through cooling towers, and other measures.
- Ensure that the rate structure incentivizes conservation while providing sufficient revenue for delivery and other essential services.

3. CONTROL RUNOFF FROM 10% OF IMPERVIOUS SURFACES THROUGH GREEN INFRASTRUCTURE

Introduction

Green infrastructure is the core of the sustainable approach presented in this Plan. New York City's goal for green infrastructure is to capture the first inch of rainfall on 10% of the impervious areas in combined sewer watersheds through detention or infiltration source controls. The City proposes to meet this 20-year goal by achieving 1.5% impervious area capture by 2015, an additional 2.5% by 2020, an additional 3% by 2025, and the remaining 3% by 2030. Policies to encourage green infrastructure will result in continued landscape penetration after 2030.

New York City receives about 43 to 50 inches of precipitation per year with little variation from month to month. The rain, snow, sleet, and other precipitation lands upon various urban surfaces, including rooftops, concrete, asphalt, trees, and open space. Of these surfaces, approximately 72% are impervious, meaning that water is unable to infiltrate the ground or to be absorbed by plants, which are parts of the natural hydrologic cycle. Rather, impervious surfaces shed water, which then becomes runoff that eventually reaches the City's sewer system or is discharged directly to adjacent waterbodies.

Source controls moderate or reverse these effects of development by using, enhancing, or mimicking the natural hydrologic cycle processes of infiltration, evapotranspiration,[1] and reuse. Source controls work by slowing down or absorbing rainfall before it can enter the sewers. Green infrastructure infiltration technologies currently in use or that are being piloted throughout the City include green roofs, enhanced tree pits, bioinfiltration, vegetated swales, pocket wetlands, and porous and permeable pavements. Vegetated green infrastructure can be used where plantings can be worked into the urban or suburban landscape, depending upon the underlying soil conditions, bedrock, water table, and underground utilities (EPA, "Green Infrastructure: Managing Wet Weather with Green Infrastructure," website, 2010). Other source controls use detention technologies, such as blue roofs and subsurface detention systems. For simplicity, this report uses the term "green infrastructure" to refer to all decentralized source controls.

The strategies to achieve the 10% goal vary by land use (Table 10, following page). DEP's analysis shows that there are opportunities to incorporate green infrastructure in 52% of the land area of the City, well more than needed to meet the goal of capturing rainfall from 10% of the impervious area in 20 years (Tables 10 and 11, following pages). For a highly urbanized city, the goal of 10% capture over 20 years is ambitious but achievable.

DEP's comprehensive analysis of these opportunities is based upon its unprecedented review of land uses, impervious surfaces, development trends, planned road reconstruction projects, and other opportunities throughout the city. Its analysis was based upon construction permit, demographic, and geospatial data from the Departments of Finance, City Planning, and Buildings, in addition to original satellite imagery and analysis that it commissioned. Land uses comprising significant portions of CSO drainage areas or that provide significant surface area for green

[1] Evapotranspiration is the loss of water from the soil both by evaporation and by transpiration from plants.

infrastructure are identified as opportunities based on this analysis. For each opportunity area, DEP has developed related strategies for implementing green infrastructure (Table 10). These amounts vary by watershed (Table 11, following page).

Table 10: Green Infrastructure Opportunities, Strategies, and Technologies (citywide)

Land Use	% of Combined Sewer Watershed	Potential Strategies and Technologies
New development and redevelopment	5.0%	Stormwater performance standard for new and expanded development
		Rooftop detention; green roofs; subsurface detention and infiltration
Streets and sidewalks	26.6%	Integrate stormwater management into capital program in partnership with DOT, DDC, and DPR
		Enlist Business Improvement Districts and other community partners
		Create performance standard for sidewalk reconstruction
		Swales; street trees; Greenstreets; permeable pavement
Multi-family residential complexes	3.4%	Integrate stormwater management into capital program in partnership with NYCHA and HPD
		Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels or cisterns; rain gardens; swales; street trees; Greenstreets; permeable pavement
Parking lots	0.5%	Sewer charge for stormwater
		DCP zoning amendments
		Continue demonstration projects in partnership with MTA and DOT
		Swales; permeable pavement; engineered wetlands
Parks	11.6%	Partner with DPR to integrate green infrastructure into capital program
		Continue demonstration projects in partnership with DPR
		Swales; permeable pavement; engineered wetlands
Schools	1.9%	Integrate stormwater management into capital program in partnership with DOE
		Rooftop detention; green roofs; subsurface detention and infiltration
Vacant lots	1.9%	Grant programs
		Potential sewer charge for stormwater
		Rain gardens; green gardens
Other public properties	1.1%	Integrate stormwater management into capital programs
		Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels; permeable pavement
Other existing development	48.0%	Green roof tax credit
		Sewer charges for stormwater
		Continue demonstration projects and data collection
		Rooftop detention; green roofs; subsurface detention and infiltration; rain barrels or cisterns; rain gardens; swales; street trees; Greenstreets; permeable pavement

For example, multi-family residential complexes generally contain open space areas for recreation and community uses or parking areas for residents. These open spaces provide significant opportunities for porous pavement, bioinfiltration swales and rain gardens, or subsurface detention. New development provides opportunities to incorporate source controls such as rooftop detention, green roofs, subsurface detention, and infiltration technologies.

The remaining 48% of the City's land area is made up of other existing development such as commercial uses under one acre, industrial and manufacturing uses, and transportation and utility uses. DEP will encourage green infrastructure in these areas, but is less likely to rely upon retrofits in these areas to meet its goal of managing runoff from 10% of impervious surfaces.

In anticipation of the development of this Green Infrastructure Plan, and under its obligation to its customers to pursue cost-effective techniques for controlling pollution, DEP has already committed several million dollars towards demonstration projects, modeling, mapping, and further

Table 11: Summary of Green Infrastructure Opportunities, by Watershed

Opportunities	Alley Creek	Bergen and Thurston	Bronx River	Coney Island Creek	East River & Open Waters	Flushing Bay	Flushing Creek	Gowanus Canal	Hutchinson River	Jamaica Bay & CSO Tributaries	Newtown Creek	Paerdegat Basin	Westchester Creek	All Drainage Areas
	% of CSO Drainage Area													
New development & redevelopment	4	5	3	3	5	6	5	7	4	4	5	4	4	**5**
Vacant lots	0.4	1	2	1	2	1	1	2	4	4	2	1	2	**2**
Right-of-way*	24	26	27	30	25	30	26	31	27	28	32	31	27	**27**
DDC projects	*1*	*4*	*0.5*	*0.2*	*1*	*1*	*1*	*0.004*	*1*	*2*	*3*	*0.3*	*1*	***1***
Commercial corridors	-	*0.1*	*0.3*	*0.3*	*1*	-	*0.2*	*1*	-	*1*	*0.2*	*0.1*	-	***1***
Other streets	*17*	*14*	*18*	*20*	*16*	*19*	*18*	*20*	*19*	*17*	*19*	*21*	*19*	***17***
Other sidewalks	*6*	*7*	*8*	*10*	*7*	*9*	*7*	*10*	*8*	*8*	*9*	*10*	*8*	***8***
Multi-family residential complexes	4	0.3	5	0.1	3	3	4	1	5	7	1	1	6	**3**
Commercial development with parking lots	2	0.5	0.5	-	0.3	0.5	1	2	1	1	-	0.1	2	**0.5**
Schools	3	1	2	1	2	2	3	2	2	2	3	2	1	**2**
Parks	14	10	11	2	15	1	15	2	2	9	3	1	5	**12**
Other public properties	0.1	1	2	0.5	-	1	1	15	5	4	1	1	4	**1**
Total	**53**	**45**	**54**	**37**	**53**	**44**	**54**	**61**	**50**	**58**	**47**	**43**	**51**	**52**

*The ROW categories are not additive; they may be greater or smaller than ROW totals due to overlaps or rounding.

analysis. DEP has allocated $5.7 million for various source control demonstration projects, under an environmental benefit program with DEC undertaken in connection with the settlement of an enforcement action taken by New York State and DEC for violations of New York State Law and DEC regulations. These funds include $2.6 million in green infrastructure grants to non-profit and academic organizations to build green infrastructure in the Gowanus and Flushing Bay watersheds.

In addition, DEP has committed $15 million for a green infrastructure planning study, under which it has built or will shortly build several green infrastructure installations on public property to provide valuable information about source control performance over time and under New York City-specific conditions.

Monitoring is a critical component of each pilot project, and is being conducted by frequent and regular site visits, scientific instrumentation, and desktop calculations. DEP has developed a set of monitoring parameters for use by other agencies, environmental and engineering firms, academic institutions and community groups to compile a standardized, robust dataset and inform future policy decisions for green infrastructure implementation citywide. These projects will be closely monitored to test the efficacy of green infrastructure over time.

Under the $15 million planning study, DEP has also dedicated resources to track source controls and to develop a citywide inventory and map. DEP will partner with community groups, environmental stewards, and academic institutions to compile data and develop a meaningful, user-friendly platform for viewing and adding source controls information to the database. Finally, the planning study has supported the modeling for this Green Infrastructure Plan and future refinements to that modeling analysis.

The results of the demonstration projects, tracking efforts, and modeling will be incorporated into watershed-specific LTCPs and the citywide LTCP.

Green Infrastructure Fund and Task Force

The City is prepared to spend up to $1.5 billion over 20 years, and $187 million in capital funds over the next four years, for green infrastructure and other elements of the Green Infrastructure Plan.

The City will prepare a Green Infrastructure Fund to supply capital and maintenance funds for the incorporation of green infrastructure in planned capital projects such as roadway reconstructions. These resources will ensure that implementation of the Green Infrastructure Plan starts incrementally, and that the City will immediately obtain the benefits of green infrastructure that will continue to accrue over time. DEP will also leverage additional resources that can be freed -up by deferring the design and construction of inefficient grey infrastructure investments. These commitments depend, of course, upon acceptance by DEC and credit given to the Green Infrastructure Plan towards meeting the City's present and future regulatory commitments.

DEP will also pursue other funding sources such as Clean Water State Revolving Funds and federal funds for green infrastructure, private funds, ecological restoration funding from the Army Corps of Engineers and other governmental partners, and stewardship and other resource commitments from community and civic groups. These amounts could be substantial. DEP expects there to be approximately $30 million a year in the Clean Water Act State Revolving Fund Green Reserve, based on recent funding levels. Already, there are $20 million in green infrastructure projects underway in New York City that are funded by the American Recovery and Reinvestment Act (ARRA). To spend these resources in the most effective way, the Green Infrastructure Task Force will identify opportunities for including green infrastructure in the scope of agencies' planned capital programs.

This Fund will be used by a Green Infrastructure Task Force comprised of city agencies, and led by the Mayor's Office and DEP. The Green Infrastructure Task Force will include various agencies with experience in planning, designing, and building cutting-edge stormwater management techniques with the goal to manage runoff from 10% of the impervious surfaces in 13 combined sewer watersheds. For example, the Department of Education is a leader in blue roof design and construction with 14 school additions currently detaining stormwater through controlled flow roof drains, and another 15 blue roofs to be constructed this year. The Department of Design and Construction has designed the Queens Botanical Garden, an internationally known example of green infrastructure, while a new DEP maintenance facility designed by DDC will harvest rainwater from a roof system and will store it in underground cisterns for re-use in washing trucks. DDC has also published several manuals on incorporating sustainable design into infrastructure and buildings.

The Department of Transportation has incorporated green infrastructure into its Street Design Manual and several of its designs for traffic calming measures and other enhancements. And the Department of Parks and Recreation pioneered the Greenstreets program and has designed enhancements that allow stormwater to be stored in roadway greening projects and to be incorporated into playground features.

The Task Force would develop approved specifications for green infrastructure to streamline design and permitting processes. DEP has already collaborated with other agencies to develop green infrastructure designs for demonstration projects in the right-of-way. As a result, approved specifications for design features such as curb cuts and catch basins are readily available to DDC, DOT, DPR and other agencies for their incorporation in future right-of-way projects.

The Task Force would be charged with proposing an annual spending plan for DEP's consideration. The Task Force would prioritize the selection of projects and develop and implement green infrastructure plans for specific watersheds. These plans would provide a strategic road map for achieving widespread green infrastructure penetration in high priority areas based on the modeled benefits and costs of the Green Infrastructure Plan.

The Green Infrastructure Task Force will be supported by a dedicated DEP staff of engineers, landscape architects, and planners with experience in the design and construction of green infrastructure.

From 2010 to 2013, the City will:

- Prepare the Green Infrastructure Fund.
- Establish the Green Infrastructure Task Force.
- Develop approved specifications for green infrastructure in commonly-used applications.
- Streamline design and permitting processes for the incorporation of green infrastructure in public projects.
- Engage in watershed-level planning to develop annual spending plans for green infrastructure.

Stormwater performance standard and opportunities in new development

New development represents a significant opportunity for citywide implementation because source controls can be readily incorporated into design and can be built at a relatively small, incremental cost above overall construction costs. DEP has developed a proposed performance standard for new development that would require a stricter stormwater runoff release rate into the sewer system. The performance standard would encourage use of several types of stormwater management technologies to provide developers, engineers, and architects with flexible, cost-effective alternatives.

The performance standard was identified as a key implementation strategy in the Mayor's *Sustainable Stormwater Management Plan* and was endorsed by the Green Codes Task Force in its 2010 Report. DEP will begin stakeholder outreach to obtain input on proposed rule language in Fall 2010 prior to initiating the City Administrative Procedure Act (CAPA) promulgation process. Upon adoption, the performance standard would be incorporated into the Rules of the City of New York (RCNY).

Proposed stricter release rates could be met by rooftop or subsurface systems (Figure 14). Detention systems would continue to be a key strategy for on-site stormwater management due to New York City's spatial and subsurface conditions, and to ensure the protection of the city's sewer system. However, design guidelines would be provided to the development community to encourage open-bottom detention systems that would allow for infiltration, where feasible. Approvable systems would include blue roofs, green roofs, detention tanks, gravel beds, storm chambers, and perforated pipes. DEP and DOB are currently developing design guidelines and criteria for each of the approvable systems to assist the development community in selecting the appropriate system and achieving the performance standard.

Figure 14: Potential Gravel Bed to Control Runoff from New Development

Significantly stricter runoff release rates for new development would slow the flow of stormwater into the sewer system, thereby freeing up storage capacity. For a half-acre property, the proposed performance standard would reduce short-term (6-minute) peak discharges into the system by 80% to 90%, and would reduce longer term (1-hour) peak discharges into the system by 20% to 50%. The benefits would accrue incrementally over time as the acreage of new developments grows within a drainage area.

DEP evaluated prototypical lots to determine potential site constraints, if any, for new development that would comply with the proposed rule. Subsurface detention systems under the new rule would require a larger footprint and shallower depths than current systems, due to the stricter release rate. In addition, buffer areas for buildings and property lines would be required for any infiltration technologies. In a 10,000 sq. ft. prototypical lot, approximately 75% of the lot is available for a building footprint despite the increase in surface area compared to a detention tank under existing rules. If a developer sought to use the entire building lot for development, then other alternatives would be available, such as blue and green roofs, and tanks in basements.

In addition to the analysis of potential site constraints, DEP evaluated the costs of the proposed rule compared to total development costs (Table 12). By providing a range of detention options, developers could select the most cost-effective option based on topography, subsurface conditions, and building design and footprint. Subsurface tanks and rooftop detention systems, or blue roofs, are considered to be the low-cost options for new buildings.

From 2010 to 2013, DEP will:

- Complete its stakeholder outreach (Fall 2010).
- Adopt a performance standard rule and issue a design manual (Winter 2010 / 2011).
- Encourage the adoption of green infrastructure in new developments.
- Expand its site connection permit review unit to provide advice and guidance about ways to meet the performance standard with green infrastructure techniques.

Table 12: Costs for Proposed Stormwater Performance Standard*

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Building Type	Low-Density Residential		Office Building Medium-Density Residential		Office Building Medium-Density Residential		Big Box Retail	
Lot Size	5000		10,000		20,000		43,560	
Zoning	R4		R6A/C4-2A		R6A/C4-2A		C8-1	
FAR	0.9		3		3		1	
Building Footprint, sq ft	1,500		6,000		12,000		21,780	
Development Size, sq ft	4,500		30,000		60,000		43,560	
Runoff Coefficient	0.7	0.9	0.7	0.9	0.7	0.9	0.7	0.9
Proposed Rule Compliance Cost	$20,000-26,000	$23,000-27,000	$35,000-37,000	$43,000-47,000	$59,000-80,000	$71,000-97,000	$98,000-127,000	$106,000-167,000
Increment of Proposed Rule	$3,000-9,000	$4,000-9,000	$15,000-17,000	$15,000-19,000	$32,000-53,000	$32,000-58,000	$44,000-73,000	$31,000-93,000
Proposed Rule ÷ Total Development Cost* (%)	1.1-1.4%	1.3-1.5%	0.3%	0.4%	0.3%	0.3-0.4%	0.6-0.7%	0.6-1.0%

* Total development cost is based on $400 per square foot. Does not include design and construction management costs; costs based on tanks, gravel beds, and combination tank and blue roof systems.

Opportunities and initiatives in existing development

Much of New York City is already built, and for that reason, DEP is piloting green infrastructure that can be retrofitted on existing development such as rain barrels and rooftop detention.

Table 13: DEP Retrofit Demonstration Projects

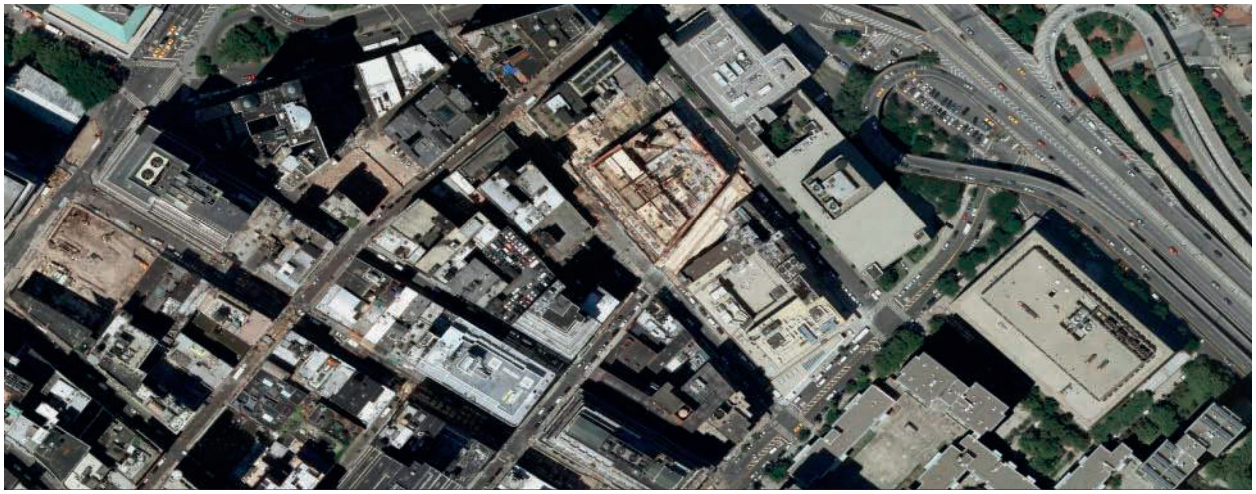
Green Infrastructure Pilot	Location	Type	Status	Construction Completion
Rain Barrel give-away program	Jamaica Bay	1,000 rain barrels	Completed	2008-2009
MTA parking lot*	Jamaica Bay	Parking lot detention/ bioinfiltration	In construction	Fall 2010
Blue roof/green roof comparison*	Jamaica Bay	Blue/green roofs	Completed	August 2010
DEP rooftop detention	Newtown Creek	Blue roof	Design	Fall 2010
NYCHA residential retrofit	Bronx River	Variety of on-site BMPs	Design	Fall 2010
DOT parking lots*	Jamaica Bay	Parking lot detention/ bioinfiltration/porous pavement	Design	Fall 2010

* This project was undertaken in connection with the settlement of an enforcement action taken by New York State and DEC for violations of New York State Law and DEC regulations.

Rooftops

Installing source controls on existing rooftops is a primary implementation strategy because rooftops comprise approximately 28% of New York City's total impervious surface area (Figure 15). Two alternatives to conventional rooftop surfaces are being tested by DEP and partner agencies: green roofs and blue roofs.

Figure 15: Rooftops in Downtown Manhattan



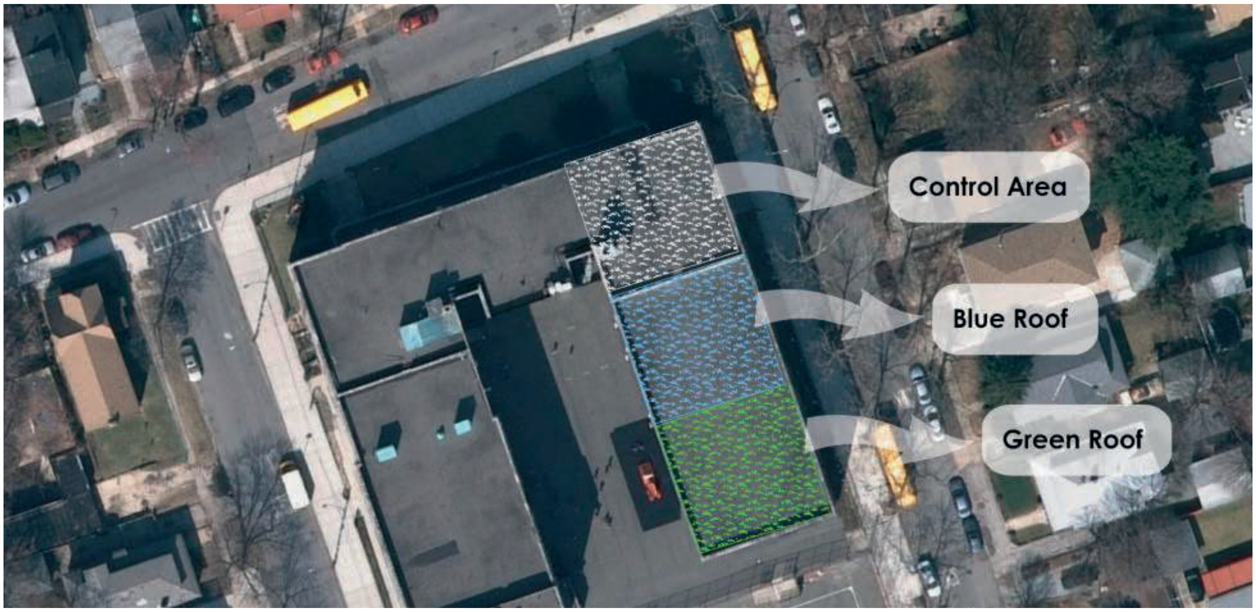
Green roofs

Green roofs consist of a vegetative layer that grows in a specially-designed soil, which sits on top of a drainage layer. The green roof at the Paerdegat Basin CSO Detention Facility is shown in Figure 16. Green roofs are more costly than conventional roofs but they are capable of absorbing and retaining large amounts of stormwater. In other cities, green roofs on just 10% of buildings are projected to reduce runoff by 2.7% for the region and 54% for individual buildings. In addition, green roofs provide sustainability benefits such as absorbing air and noise pollution, rooftop cooling by reducing ultraviolet radiation absorption, creating living environments, and increasing the quality-of-life for residents.

Figure 16: Green Roof at DEP's Paerdegat Basin CSO Detention Facility

To encourage installation of green roofs, the City provides a Green Roof Tax Abatement from City property taxes of $4.50 per square foot of green roof, up to $100,000. Property owners qualify with the installation of a green roof on at least 50 percent of a roof, and preparation of a maintenance plan to ensure the viability of the vegetation and expected stormwater benefits. The program is currently scheduled to run until 2013.

Figure 17: Blue Roof / Green Roof Comparison Study



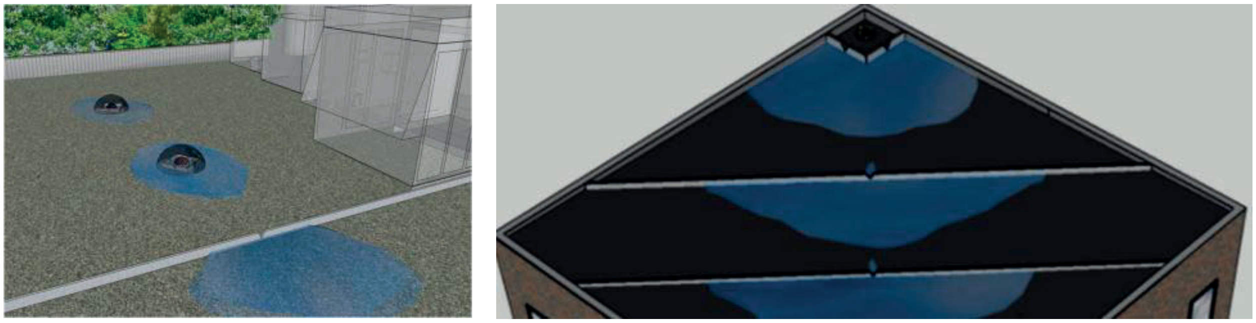
Blue roofs

Blue roofs are non-vegetated source controls that detain stormwater. Weirs at the roof drain inlets can create temporary storage and gradual release of stormwater on new, flat roofs.

In partnership with DOE, DEP will design, construct, and evaluate both the blue roof and green roof technologies on PS 118 in Queens (Figure 17). Data from the study will be collected to compare the stormwater management performance of green, blue, and control roofs during a three-year monitoring period. Because all three surfaces will be on the same building, this pilot will compare costs and benefits under similar environmental conditions.

DEP is also testing technologies that would allow for rooftop detention on existing sloped roofs; these technologies include trays, check dams, and silt socks. A DEP repair yard in the Newtown Creek watershed will host a blue roof pilot to compare these technologies (Figure 18).

Figure 18: Pilot - Blue Roof Retrofit Project



Rain barrels

Rain barrels can help reduce stormwater runoff that enters the City's sewer system. DEP distributed 1,000 rain barrels in the spring and summer of 2008 and 2009 in Queens and Brooklyn. The objective of the demonstration project was to determine homeowners' interest and ability to install and maintain rain barrels, and to use stored rainwater for irrigation (Figure 19).

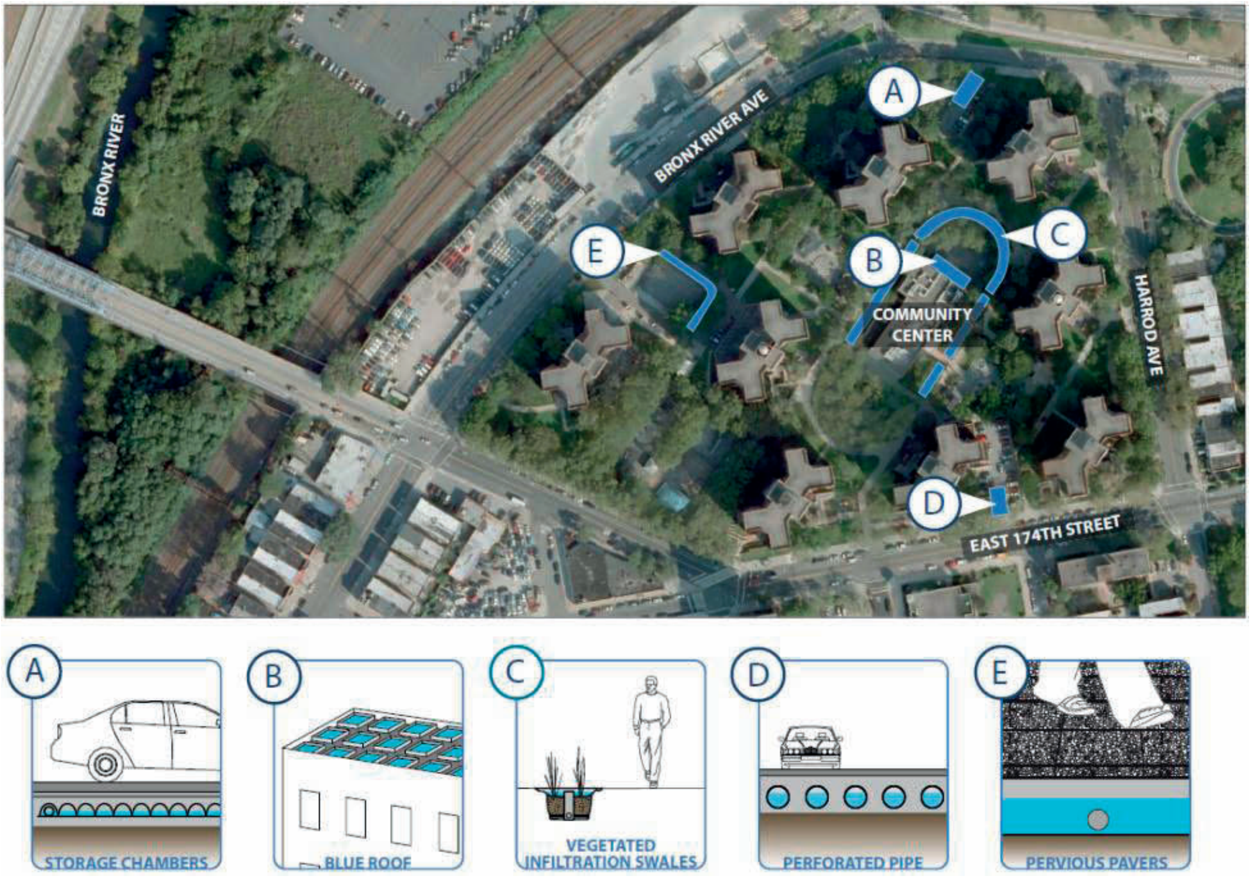
The rain barrels connect directly to the existing downspout to collect water for watering lawns and gardens, which often account for up to 40% of a household's summer water consumption in areas with single-family homes. Using the stored water can reduce the demand on the City's water supply during the summer's hottest days.

Figure 19: Rain Barrel Distribution and Workshops

High density residential complex retrofit

Multi-family residential complexes make up approximately four percent of all combined sewer watershed area. In partnership with NYCHA, DEP will construct multiple green infrastructure elements in a high-density residential housing complex (Figure 20). On the roof of a community building, DEP will test a modular tray system for detaining stormwater storage. Around the complex, two parking lots will be reconstructed with different source control technologies: a perforated pipe system that stores up to 600 cubic feet of stormwater and a subsurface storage chamber that stores up to 780 cubic feet of stormwater. A system of bioswales and bioretention areas will manage stormwater runoff from the sidewalk area. And a 150-foot by 8-foot section of sidewalk will be replaced with porous concrete drained by a stone reservoir that provides delayed discharge for stormwater.

Figure 20: Pilot - Model High Density Housing Retrofit

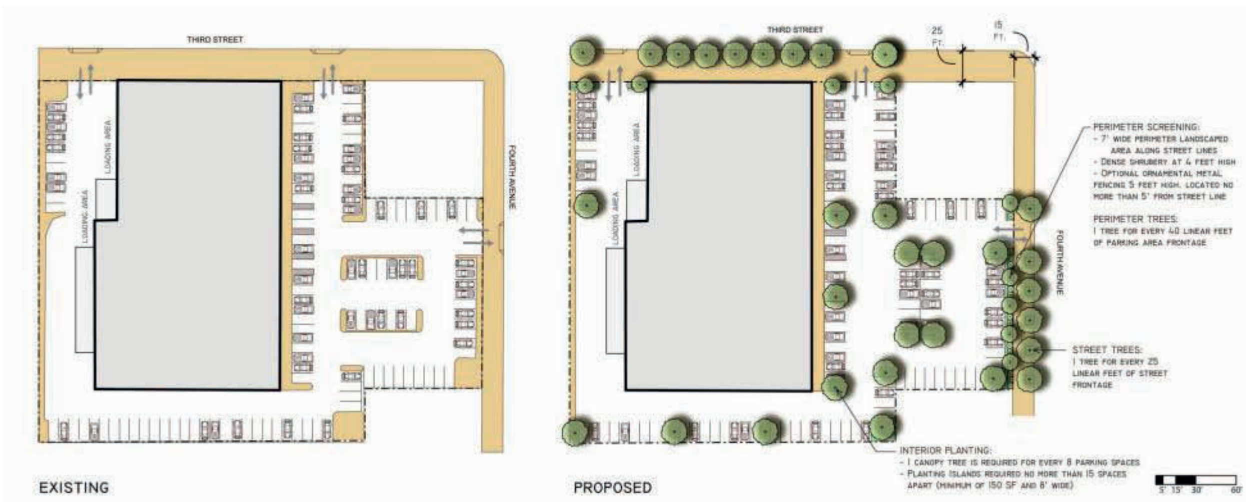


Parking lots

Parking lots make up 6% of New York City's impervious area. Design alternatives to reduce stormwater runoff from parking lots include porous asphalt, catch basins, bioinfiltration swales, and subsurface detention and infiltration systems. DEP is partnering with DOT, DCP, and MTA to encourage green infrastructure installations in parking lots. Three parking lot pilots currently in design will include bioinfiltration swales, subsurface stormwater chambers, and porous pavement.

In addition to public demonstration projects, the City enacted zoning amendments in 2008 that require commercial and community facility parking lots to construct interior and perimeter landscaping that acts as stormwater bioretention cells (Figure 21). If similar development trends continue for the next 20 years, the new zoning rules would apply to approximately 300 acres of otherwise impervious surfaces.

Figure 21: DCP Zoning Requirements for Parking Lots



Sewer charges for stormwater

DEP is piloting a sewer charge for stormwater. Ultimately, such a charge could provide a dedicated revenue stream for stormwater expenditures, to create public awareness around stormwater issues, and to encourage source controls. New York City's water and sewer use charges are currently based on the volume of potable water consumed, and there is little correlation between the stormwater generated by a property and consumption fees. Yet as stormwater management and regulatory requirements have evolved, stormwater expenditures have increased over time: DEP's stormwater-related expenditures comprise up to 20% of its budget including capital construction of CSO abatement facilities, combined and storm sewers, upgrades at WWTPs, green infrastructure, restoration, and flood control projects as well as expenses to plan, operate and maintain these facilities. These expenditures are projected to continue increasing to meet more stringent regulatory standards. To pay for rising stormwater expenditures, separate stormwater charges are used by over 500 utilities – including Philadelphia, Washington DC, San Diego, San Antonio, San Jose, Milwaukee, Detroit, St. Louis, Columbus, Seattle and Wilmington.

The pilot charge would apply to approximately 350 stand-alone parking lots that currently have no water service and therefore do not pay for wastewater services. Parking lots will be billed a sewer charge for stormwater of $0.05 per square foot of property area, a figure derived from DEP's stormwater-related capital and expense budget items. The pilot will generate approximately $0.5 million. A credit program will be in place when DEP implements this charge to incentivize approvable green infrastructure technologies.

From 2010 to 2013, DEP will:

- Launch and assess a limited pilot of sewer charges for stormwater for parking lots.
- Analyze its capital and operating budgets to isolate stormwater-related costs.
- Adopt a new billing system that will include capacity for sewer charges for stormwater.
- Map impervious surfaces throughout the City to provide a basis for a sewer charges based on impervious area.

Stormwater grant program

DEP established a $2.6 million stormwater grant program for the Flushing Bay and Gowanus Canal watersheds for stakeholder groups to build and monitor green infrastructure, under an environmental benefit program with DEC. DEP received several proposals and, in June 2010, DEP awarded grants to the highest rated proposals, which are:

- Manhattan College was awarded $660,000 for the installation of a modular green roof project on New York Hospital that is designed to control runoff from 1-1.5 inches of rainfall on a 0.5 acre roof.
- Columbia University was awarded nearly $389,000 for a Greenstreets stormwater capture system in Rego Park that will replace nearly 2,500 sq. ft. of impervious surface with permeable pavers and vegetation to capture runoff from a three acre watershed.
- The Regional Plan Association was awarded $600,000 for Sponge Park™ bioretention basins under the Long Island Expressway and near the Van Wyck Expressway that have a combined capacity to store approximately 204,000 gallons from a two-inch rain event.

- The Gowanus Canal Conservancy was awarded $583,000 for the 6th Street Green Corridor Project, which will build seven curbside swales and will capture approximately 40% of the runoff generated by over 45,000 sq. ft. of street and sidewalk surfaces.
- Unisphere, Inc. was given roughly $386,000 for treatment wetlands and rain gardens that will capture over 72,000 gallons of runoff for each 1-1.5 inch rain event.

Opportunities and initiatives in the right-of-way

The right-of-way comprises roughly 28% of all New York City CSO drainage areas, more area than any other category of City-managed land. Most of these surfaces are made of impervious asphalt and concrete and quickly funnel stormwater into the combined sewer system. The streets, sidewalks, and medians of New York City create many opportunities to incorporate green infrastructure into routine right-of-way reconstruction. DEP has partnered with DOT, DDC, and DPR to design, install, and monitor right-of-way demonstration projects.

Swales and street trees

DEP has constructed five enhanced tree pits and six streetside infiltration swales to evaluate their performance, maintenance requirements, and total costs. The design of each installation

Table 14: NYC Right-of-Way Demonstration Projects

Green Infrastructure Pilot	Sponsoring Agency	Location	Type	Status	Construction Completion
Greenstreets with stormwater capture (completed)	DPR	Manhattan (3) Bronx (5) Brooklyn (5) Queens (1) Staten Island (1)	ROW - 15 sites	Completed	2006-2009
Street trees with stormwater capture (NYSERDA funded)	DPR	Bronx	Enlarged tree pits (72 trees) with pipe inlets	Completed	2009
5 tree pits/6 swales*	DEP	Jamaica Bay	Right of Way (ROW)	Completed	2010
Greenstreets with stormwater capture (ARRA funded)	DPR	Queens	ROW - 4 sites	Completed	2010
East Houston Street reconstruction	DOT/DDC	Manhattan	ROW - 1 site	Ready to install in summer	2010
BMP grant program	DEP	Flushing and Gowanus	Variety of ROW and on-site BMPs	To be awarded in summer	Proposal dependent
North and South Conduit	DEP	Jamaica Bay	Detention/bioinfiltration	Design	September-November 2010
Greenstreets with stormwater capture (ARRA funded)	DPR	Bronx (4) Queens (13) Staten Island (5)	ROW - 22 sites	Design	2010-2012
Albert Road reconstruction	DOT/DDC	Queens	ROW - 1 site	Design	2015
Belt Parkway Bridges*	DEP	Jamaica Bay	Swales	To be installed after bridge construction complete	TBD
Astor Place reconstruction	DOT/DDC	Manhattan	ROW - 1 site	Design	TBD
Greenstreets with stormwater capture	DPR	Queens (1) Staten Island (1)	ROW - 2 sites	Design	TBD
Greenstreets with stormwater capture (w/ Columbia University)	DPR	Queens	ROW - 1 site	Design	TBD

* This project was undertaken in connection with the settlement of an enforcement action taken by New York State and DEC for violations of New York State Law and DEC regulations.

Figure 22: Pilot – Streetside Enhanced Tree Pits and Infiltration Swales

Commercial Corridor:
Pre-Construction

Commercial Corridor:
Post-Construction Enhanced Tree Pit

Low Density Residential Street:
Pre-Construction

Low Density Residential Street:
Post-Construction Infiltration Swale

Low Density Residential Street:
Pre-Construction

Low Density Residential Street:
Post-Construction Enhanced Tree Pit

involves a large green space in the sidewalk – i.e., 5 feet by 20 feet for enhanced tree pits and 5 feet by 40 feet for infiltration swales – with curb cuts to channel runoff from the street into the installation and allow stored stormwater or overflow to travel back to the street for conveyance to storm sewer catch basins (Figure 22). Specifications for the curb cuts and attached plate, developed specifically for the demonstration projects, were reviewed and approved by DOT, DPR, and DEP and are readily available for future applications. The enhanced tree pits were constructed with additional subsurface storage technologies; as a result, stormwater will be stored for an extended period of time to allow for infiltration and to provide a reservoir of water for the trees. Each of these pilots will be monitored for a period of three years.

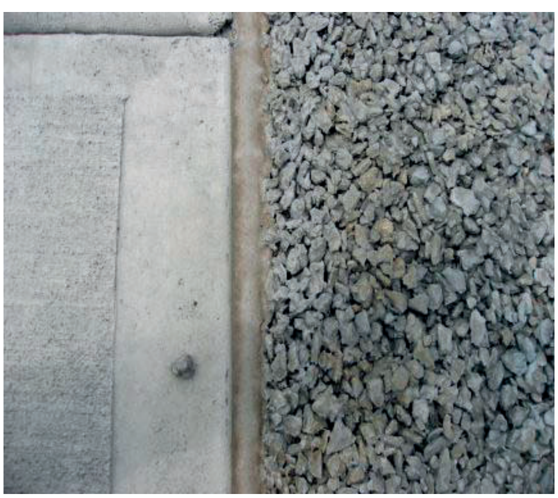
Greenstreets

Launched by DPR and DOT in 1996, the Greenstreets program is a citywide program to convert paved, vacant traffic islands and medians into green spaces filled with shade trees, flowering trees, shrubs, and groundcover. Many Greenstreets installations use vegetated controls such as bioswales and tree pits to use stormwater, and some include a gravel layer to provide more storage volume. At least 30 new Greenstreets with stormwater capture designs have been designed or constructed throughout the City within the past five years. As a result of a $2 million ARRA grant, DPR is building at least 26 more Greenstreets with stormwater capture.

Permeable concrete and asphalt pavement

Permeable concrete and asphalt pavement have more void space than conventional treatments. Their porous surfaces capture rainwater and allow it to percolate to the ground or a catch basin. While the demonstration projects will test whether such materials can last in our climate, evidence from other northern areas suggests that snow melts quicker on pervious surfaces and does not buckle and crack. These surfaces are suited for many uses including sidewalks, parking lots, low traffic residential streets, recreation areas, and schoolyards. In addition to installations of porous pavement at the NYCHA housing pilot and the parking lot pilots discussed above, DEP has installed 6,000 square feet of porous concrete adjacent to the Paerdegat Basin CSO Detention Facility and is piloting permeable asphalt at the English Kills Aeration Facility. DEP will monitor the installations to determine maintenance requirements.

Figures 23: Pilot - Porous Concrete Sidewalk at DEP's Paerdegat Basin CSO Detention Facility



Opportunities and initiatives in parks

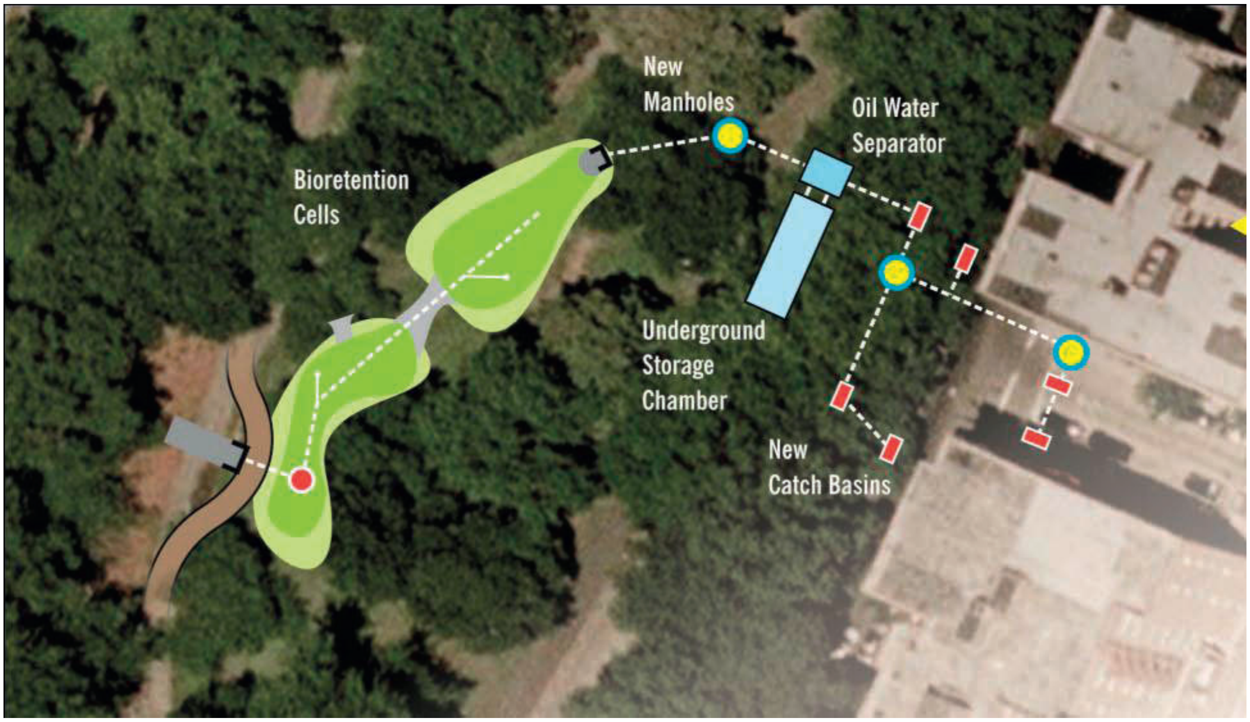
In partnership with DPR, DEP has been able to design and install various green infrastructure pilot projects around the city.

Table 15: NYC Park Demonstration Projects

Green Infrastructure Pilot	Sponsoring Agency	Location	Type	Status	Approximate Construction
Shoelace Park (224th st)	DEP	Bronx River	Detention/bioinfiltration	Design	September - November 2010
Starlight Park	DPR/NYSDOT	Bronx	Rain gardens (11)	Design	2010
Shoelace Park (211th st)	DPR	Bronx River	Bioswale	Construction	2010
Shoelace Park (226th st)	DEP	Bronx River	Detention/bioinfiltration	Proposed	2012
Shoelace Park (219th st)	DPR	Bronx River	Rain Garden	Completed	2009
Last Chance Pond	DPR	Staten Island	Constructed wetlands	Design	TBD
Meadow Lake	DPR	Queens	Wetland restoration and bioswales and rain gardens	Design / Pre-Contract	2012
Hunters Point South Waterfront Park	EDC/DPR	Queens	ROW, swales	Design	TBD

In 2010 the City will design and build source controls, such as detention and bioinfiltration systems, in Shoelace Park, in the Bronx River watershed. The City is designing stormwater controls in five other parks to include green infrastructure such as constructed or restored wetlands, bioswales, and rain gardens.

Figure 24: Pilot - Detention and Bioinfiltration at Shoelace Park



Watershed-level opportunities, performance, and costs

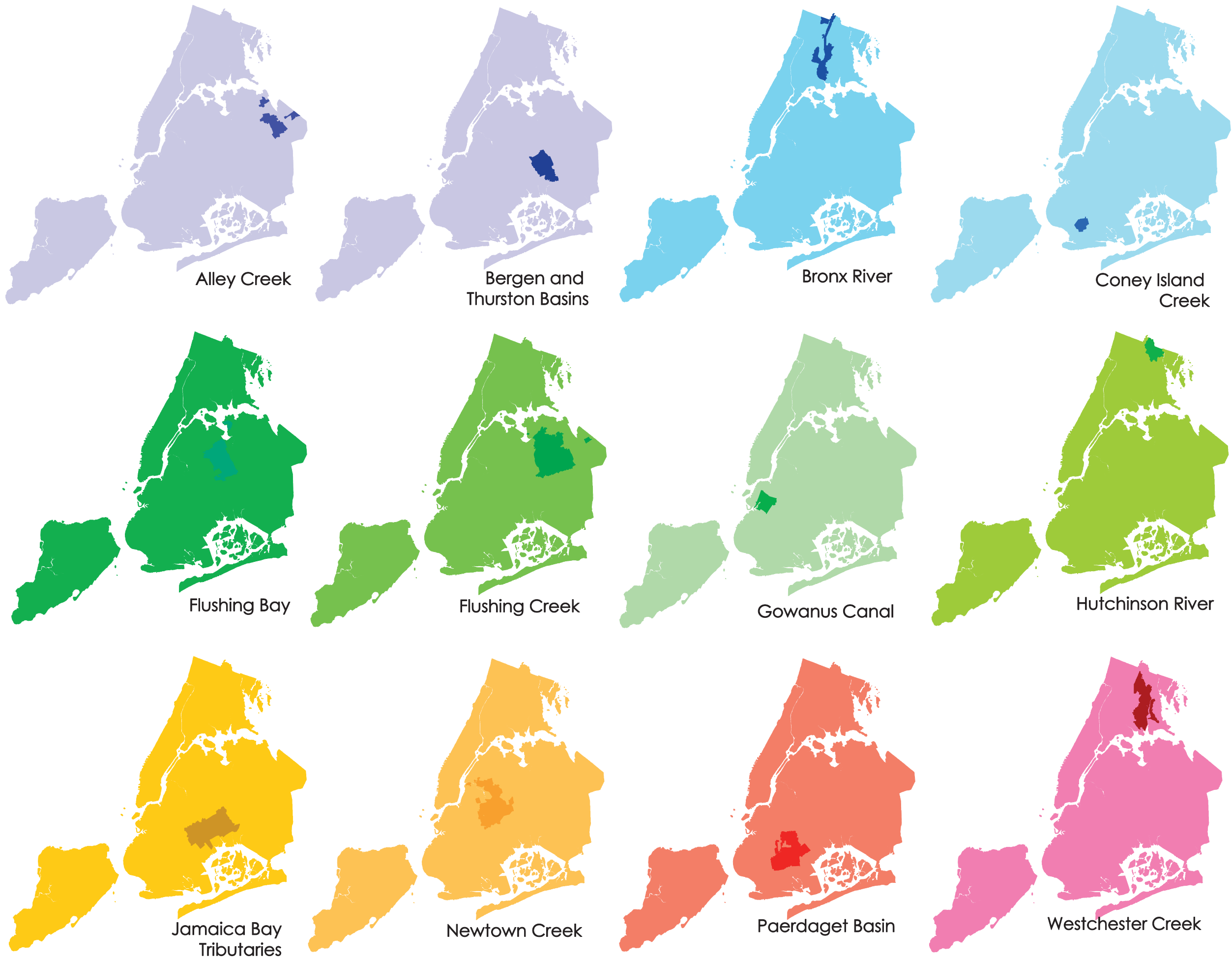
Watersheds are the critical unit of analysis for controlling CSOs. DEP is required to develop LTCPs on a watershed basis, and consequently the Green Infrastructure Task Force will seek to direct the Green Infrastructure Fund to public projects in the watersheds where CSO reductions will have the greatest impact. DEP has already started the necessary watershed-level planning, as demonstrated in the following section on watershed-specific opportunities for green infrastructure.

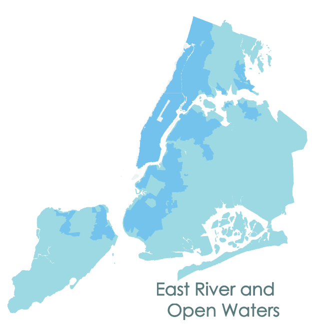
The opportunities tables on the first page of each specific watershed identify relevant facts such as impervious cover, existing land uses, trends in new development, right-of-way opportunities, DEC and ecological classifications, existing water and shoreline uses, and socio-economic statistics. A cost-benefit analysis provides details on watershed-specific CSO volume reductions that would be achieved through a Grey Strategy or a Green Strategy, and the total and per gallon capital costs associated with these reductions. The watershed-specific analyses indicate significant variations in costs and benefits that reflect the underlying land uses, geographic sizes, and DEP infrastructure.

The following, facing pages in each watershed section contain an aerial photograph of each watershed. The combined sewer watershed boundaries are shown on each map. All maps are accompanied with pie-charts that allow the user to quickly quantify land uses geographically represented in the map (follow the map legend for corresponding colors in the pie-chart). These geographic analyses are the bases for the highlighted green infrastructure opportunities tables in the beginning of each watershed section. To estimate future new development, DEP used the Department of Finance Real Property Assessment, and Department of City Planning MapPLUTO databases to analyze the underlying land uses and to estimate recent development trends. New development and vacant lots are identified in connection with proposed on-site stormwater performance standards. To identify opportunities to build green infrastructure on public property, the maps show schools, parks, multi-family complexes, and other areas where the agency can increase its ongoing partnerships to build demonstration projects with DOE, DPR, and NYCHA. To identify green infrastructure opportunities in the right-of-way, DEP obtained data about DDC's planned projects through 2020, including water main and sewer replacements, sidewalk reconstructions, and street reconstructions. The maps also indicate commercial corridors where there are potential partnerships with Business Improvement Districts (BIDs). Commercial developments with parking lots are identified to potentially expand DEP's and other City agencys' current parking lot initiatives.

The maps also show known locations of existing and planned green infrastructure installations based upon current DEP projects, and data provided by Columbia University, Bronx River Alliance, NYC Soil and Water Conservation District, DPR, Mayor's Office of Long-Term Planning and Sustainability, and eDesign Dynamics/Drexel University. DEP is committed to tracking and mapping future green infrastructure installations.

Watershed-level opportunities, performance, and costs





The East River and Open Waters watershed map is not included due to scale.

ALLEY CREEK

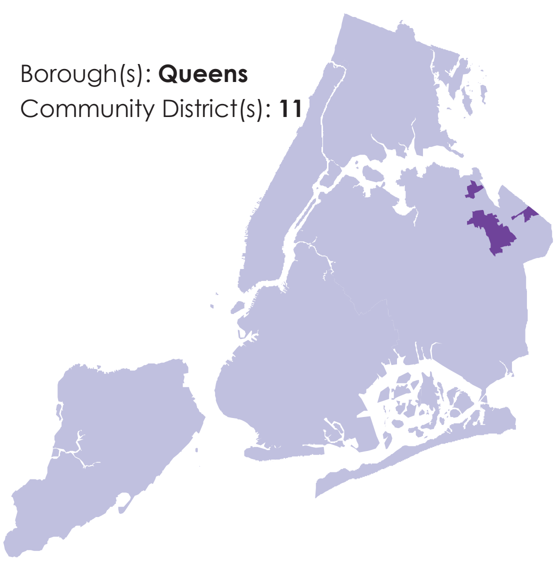
Total Watershed Drainage Area:	**4,879 acres**
Combined Sewer Contributory Area:	**2,292 acres**
Combined Sewer Contributory Impervious Area:	**1,490 acres**
Opportunity Area for Source Controls:	**1,230 acres**

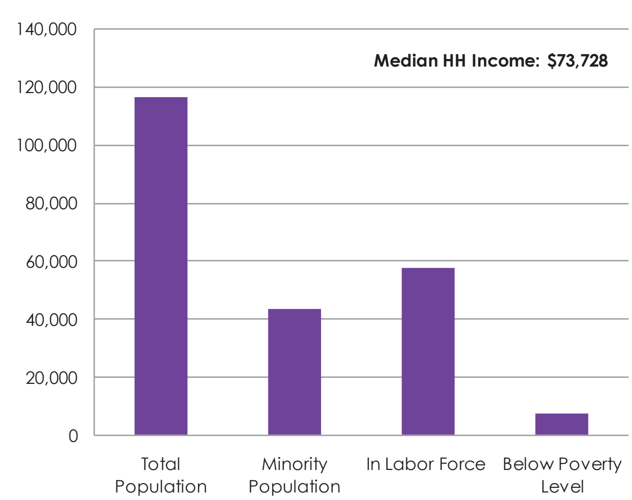
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **53%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	102	4%
Vacant lots	9	0.4%
Right-of-way	569	24%
Planned ROW Projects	17	1%
Other streets	402	17%
Other sidewalks	151	6%
Multi-family residential complexes	105	4%
Commercial development with parking lots	40	2%
Schools	76	3%
Parks	327	14%
Other public properties	2	0.1%
TOTAL	1,230	53%

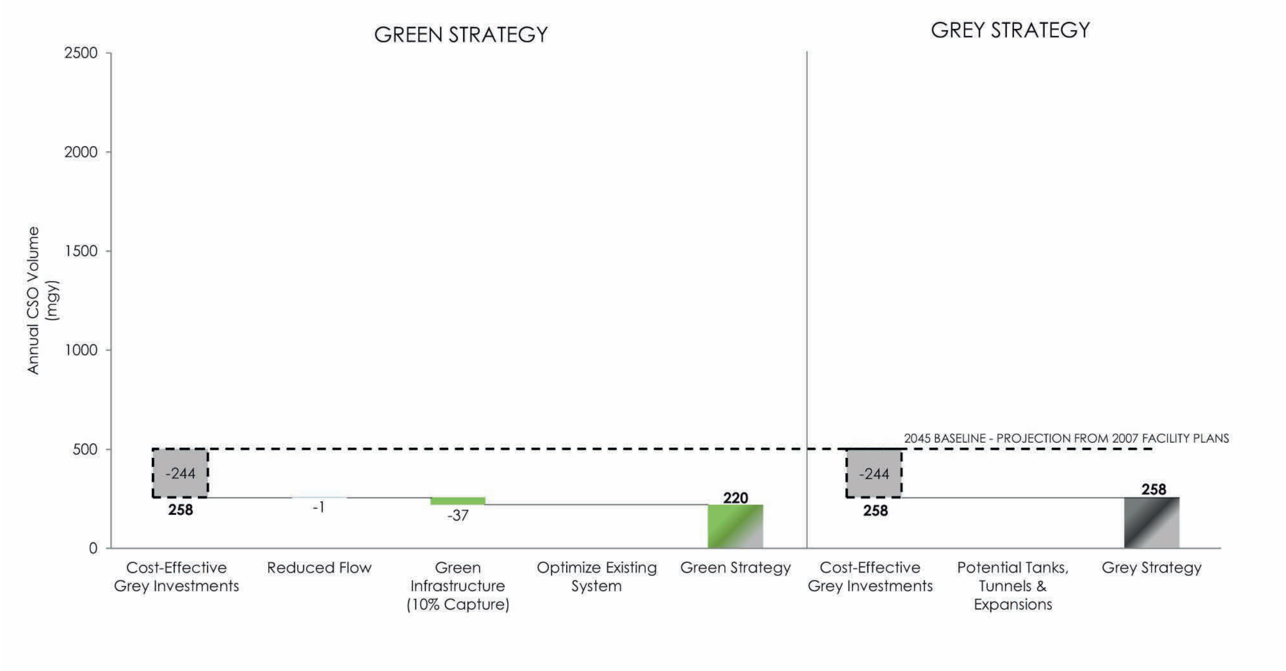
Wastewater Treatment Plant(s):	**Tallman Island**
NYSDEC Classification(s):	**Class I & SB – Primary and Secondary Contact, Bathing and Fishing**
Ecological Classification(s):	**Special Natural Waterfront Area (DCP)**
Significant Coastal Fish & Wildlife Habitats	**Recreational Boating and Fishing**
Existing Water Uses: Shoreline Uses:	**Residential, Recreational, Parkland and Open Space**

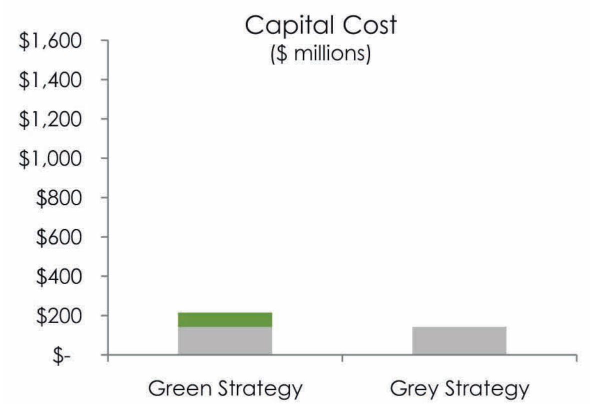
Borough(s): **Queens**
Community District(s): **11**

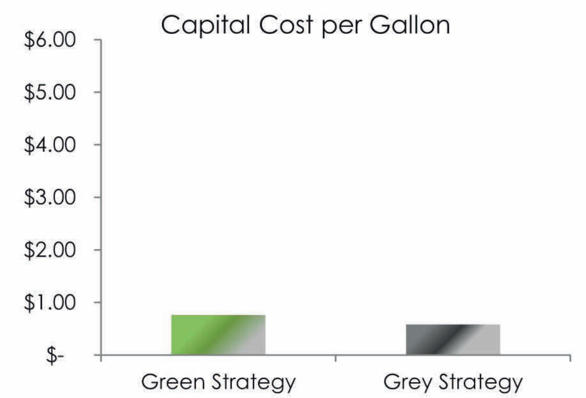




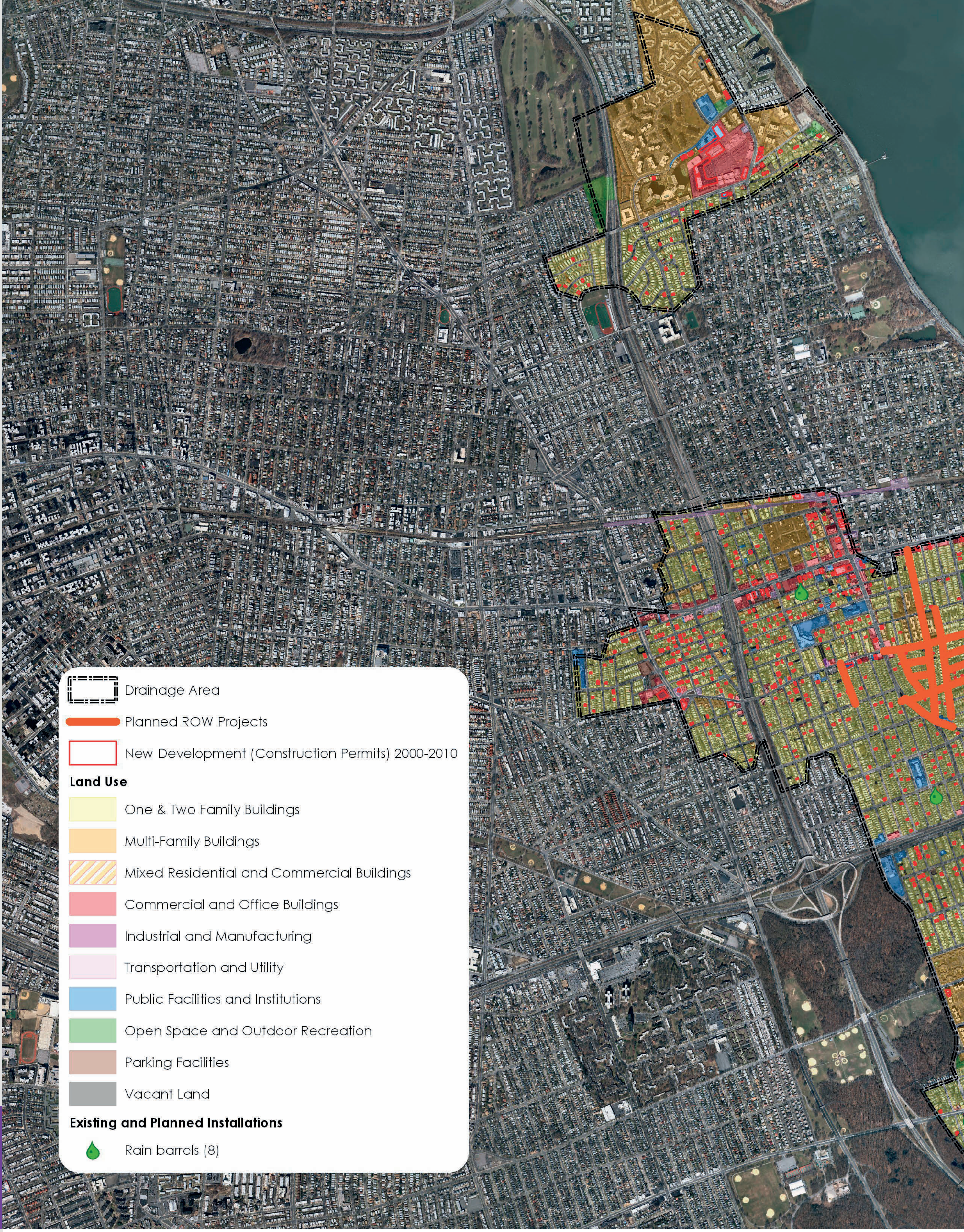
PERFORMANCE AND COSTS







	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Outfall & Sewer System Improvements, CSO Facility	244	$142	$0.58
PLUS Reduced Flow	1	-	-
PLUS Green Infrastructure (10% Capture)	37	$72	$1.96
PLUS Tide Gate Repair and Interceptor Cleaning	NA	NA	NA
Green Strategy Total	**282**	**$214**	**$0.76**
Cost-Effective Grey Infrastructure Investments	244	$142	$0.58
PLUS Potential Tanks, Tunnels & Expansions	NA	NA	NA
Grey Strategy Total	**244**	**$142**	**$0.58**



GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES

0%
1%
18%
43%
6%
1%
0%
4%
1%
26%
0
1,250
2,500
5,000
7,500
10,000
Feet

BERGEN AND THURSTON BASINS

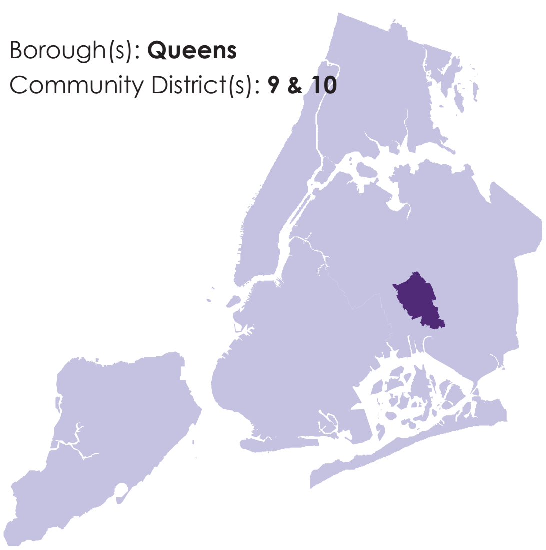
Total Watershed Drainage Area: **22,093 acres**
Combined Sewer Contributory Area: **2,873 acres**
Combined Sewer Contributory Impervious Area: **2,413 acres**
Opportunity Area for Source Controls: **1,297 acres**

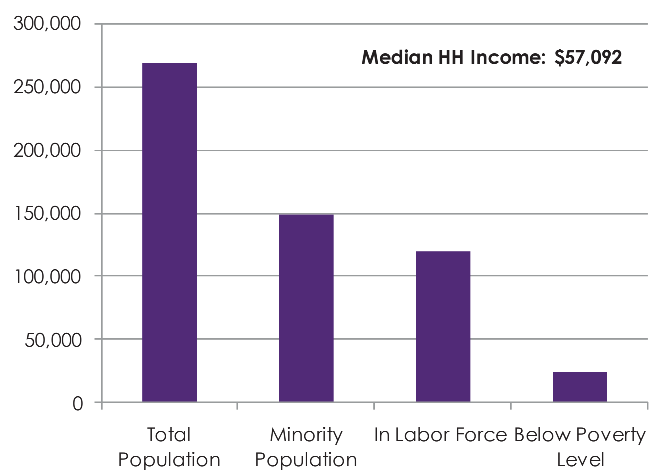
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **45%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	138	5%
Vacant lots	23	1%
Right-of-way	760	26%
Planned ROW Projects	121	4%
Commercial corridors	2	0.1%
Other streets	420	14%
Other sidewalks	218	7%
Multi-family residential complexes	8	0.3%
Commercial development with parking lots	13	0.5%
Schools	24	1%
Parks	293	10%
Other public properties	38	1%
TOTAL	1,297	45%

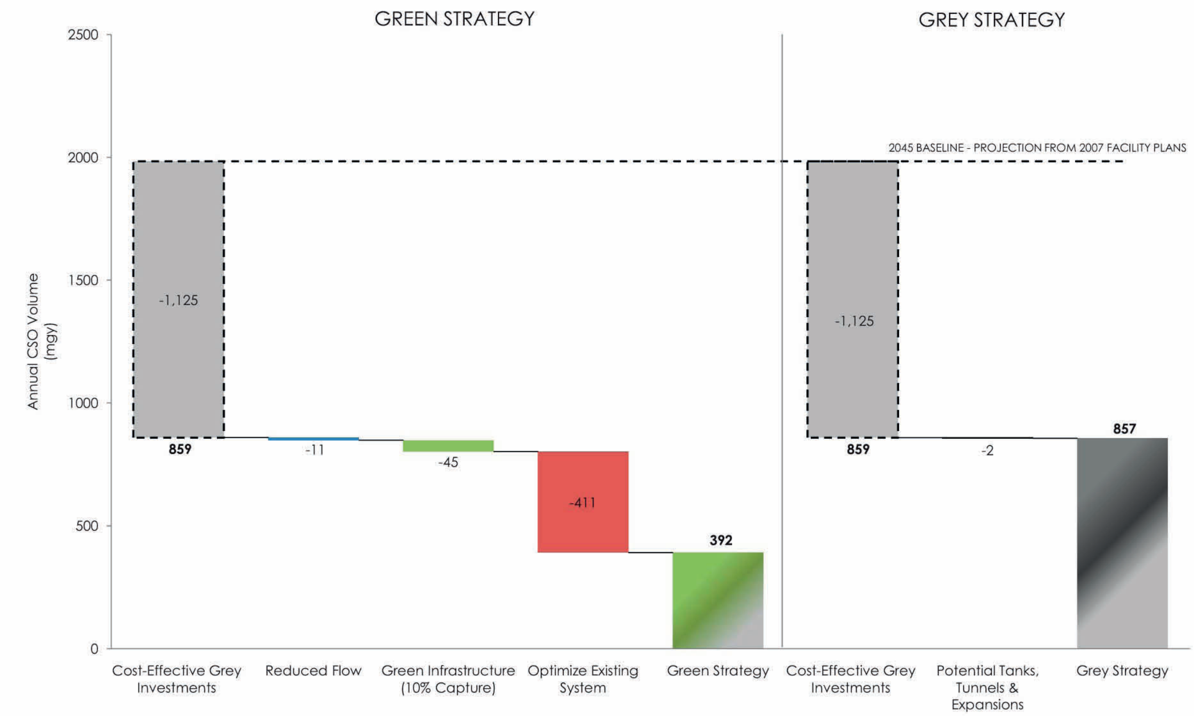
Wastewater Treatment Plant(s): **Jamaica**
NYSDEC Classification(s): **Class I – Secondary Contact, Boating and Fishing**
Ecological Classification(s): **Significant Coastal Fish and Wildlife Habitat Special Natural Waterfront Area (DCP)**
Existing Water Uses: **Commercial Barge Traffic, Recreational Boating and Fishing**
Shoreline Uses: **Residential, Industrial, Commercial, Recreational, Parkland and Open Space**

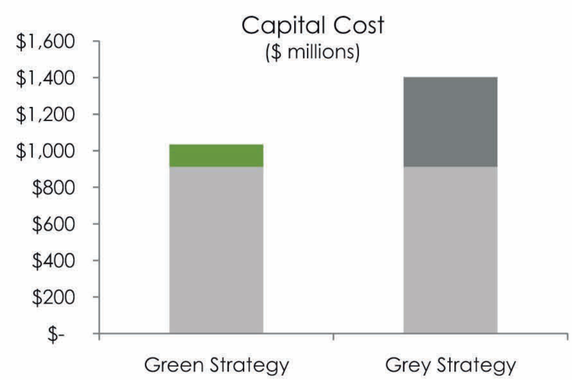
Borough(s): **Queens**
Community District(s): **9 & 10**

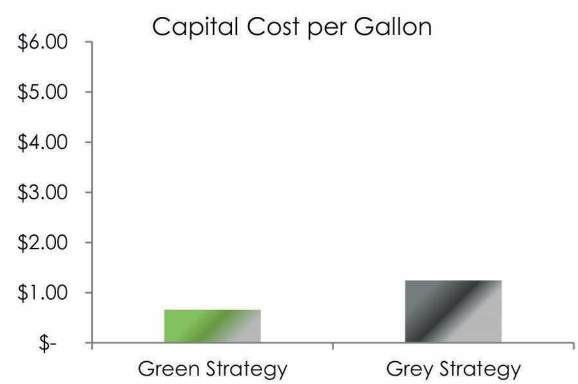




PERFORMANCE AND COSTS







	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Meadowmere & Warnerville DWO Abatement, Sewer System Improvements, Regulator Automation, High Level Sewer Separation in Southeast Queens.	1,125	$912	$0.81
PLUS Reduced Flow	11	-	-
PLUS Green Infrastructure (10% Capture)	45	$121	$2.67
PLUS Tide Gate Repair and Interceptor Cleaning	411	$12.33	$0.03
Green Strategy Total	**1,592**	**$1,046**	**$0.66**
Cost-Effective Grey Infrastructure Investments	1,125	$912	$0.81
PLUS Potential Tanks, Tunnels & Expansions	2	$490	$245.00
Grey Strategy Total	**1,127**	**$1,402**	**$1.24**

GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES


1%
1%
14%
4%
6%
2%
3%
3%
9%
57%
Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Existing and Planned Installations
Rain barrels (12)

BRONX RIVER

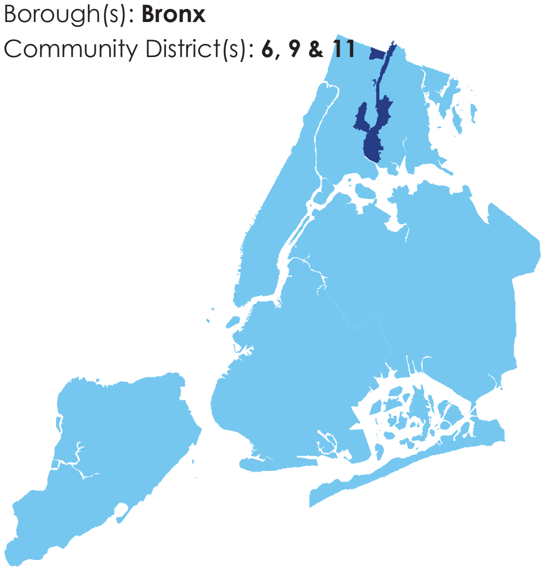
Total Watershed Drainage Area:	**4,160 acres**
Combined Sewer Contributory Area:	**2,842 acres**
Combined Sewer Contributory Impervious Area:	**2,331 acres**
Opportunity Area for Source Controls:	**1,609 acres**

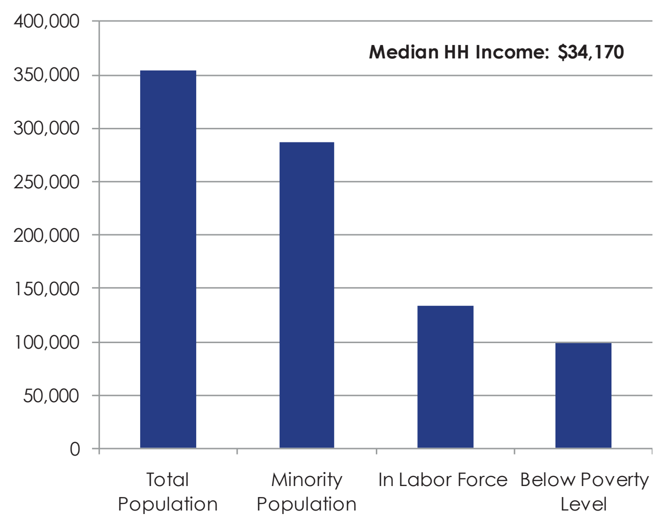
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **54%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	103	3%
Vacant lots	53	2%
Right-of-way	812	27%
Planned ROW Projects	14	0.5%
Commercial corridors	9	0.3%
Other streets	547	18%
Other sidewalks	242	8%
Multi-family residential complexes	161	5%
Commercial development with parking lots	14	0.5%
Schools	65	2%
Parks	337	11%
Other public properties	64	2%
TOTAL	1,609	54%

Wastewater Treatment Plant(s):	**Hunts Point**
NYSDEC Classification(s):	**Class I – Secondary Contact, Boating and Fishing**
Ecological Classification(s):	**Special Natural Waterfront Area (DCP)**
Existing Water Uses:	**Pedestrian and Bicycle Trailways, Recreational Boating**
Shoreline Uses:	**Industrial, Residential, Recreational, Parkland and Open Space, Commercial**

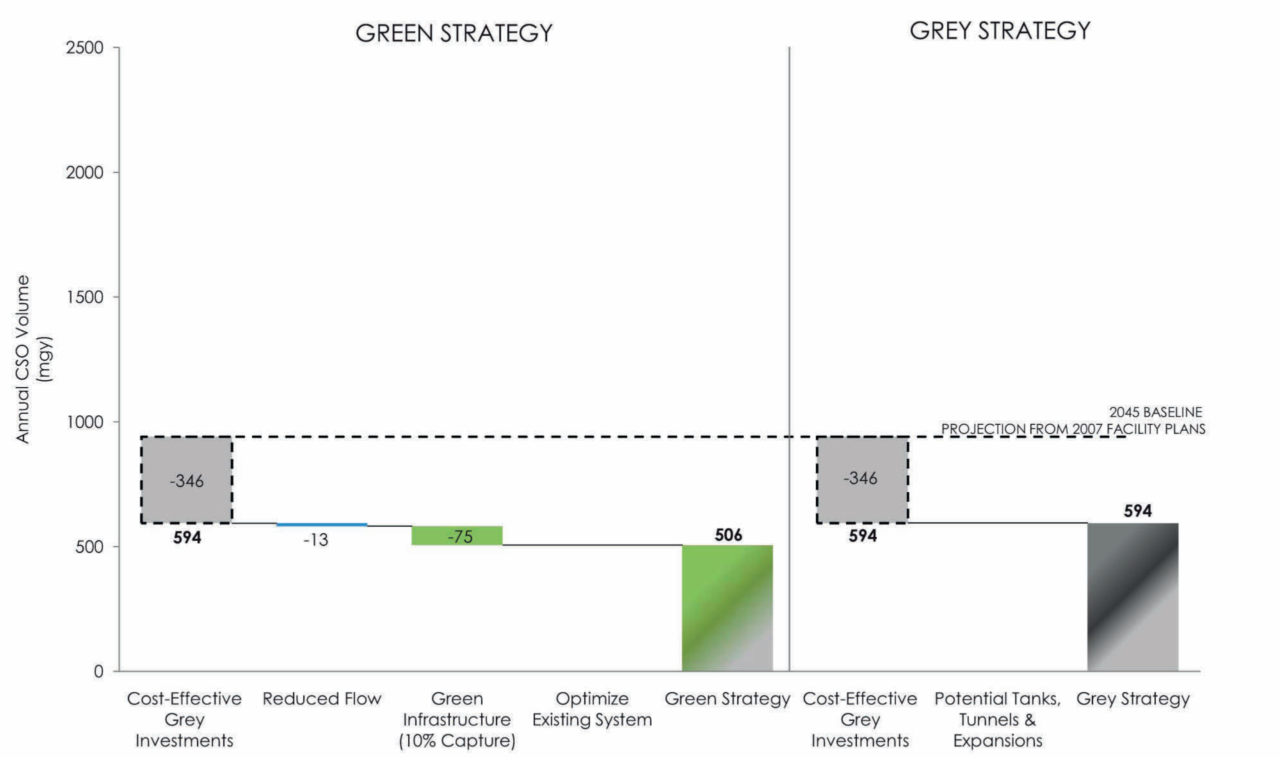
Borough(s): **Bronx**
Community District(s): **6, 9 & 11**

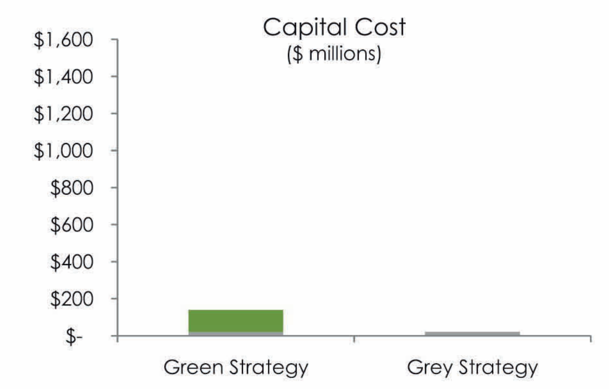


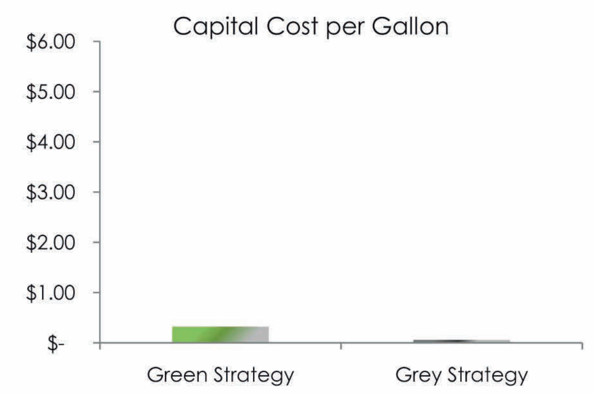


BRONX RIVER

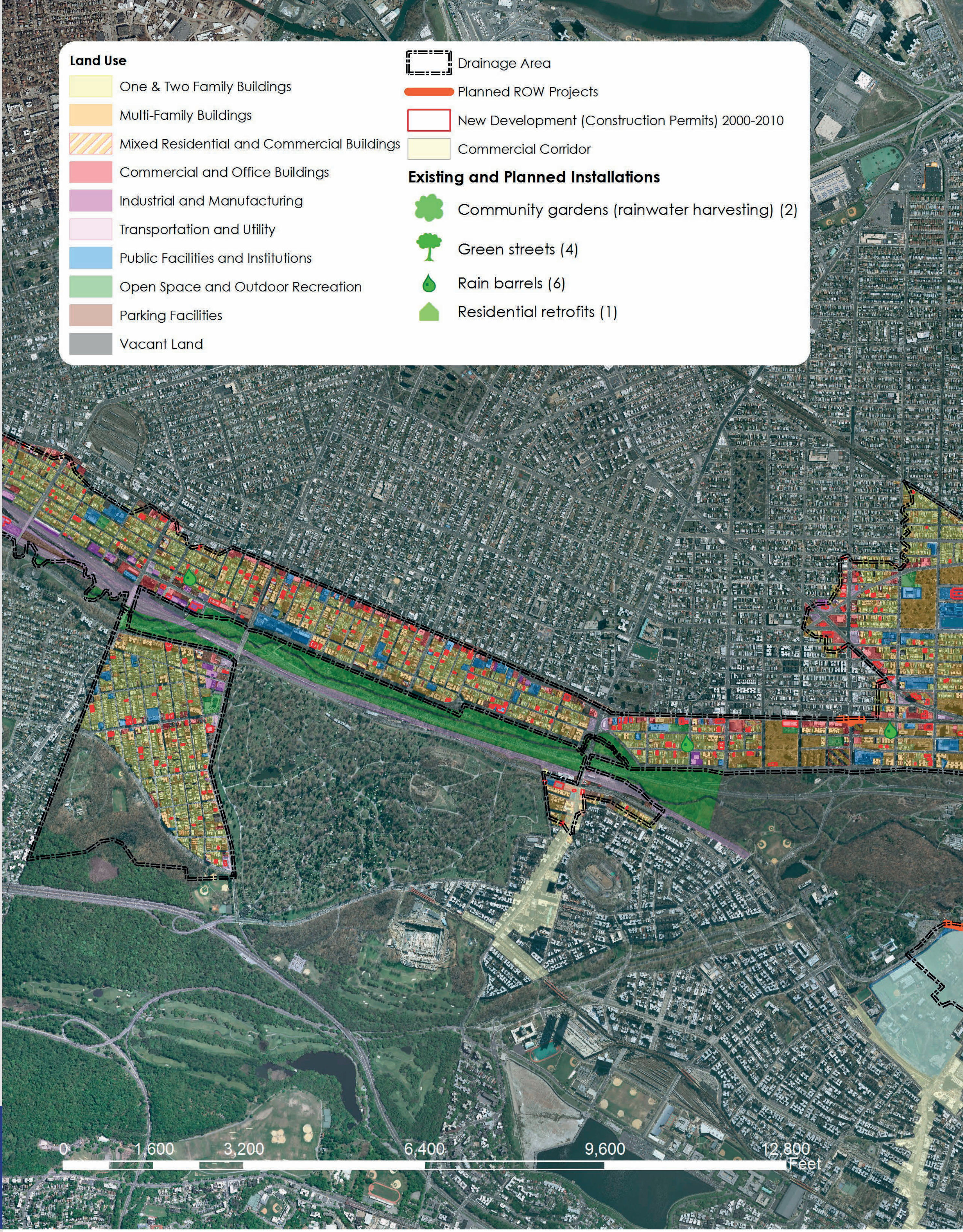
PERFORMANCE AND COSTS

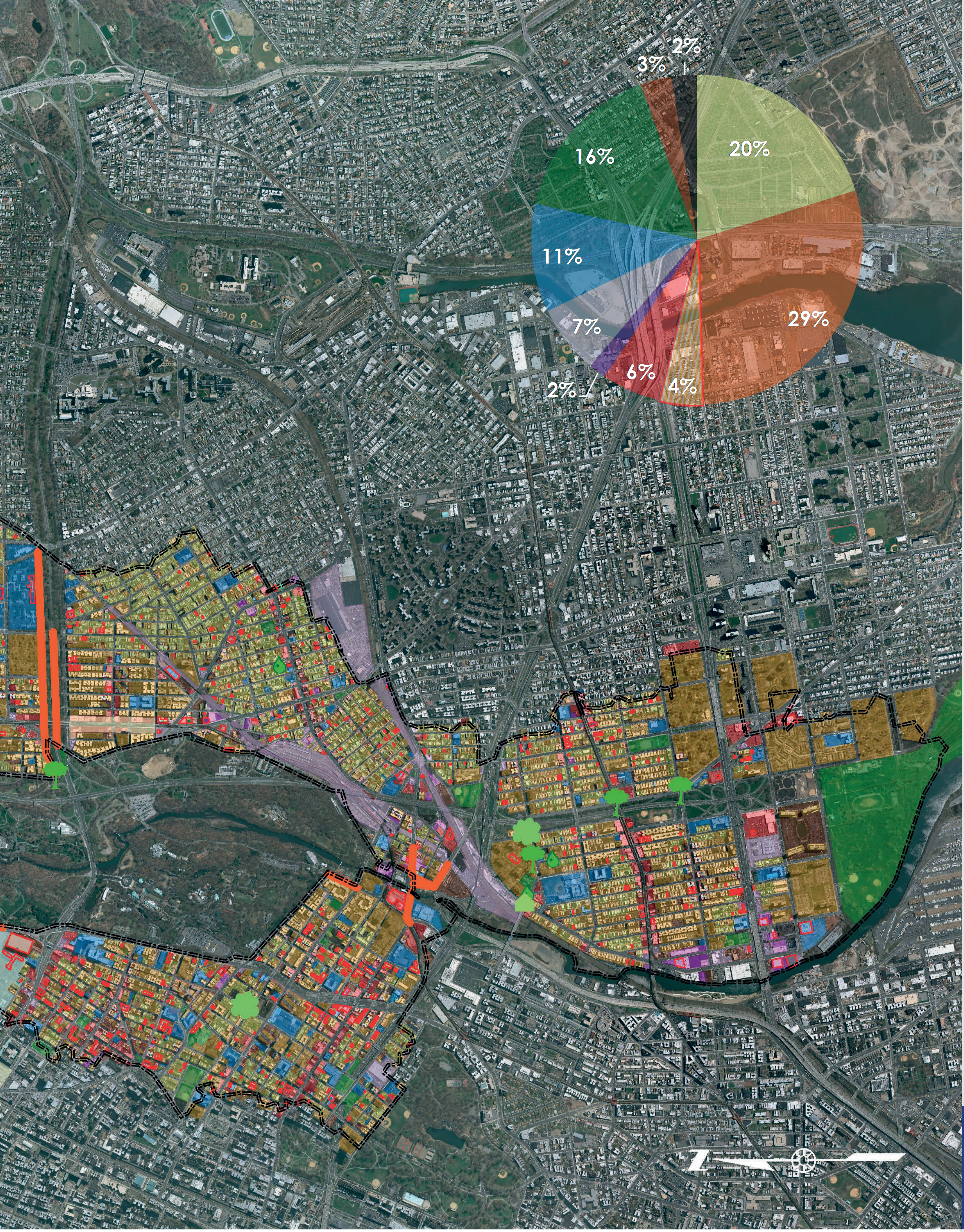






	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Hunts Point WWTP Headworks Improvements	346	$20	$0.06
PLUS Reduced Flow	13	-	-
PLUS Green Infrastructure (10% Capture)	75	$119	$1.58
PLUS Tide Gate Repair and Interceptor Cleaning	NA	NA	NA
Green Strategy Total	**434**	**$140**	**$0.32**
Cost-Effective Grey Infrastructure Investments	346	$20	$0.06
PLUS Potential Tanks, Tunnels & Expansions	NA	NA	NA
Grey Strategy Total	**346**	**$20**	**$0.06**


Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Existing and Planned Installations
Community gardens (rainwater harvesting) (2)
Green streets (4)
Rain barrels (6)
Residential retrofits (1)
0
1,600
3,200
6,400
9,600
12,800
Feet


2%
3%
20%
16%
11%
29%
7%
6%
4%
2%

CONEY ISLAND CREEK

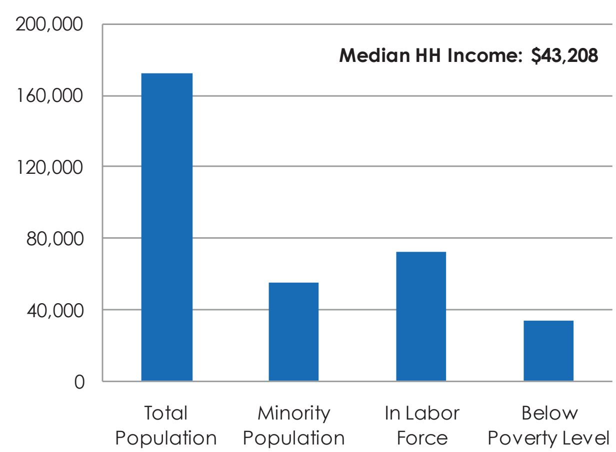
Total Watershed Drainage Area:	**3,120 acres**
Combined Sewer Contributory Area:	**723 acres**
Combined Sewer Contributory Impervious Area:	**694 acres**
Opportunity Area for Source Controls:	**262 acres**

The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **37%** of the combined sewer contributory area.

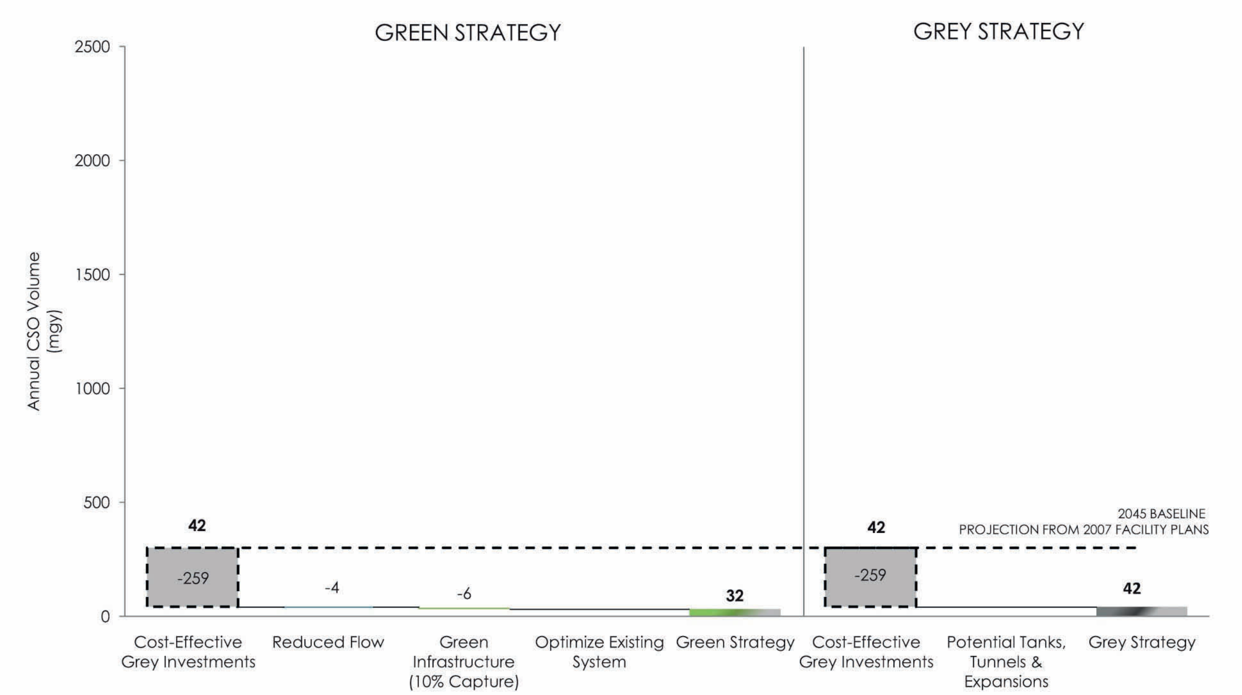
Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	22	3%
Vacant lots	6	1%
Right-of-way	209	30%
Planned ROW Projects	2	0.2%
Commercial corridors	2	0.3%
Other streets	138	20%
Other sidewalks	68	10%
Multi-family residential complexes	1	0.1%
Schools	10	1%
Parks	11	2%
Other public properties	3	0.5%
TOTAL	262	37%

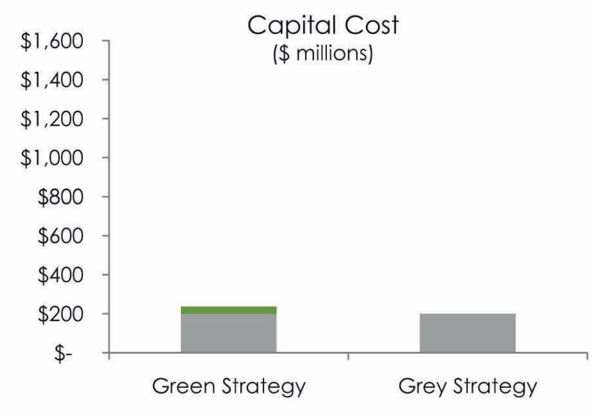
Wastewater Treatment Plant(s):	**Owls Head**
NYSDEC Classification(s):	**Class I – Secondary Contact, Boating and Fishing**
Ecological Classification(s):	**No Designation**
Existing Water Uses:	**Recreational Boating and Fishing**
Shoreline Uses:	**Commercial, Recreational, Residential, Parkland and Open Space**

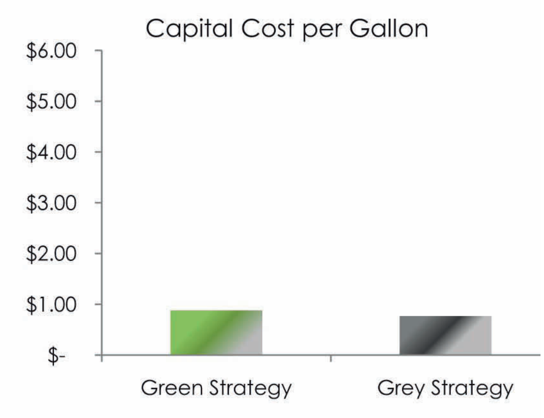
Borough(s): **Brooklyn**
Community District(s): **11**



PERFORMANCE AND COSTS







	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Avenue V Pump Station Upgrade & Force Main	259	$199	$0.77
PLUS Reduced Flow	4	-	-
PLUS Green Infrastructure (10% Capture)	6	$37	$6.40
PLUS Tide Gate Repair and Interceptor Cleaning	NA	NA	NA
Green Strategy Total	**269**	**$236**	**$0.88**
Cost-Effective Grey Infrastructure Investments	259	$199	$0.77
PLUS Potential Tanks, Tunnels & Expansions	NA	NA	NA
Grey Strategy Total	**259**	**$199**	**$0.77**

GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES


1%
2%
1%
2%
4%
4%
1%
7%
55%
23%
Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land

EAST RIVER AND OPEN WATERS

Total Watershed Drainage Area:	**90,966 acres**
Combined Sewer Contributory Area:	**50,774 acres**
Combined Sewer Contributory Impervious Area:	**41,127 acres**
Opportunity Area for Source Controls:	**30,607 acres**

The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **53%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	3,124	5%
Vacant lots	1,259	2%
Right-of-way	14,590	25%
Planned ROW Projects	506	1%
Commercial corridors	683	1%
Other streets	9,292	16%
Other sidewalks	4,201	7%
Multi-family residential complexes	1,833	3%
Commercial development with parking lots	183	0.3%
Schools	1,030	2%
Parks	8,589	15%
TOTAL	30,607	53%

Wastewater Treatment Plant(s): **Red Hook, Newtown Creek, Bowery Bay, Wards Island, Hunts Point, Tallman Island, North River, Port Richmond, Owls Head**

NYSDEC Classification(s):
Class I – Secondary Contact, Boating and Fishing (East River, Harlem River, Hudson River and Upper bay)
Class SA – Primary and Secondary Contact, Shellfishing (Lower Bay and Raritan Bay)
Class SB – Primary and Secondary Contact, Fishing and Bathing (East River, Hudson River, Lower Bay and Raritan Bay)
Class SD – Fish Survival (Arthur Kill and Kill Van Kull)

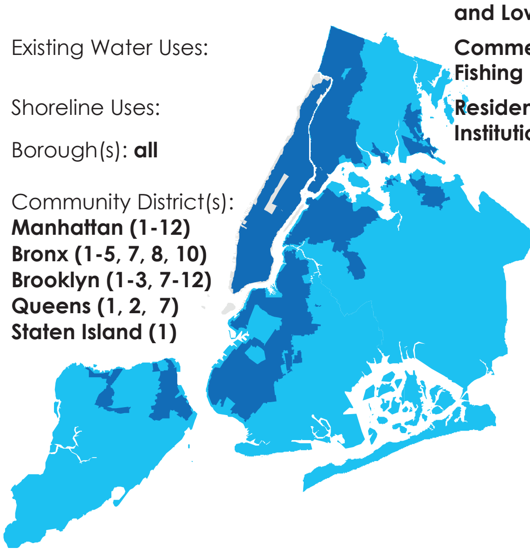
Ecological Classification(s): **Special Natural Waterfront Area (DCP, East River) Significant Coastal Fish and Wildlife Habitats (NYSDOS, Arthur Kill, East River, Hudson River, Kill Van Kull and Lower Bay)**

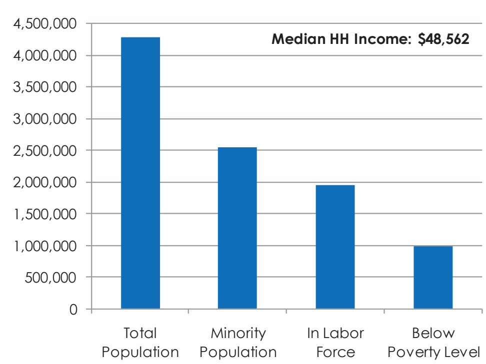
Existing Water Uses: **Commercial and Municipal Shipping and Barging, Recreational Boating, Fishing and Swimming, Shellfishing**

Shoreline Uses: **Residential, Commercial, Municipal, Industrial , Recreational , Institutional, Military, Swimming, Private Beach Clubs, Parks and Open Space**

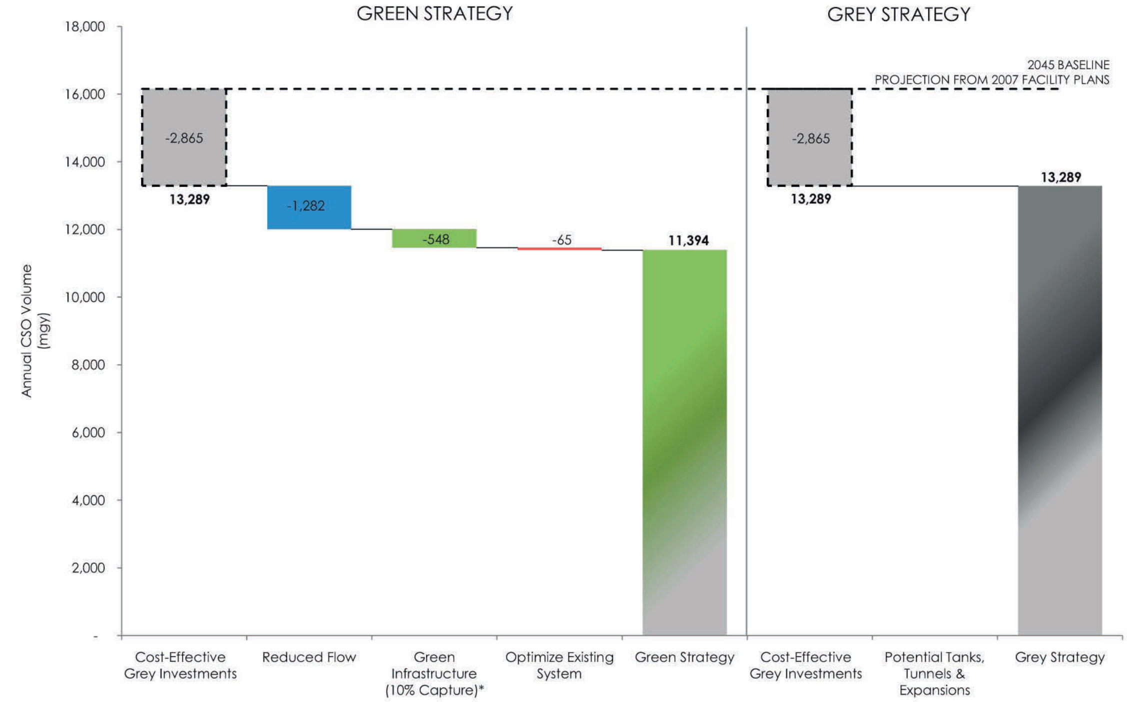
Borough(s): **all**

Community District(s):
Manhattan (1-12)
Bronx (1-5, 7, 8, 10)
Brooklyn (1-3, 7-12)
Queens (1, 2, 7)
Staten Island (1)

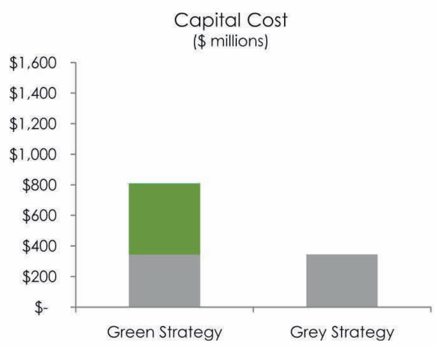


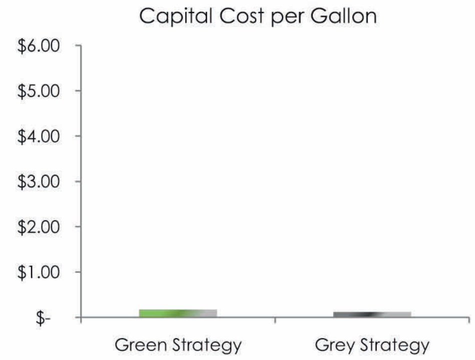


PERFORMANCE AND COSTS



* East River Green Infrastructure numbers only include private investment.





	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Bowery Bay WWTP Headworks Improvements, Regulator Automation, Port Richmond Throttling Facility, In-Line Storage, East River Plan Regulator Improvements, Wards Island WWTP Flow Maximization, Gravity Diversion at Hannah Street Pump Station, Divert Low-Lying Sewers, Raise Weir at Regulator, Tallman Island WWTP Flow Maximization	2,865	$345	$0.12
PLUS Reduced Flow	1,282	-	-
PLUS Green Infrastructure (10% Capture)	548	$463	$0.84
PLUS Tide Gate Repair and Interceptor Cleaning	65	$1	$0.02
Green Strategy Total	**4,760**	**$808**	**$0.17**
Cost-Effective Grey Infrastructure Investments	2,865	$345	$0.12
PLUS Potential Tanks, Tunnels & Expansions	NA	NA	NA
Grey Strategy Total	**2,865**	**$345**	**$0.12**

FLUSHING BAY

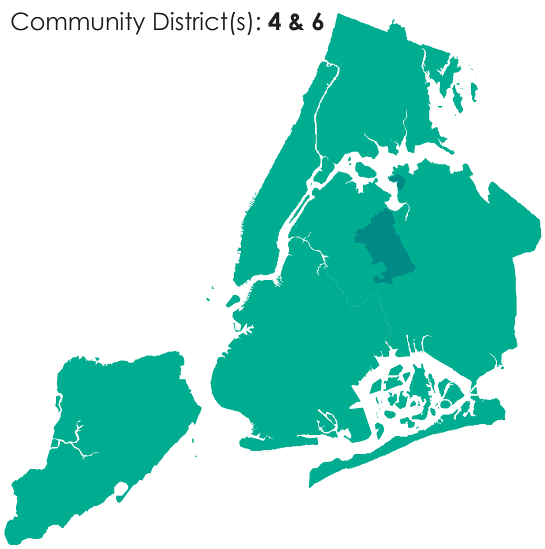
Total Watershed Drainage Area:	**6,423 acres**
Combined Sewer Contributory Area:	**4,499 acres**
Combined Sewer Contributory Impervious Area:	**4,049 acres**
Opportunity Area for Source Controls:	**1,973 acres**

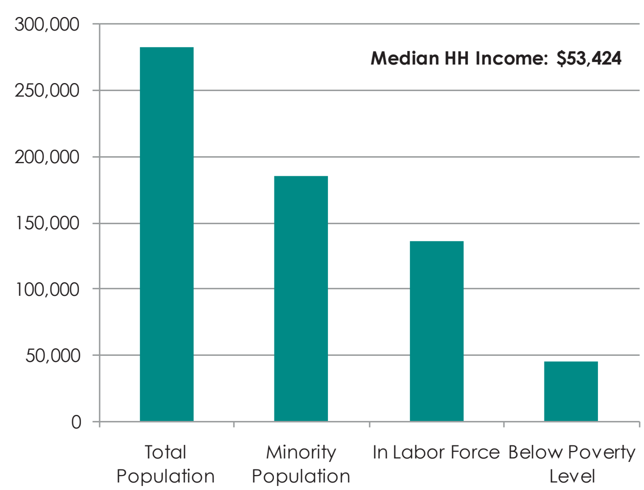
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **44%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	258	6%
Vacant lots	48	1%
Right-of-way	1,335	30%
Planned ROW Projects	64	1%
Other streets	871	19%
Other sidewalks	400	9%
Multi-family residential complexes	115	3%
Commercial development with parking lots	22	0.5%
Schools	67	2%
Parks	61	1%
Other public properties	65	1%
TOTAL	1,973	44%

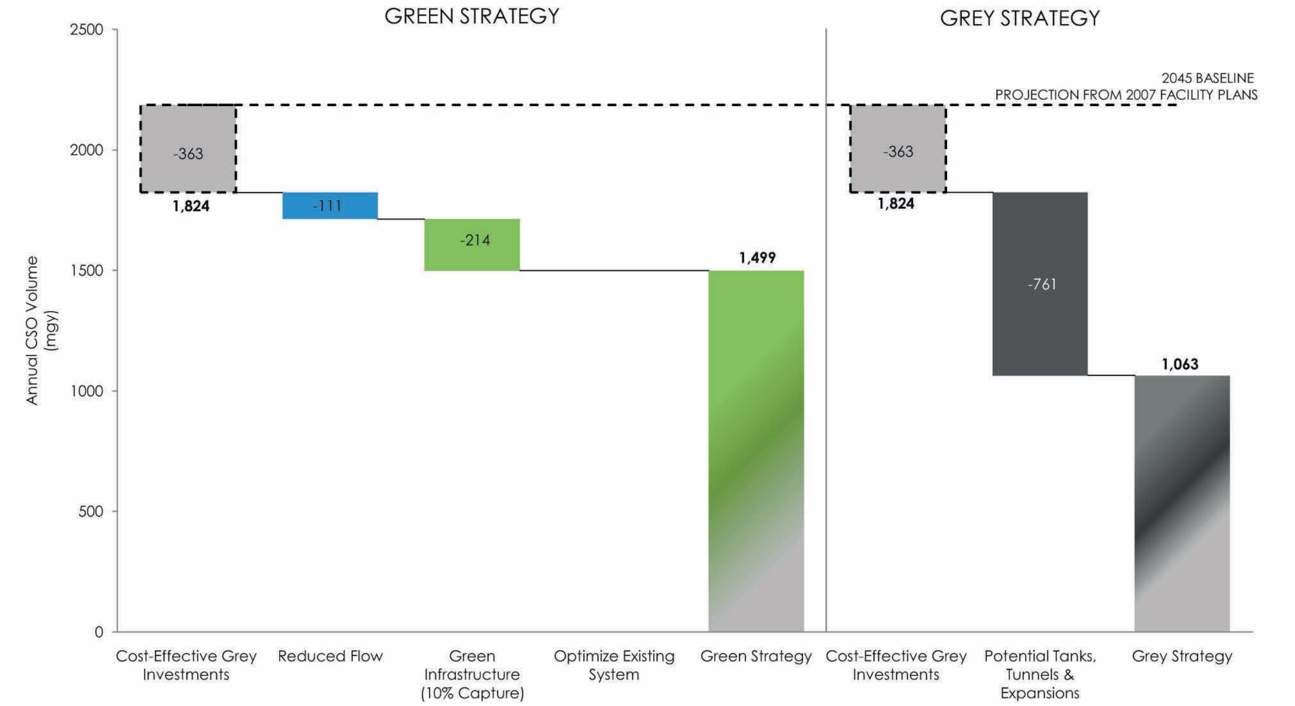
Wastewater Treatment Plant(s):	**Bowery Bay and Tallman Island**
NYSDEC Classification(s):	**Class I – Secondary Contact, Boating and Fishing**
Ecological Classification(s):	**Special Natural Waterfront Area (DCP)**
Existing Water Uses:	**Commercial and Municipal Barge Traffic, Recreational Boating**
Shoreline Uses:	**Commercial, Industrial, Institutional, Municipal, Recreational, Parkland and Open Space**

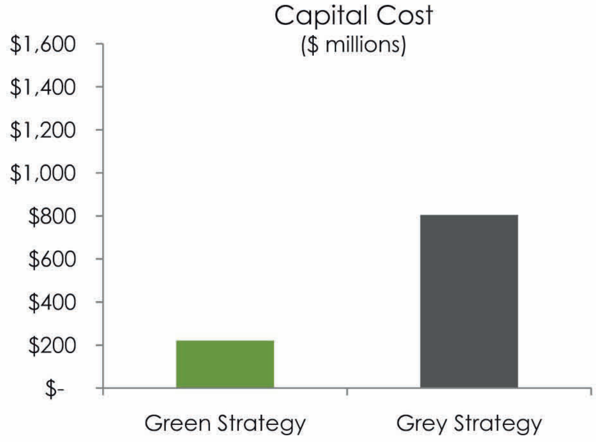
Borough(s): **Queens**
Community District(s): **4 & 6**

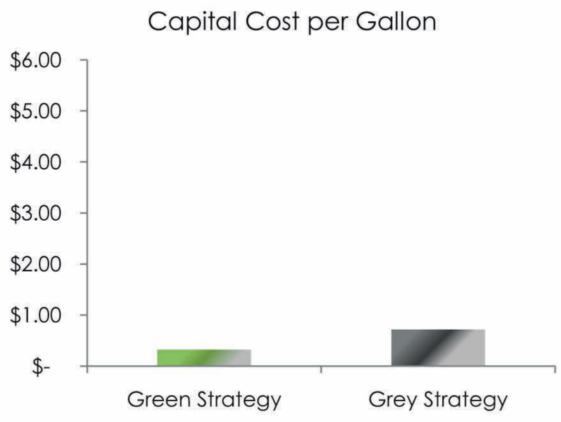




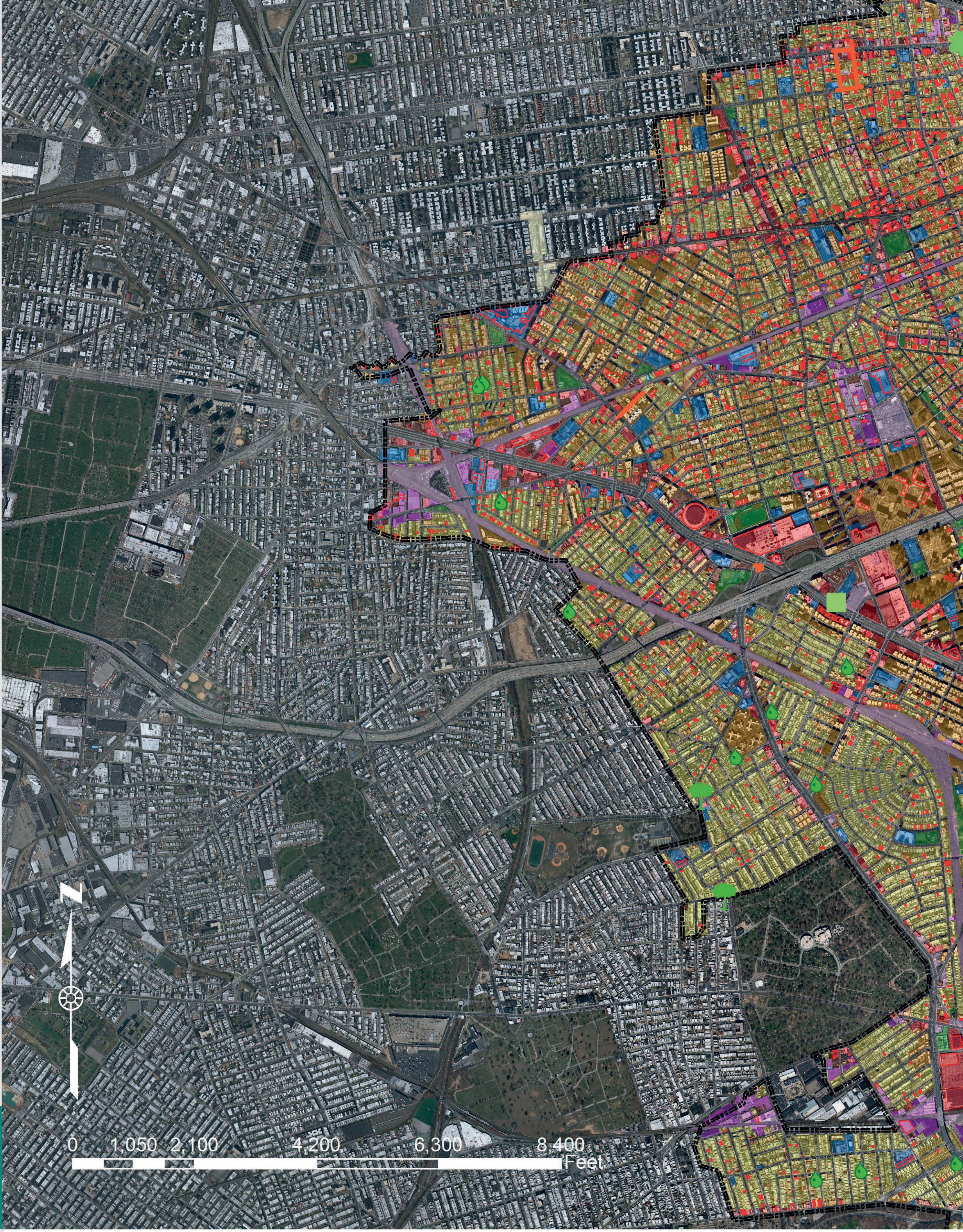
PERFORMANCE AND COSTS





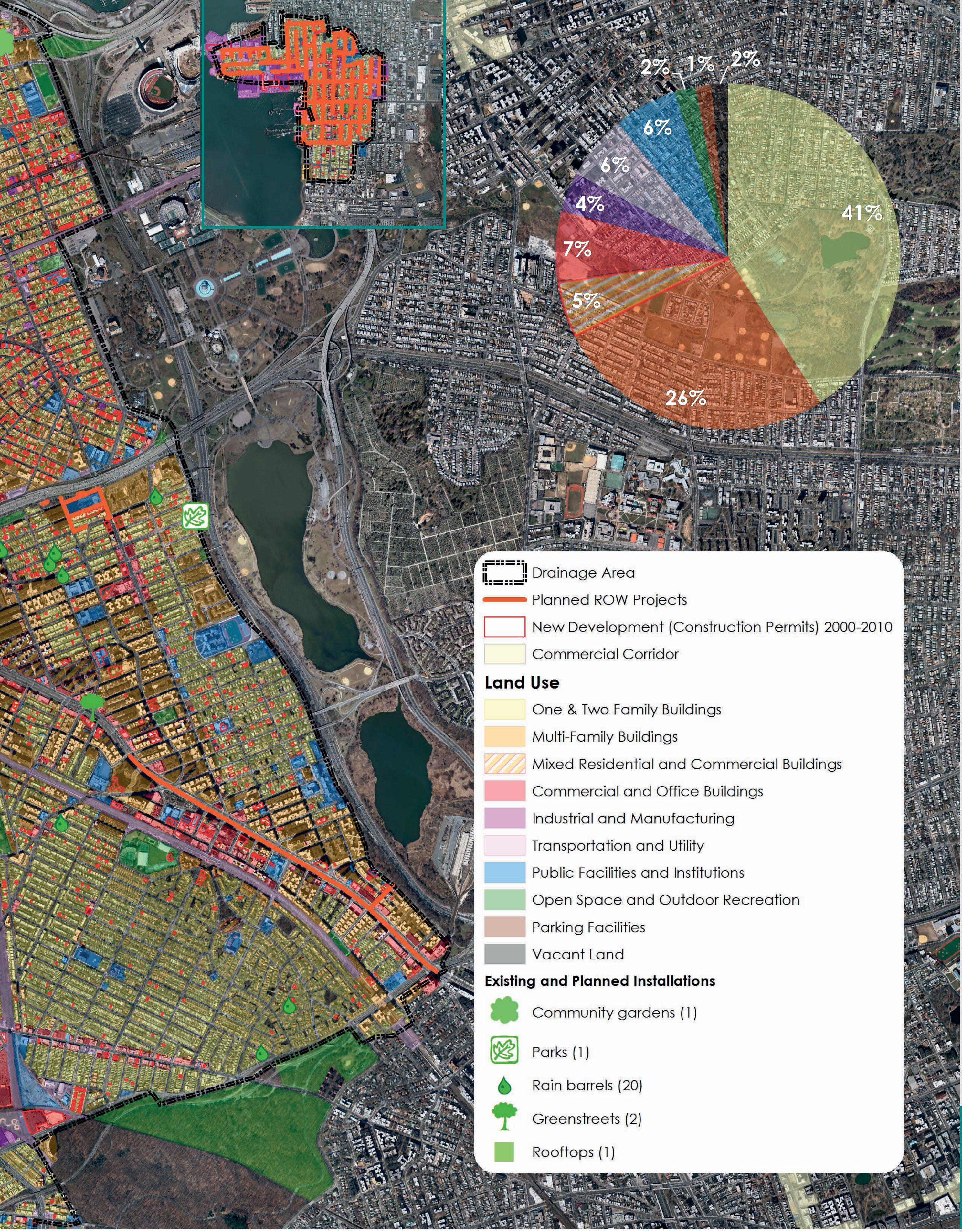


	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Regulator Modifications	363	$5	$0.01
PLUS Reduced Flow	111	-	-
PLUS Green Infrastructure (10% Capture)	214	$216	$1.01
PLUS Tide Gate Repair and Interceptor Cleaning	NA	NA	NA
Green Strategy Total	**688**	**$221**	**$0.32**
Cost-Effective Grey Infrastructure Investments	363	$5	$0.01
PLUS Potential Tanks, Tunnels & Expansions—Flushing Bay CSO Tunnel	761	$800	$1.05
Grey Strategy Total	**1,124**	**$805**	**$0.72**



GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES


2%
1%
2%
6%
6%
4%
7%
5%
41%
26%
Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Existing and Planned Installations
Community gardens (1)
Parks (1)
Rain barrels (20)
Greenstreets (2)
Rooftops (1)

FLUSHING CREEK

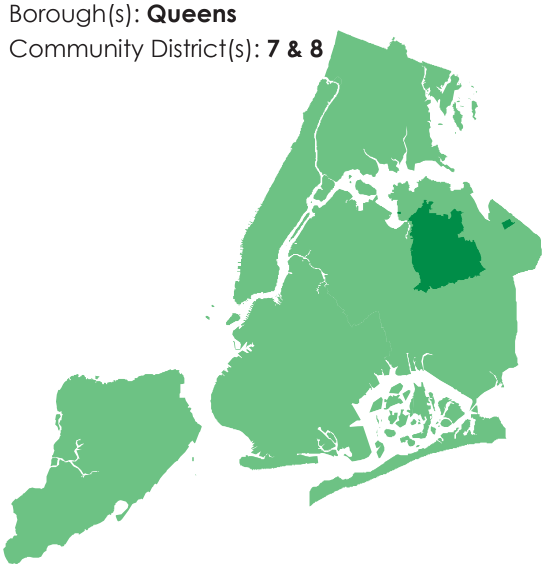
Total Watershed Drainage Area:	**9,954 acres**
Combined Sewer Contributory Area:	**8,342 acres**
Combined Sewer Contributory Impervious Area:	**5,923 acres**
Opportunity Area for Source Controls:	**4,408 acres**

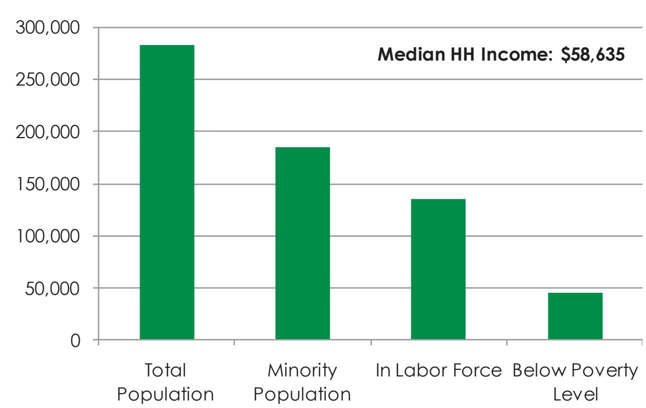
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **54%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	373	5%
Vacant lots	52	1%
Right-of-way	2,091	26%
Planned ROW Projects	68	1%
Commercial corridors	13	0.2%
Other streets	1,432	18%
Other sidewalks	579	7%
Multi-family residential complexes	345	4%
Commercial development with parking lots	59	1%
Schools	211	3%
Parks	1,212	15%
Other public properties	66	1%
TOTAL	4,408	54%

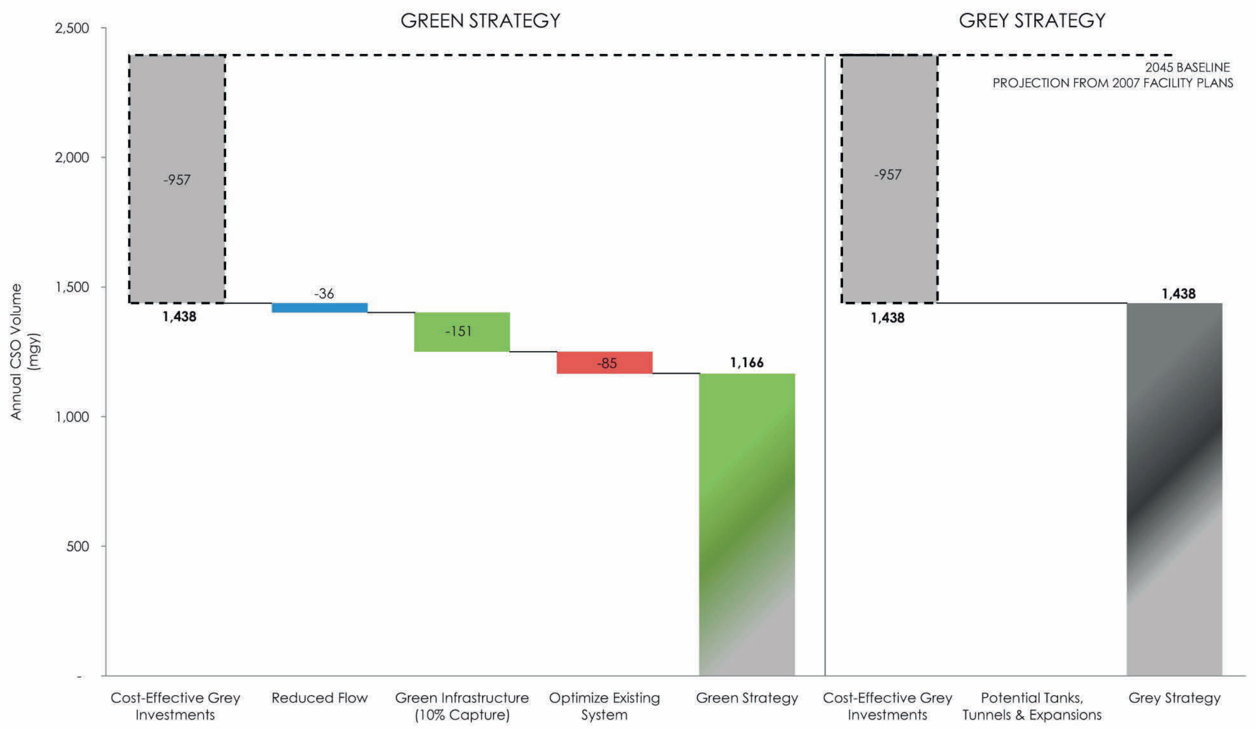
Wastewater Treatment Plant(s):	**Bowery Bay and Tallman Island**
NYSDEC Classification(s):	**Class I – Secondary Contact, Boating and Fishing**
Ecological Classification(s):	**Special Natural Waterfront Area (DCP)**
Existing Water Uses:	**Commercial Barge Traffic and Recreational Boating**
Shoreline Uses:	**Commercial, Industrial, Institutional, Municipal, Recreational, Parkland and Open Space**

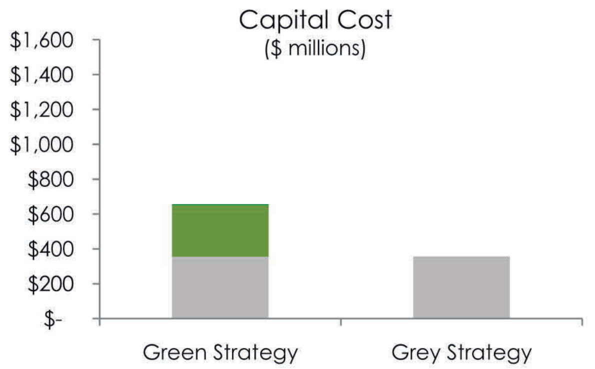
Borough(s): **Queens**
Community District(s): **7 & 8**

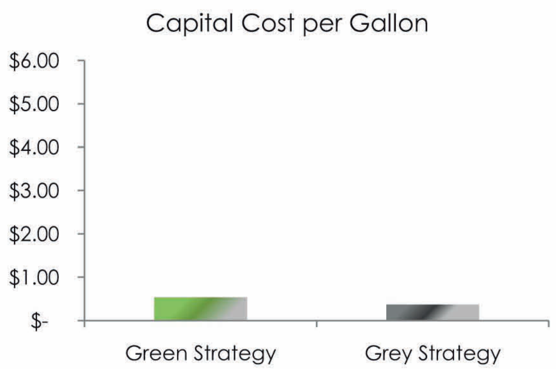




PERFORMANCE AND COSTS



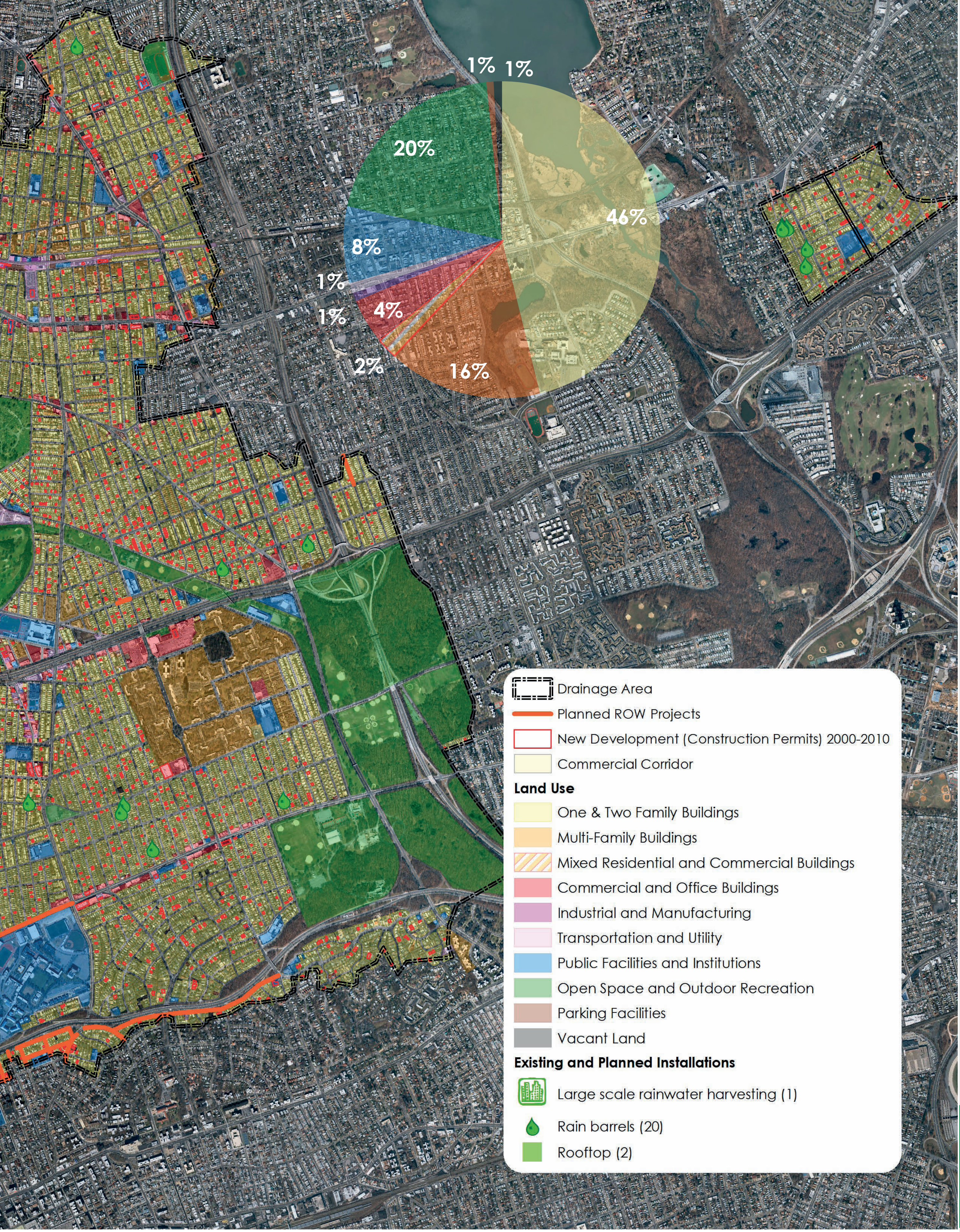




	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—CSO Facility	957	$356	$0.37
PLUS Reduced Flow	36	-	-
PLUS Green Infrastructure (10% Capture)	151	$298	$1.97
PLUS Tide Gate Repair and Interceptor Cleaning	85	$3	$0.03
Green Strategy Total	**1,229**	**$656**	**$0.53**
Cost-Effective Grey Infrastructure Investments	957	$356	$0.37
PLUS Potential Tanks, Tunnels & Expansions	NA	NA	NA
Grey Strategy Total	**957**	**$356**	**$0.37**

GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES


1%
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Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Existing and Planned Installations
Large scale rainwater harvesting (1)
Rain barrels (20)
Rooftop (2)

GOWANUS CANAL

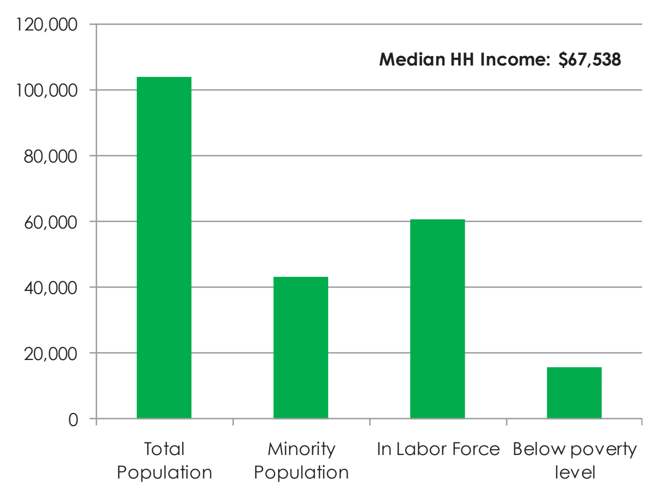
Total Watershed Drainage Area:	**1,758 acres**
Combined Sewer Contributory Area:	**1,524 acres**
Combined Sewer Contributory Impervious Area:	**1,387 acres**
Opportunity Area for Source Controls:	**888 acres**

The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **61%** of the combined sewer contributory area.

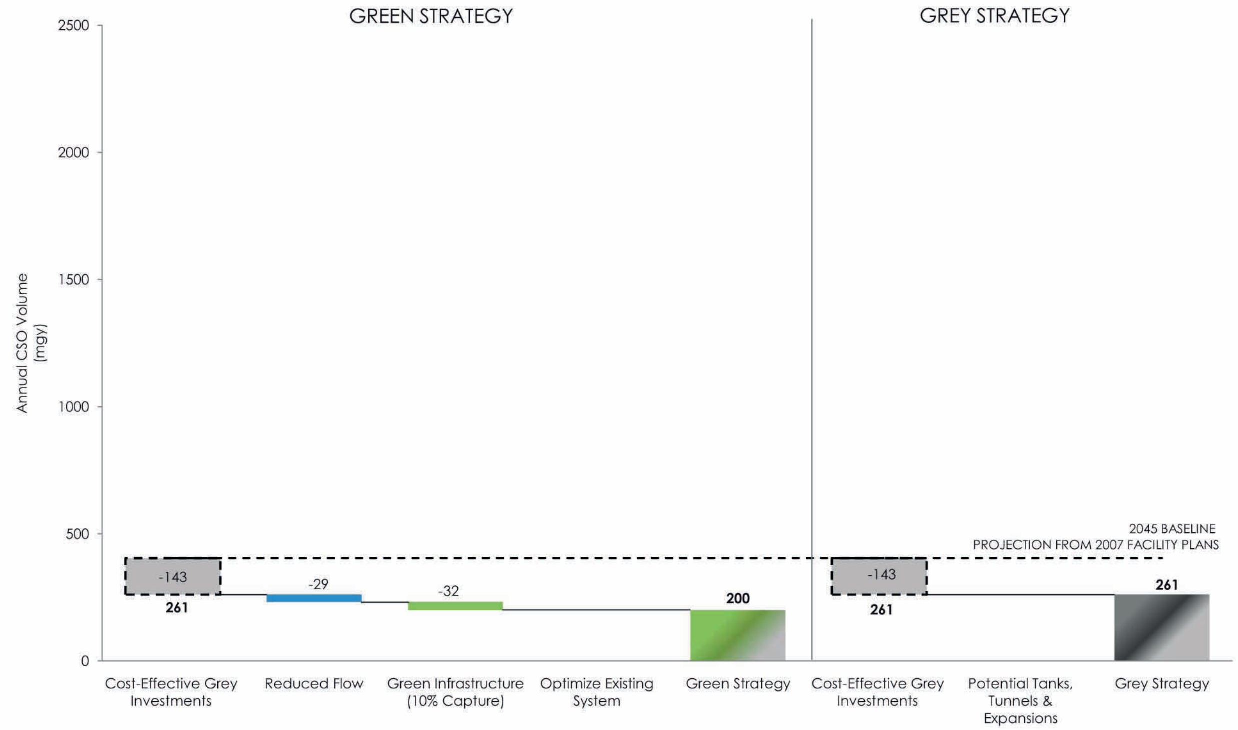
Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	100	7%
Vacant lots	32	2%
Right-of-way	449	31%
Planned ROW Projects	0.1	0.004%
Commercial corridors	12	1%
Other streets	285	19%
Other sidewalks	152	10%
Multi-family residential complexes	19	1%
Commercial development with parking lots	22	2%
Schools	28	2%
Parks	24	2%
Other public properties	213	15%
TOTAL	888	61%

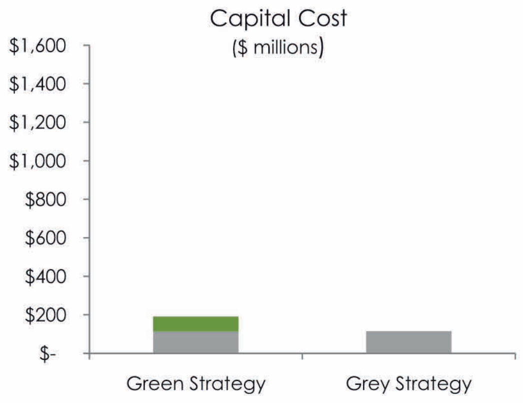
Wastewater Treatment Plant(s):	**Red Hook and Owls Head**
NYSDEC Classification(s):	**Class SD – Fish Survival**
Ecological Classification(s):	**No Designation**
Existing Water Uses:	**Commercial Shipping and Barging, Recreational Boating**
Shoreline Uses:	**Commercial, Industrial, Municipal, Parkland and Open Space**

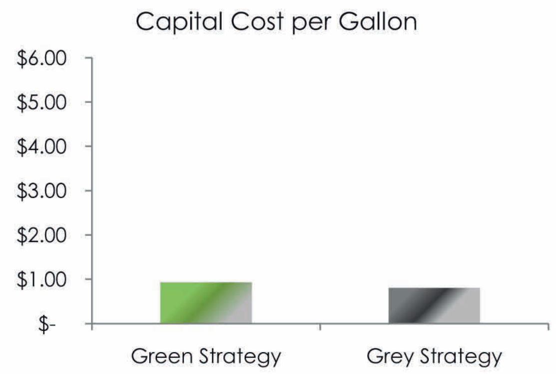
Borough(s): **Brooklyn**
Community District(s): **6**



PERFORMANCE AND COSTS







	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Gowanus Pump Station Upgrade	143	$115	$0.81
PLUS Reduced Flow	29	-	-
PLUS Green Infrastructure (10% Capture)	32	$75	$2.33
PLUS Tide Gate Repair and Interceptor Cleaning	NA	NA	NA
Green Strategy Total	**204**	**$190**	**$0.93**
Cost-Effective Grey Infrastructure Investments	143	$115	$0.81
PLUS Potential Tanks, Tunnels & Expansions	NA	NA	NA
Grey Strategy Total	**143**	**$115**	**$0.81**

GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES

3%
3%
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20%
7%
5%
11%
6%
9%
33%
Gowanus Canal Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Existing and Planned Installations
Community Gardens w/ rainwater harvesting (1)
Rain barrels (4)
Residential retrofits (1)
Rooftops (2)
ROW Swale and Tree Pits (1)

HUTCHINSON RIVER

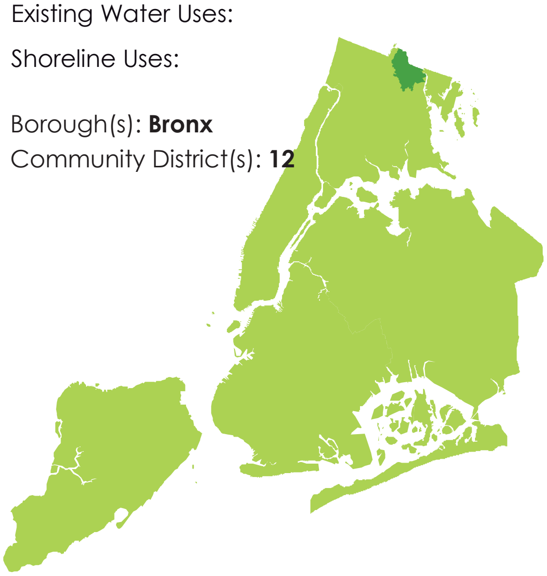
Total Watershed Drainage Area:	**2,572 acres**
Combined Sewer Contributory Area:	**1,410 acres**
Combined Sewer Contributory Impervious Area:	**1,128 acres**
Opportunity Area for Source Controls:	**687 acres**

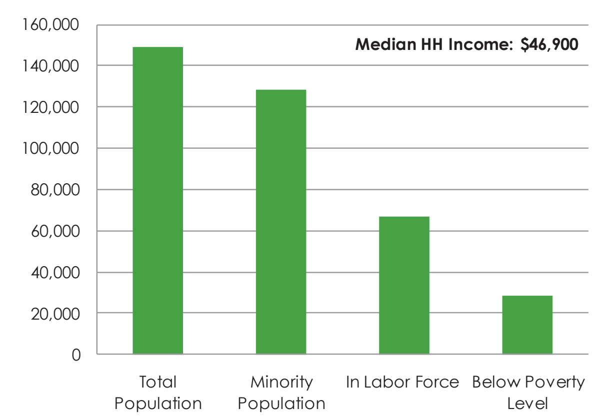
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **50%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	51	4%
Vacant lots	58	4%
Right-of-way	372	27%
Planned ROW Projects	8	1%
Other streets	260	19%
Other sidewalks	103	8%
Multi-family residential complexes	71	5%
Commercial development with parking lots	15	1%
Schools	21	2%
Parks	29	2%
Other public properties	70	5%
TOTAL	687	50%

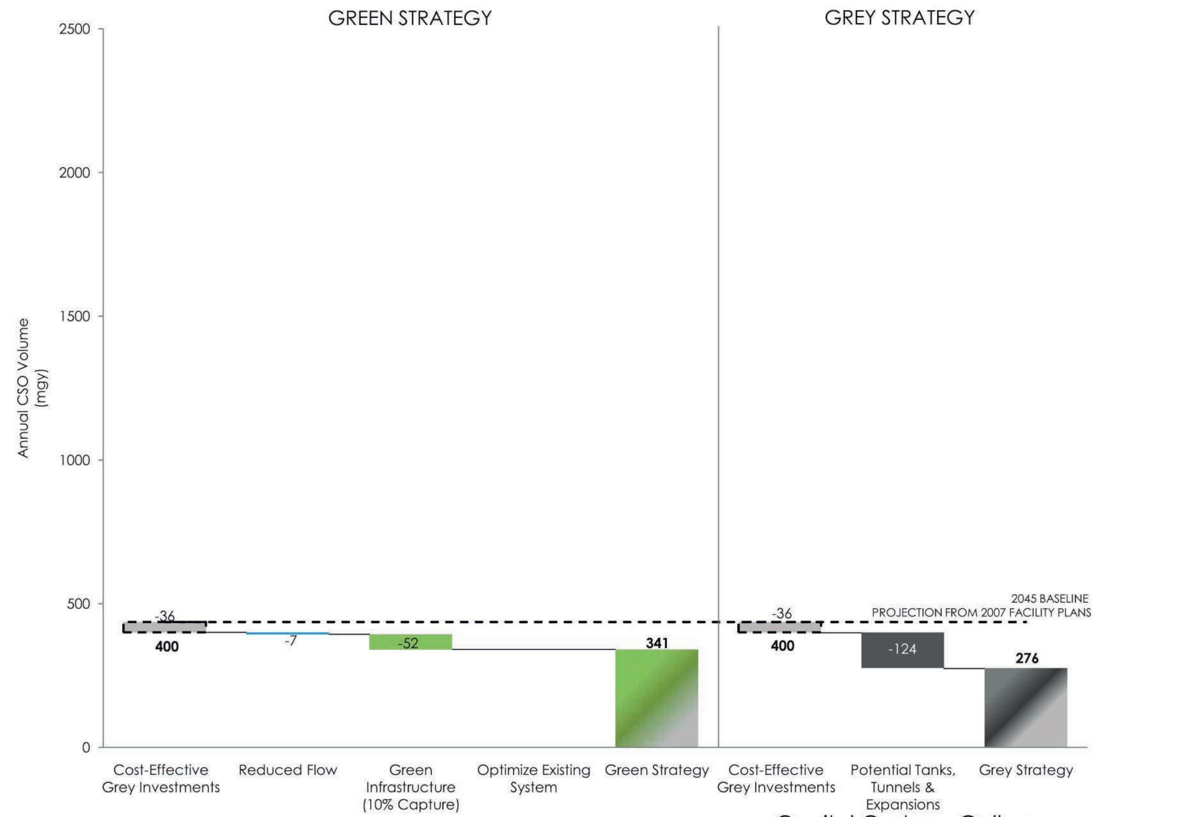
Wastewater Treatment Plant(s):	**Hunts Point**
NYSDEC Classification(s):	**Class SB – Primary and Secondary Contact, Fishing and Bathing**
Ecological Classification(s):	**Special Natural Waterfront Area (DCP)**
	Significant Coastal Fish and Wildlife Habitats
Existing Water Uses:	**Commercial Shipping and Barging, Recreational Boating**
Shoreline Uses:	**Residential, Commercial, Industrial, Recreational, Municipal, Parkland and Open Space**

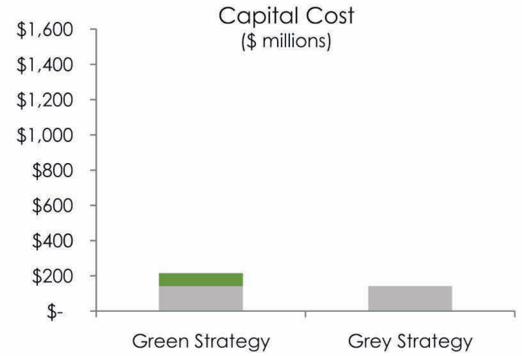
Borough(s): **Bronx**
Community District(s): **12**

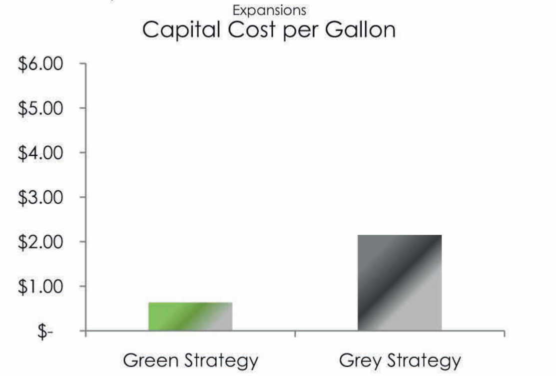




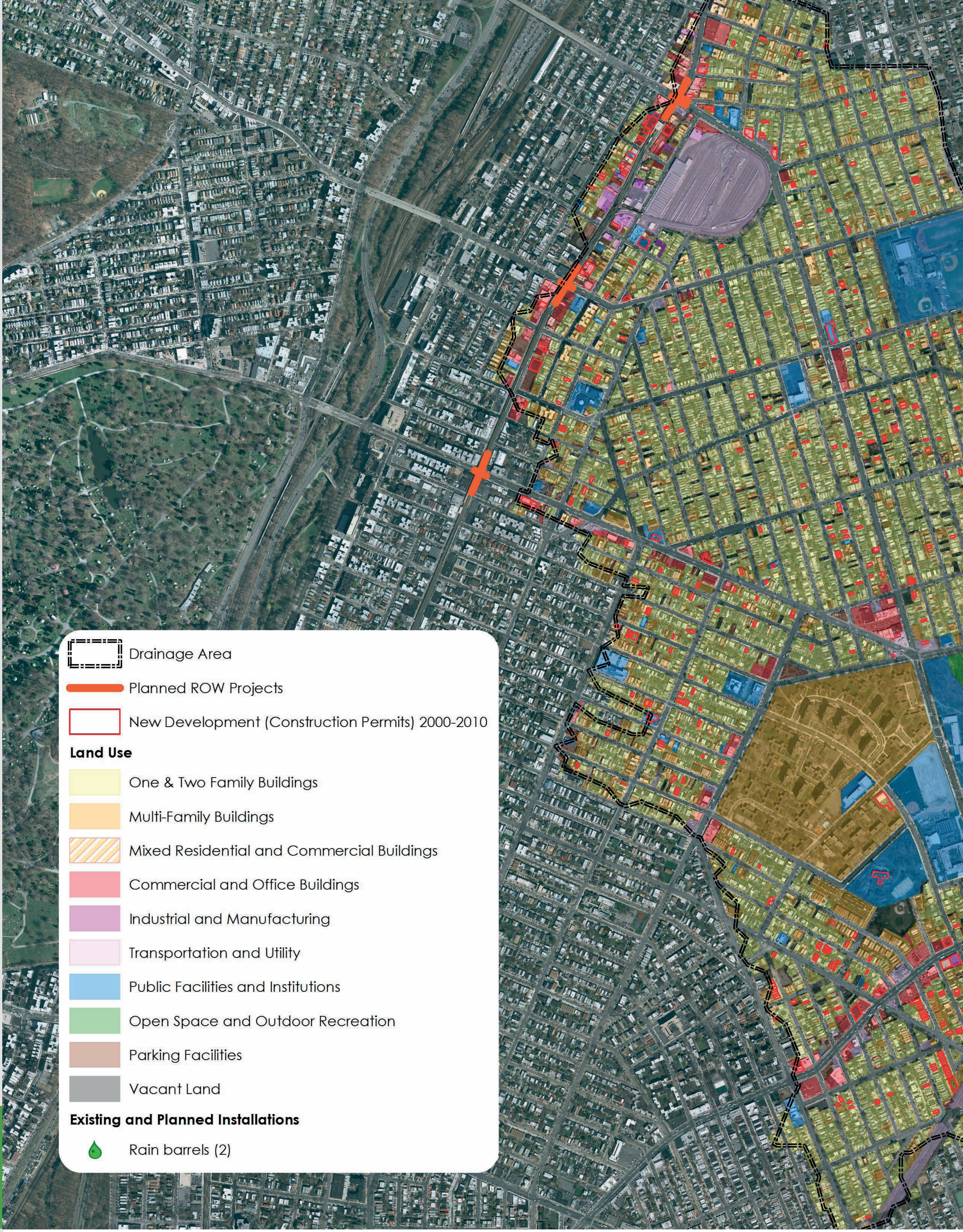
PERFORMANCE AND COSTS





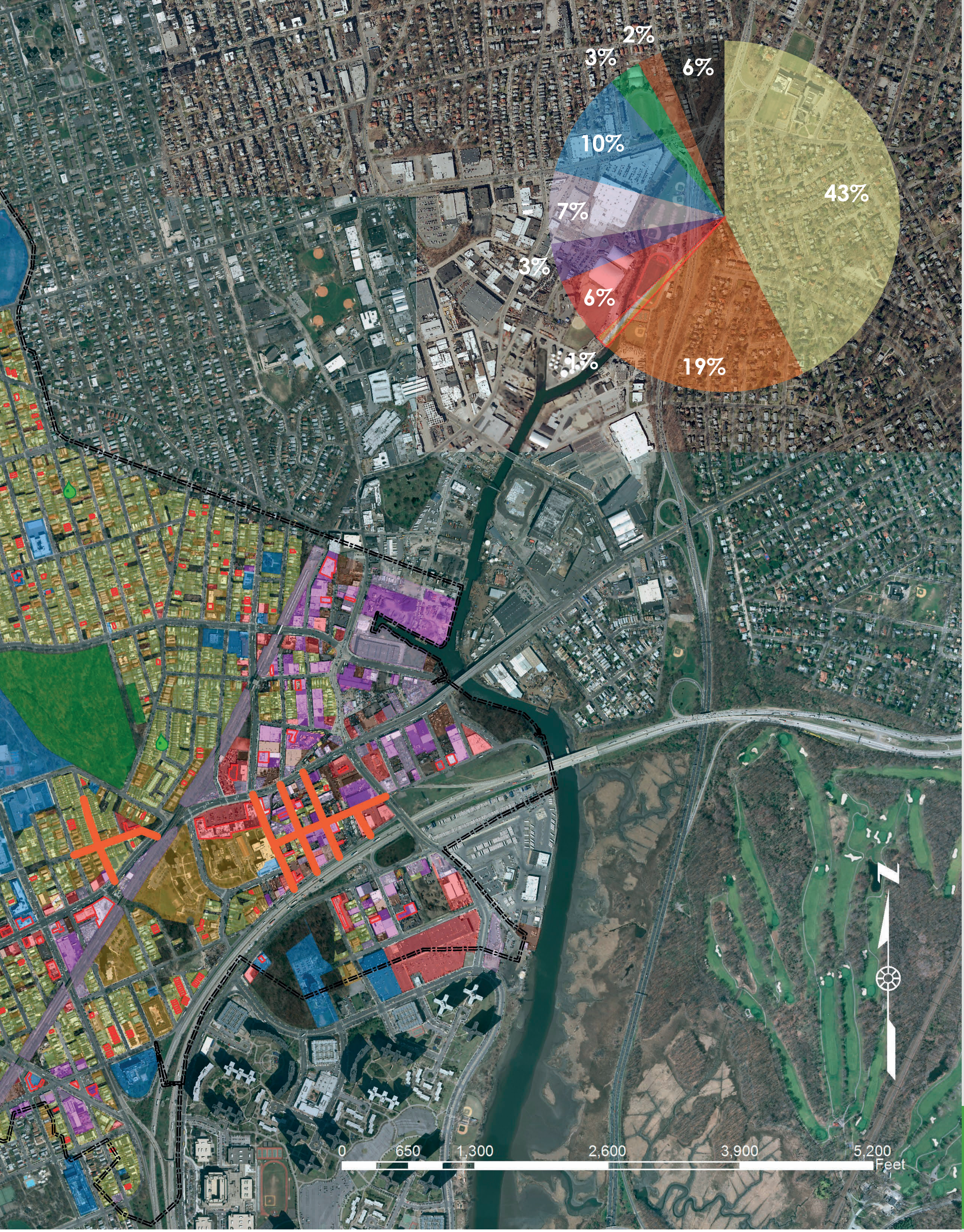


	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Hunts Point WWTP Improvements	36	$3	$0.08
PLUS Reduced Flow	7	-	-
PLUS Green Infrastructure (10% Capture)	52	$58	$1.10
PLUS Tide Gate Repair and Interceptor Cleaning	NA	NA	NA
Green Strategy Total	**95**	**$61**	**$0.64**
Cost-Effective Grey Infrastructure Investments	36	$3	$0.08
PLUS Potential Tanks, Tunnels & Expansions—CSO Retention Facilities	124	$341	$2.75
Grey Strategy Total	**160**	**$344**	**$2.15**



GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES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5,200
Feet
N

JAMAICA BAY AND CSO TRIBUTARIES

Total Watershed Drainage Area:	**50,708 acres**
Combined Sewer Contributory Area:	**6,600 acres**
Combined Sewer Contributory Impervious Area:	**5,478 acres**
Opportunity Area for Source Controls:	**3,809 acres**

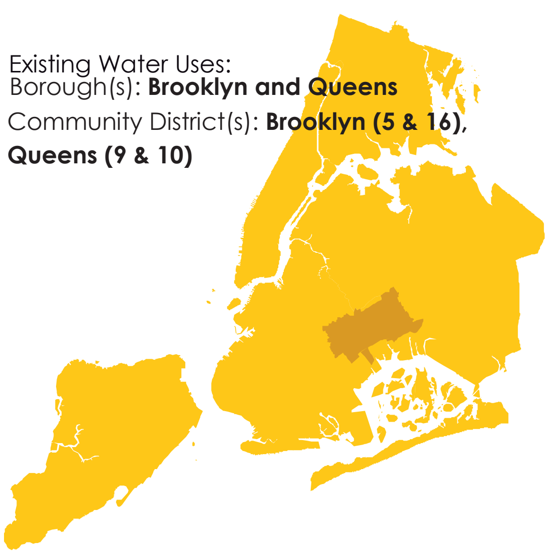
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **58%** of the combined sewer contributory area.

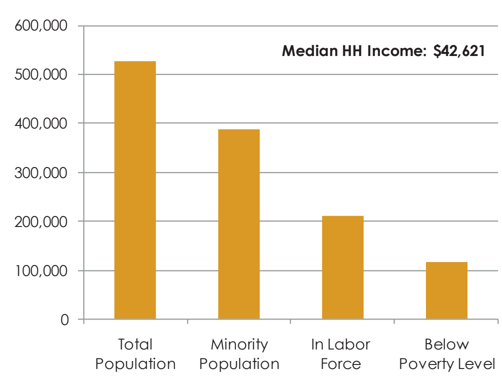
Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	**275**	**4%**
Vacant lots	**231**	**4%**
Right-of-way	**1,809**	**28%**
Planned ROW Projects	**147**	**2%**
Commercial corridors	**54**	**1%**
Other streets	**1,096**	**17%**
Other sidewalks	**517**	**8%**
Multi-family residential complexes	**445**	**7%**
Commercial development with parking lots	**34**	**1%**
Schools	**145**	**2%**
Parks	**595**	**9%**
Other public properties	**275**	**4%**
TOTAL	**3,809**	**58%**

Wastewater Treatment Plant(s):	**Rockaway and 26th Ward**
NYSDEC Classification(s):	**Class I – Secondary Contact, Boating and Fishing Class SB – Primary & Secondary Contact, Fishing and Bathing**
Ecological Classification(s):	**Critical Environmental Area, Significant Coastal Fish and Wild-life Habitat, Special Natural Waterfront Area, National Wildlife Refuge**
Existing Water Uses:	**Commercial and Municipal Shipping and Barging, Recreational Boating and Fishing, Commercial Boating, Wildlife Refuge, Municipal Vessel Traffic**

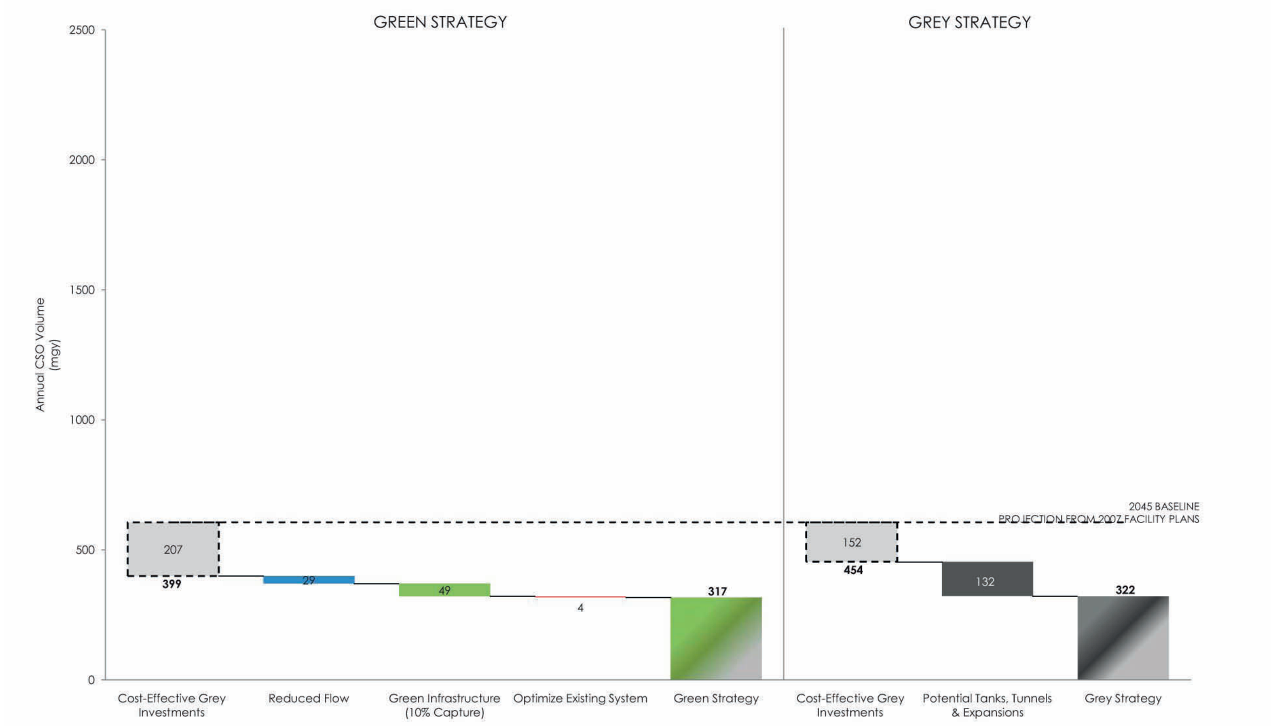
Borough(s): **Brooklyn and Queens**

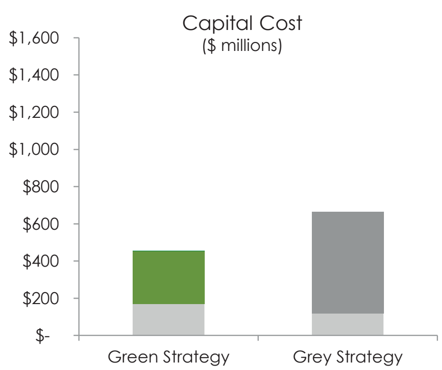
Community District(s): **Brooklyn (5 & 16), Queens (9 & 10)**

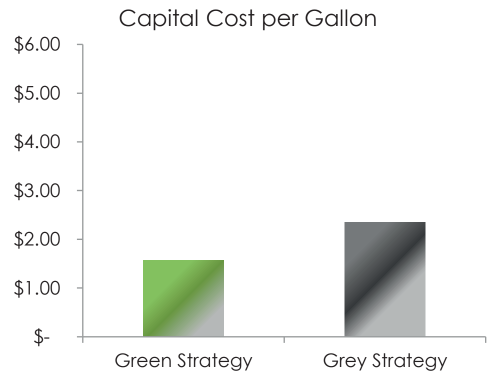




PERFORMANCE AND COSTS

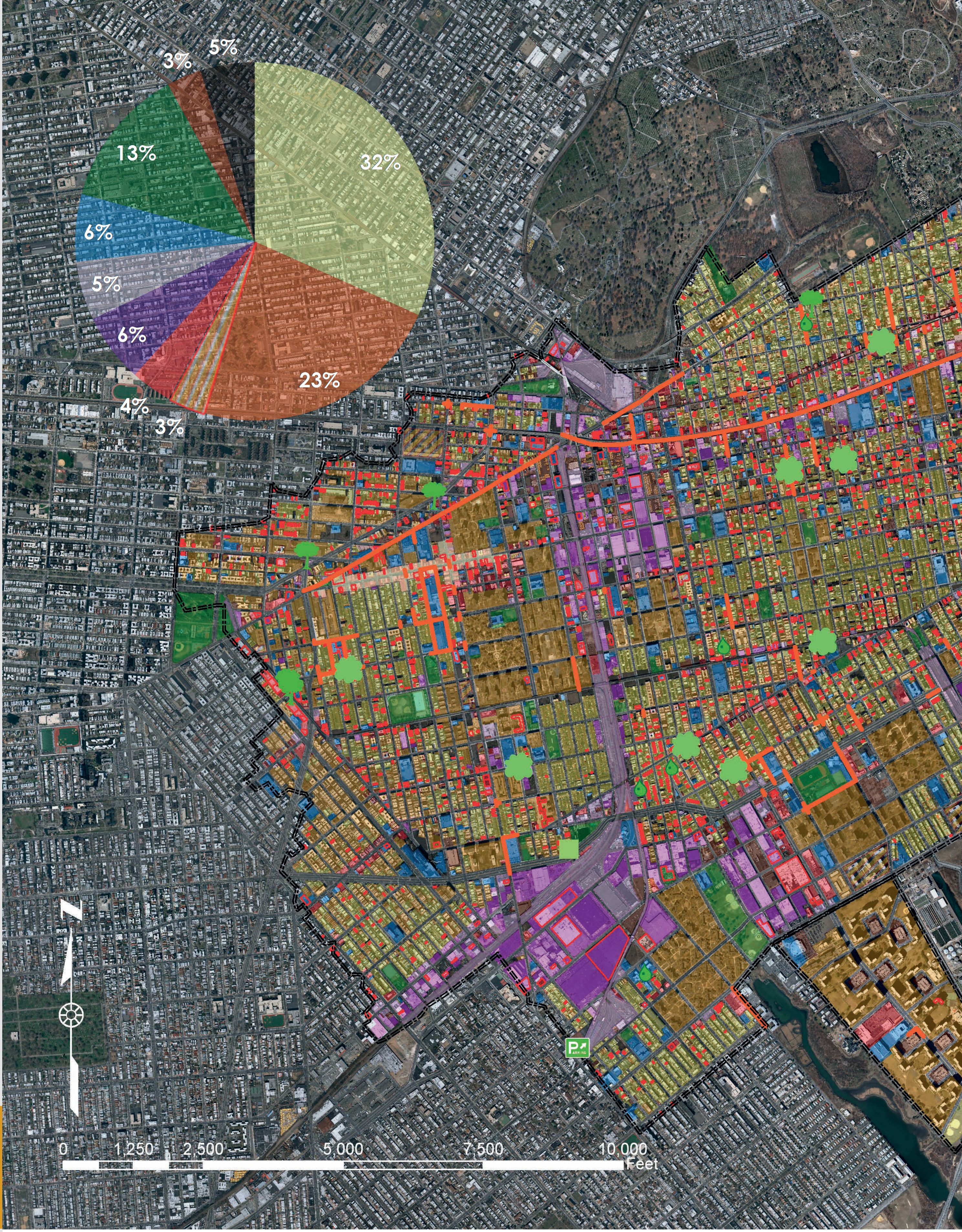






	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—26th Ward Drainage Area Sewer Cleaning, Spring Creek CSO Facility Upgrade, Parallel Interceptor & Bending Weir	207	$169	$0.82
PLUS Reduced Flow	29	-	-
PLUS Green Infrastructure (10% Capture)	49	$284	$5.80
PLUS Tide Gate Repair and Interceptor Cleaning	4	$0.12	$0.03
Green Strategy Total	**289**	**$454**	**$1.57**
Cost-Effective Grey Infrastructure Investments*	152	$119	$0.78
PLUS Potential Tanks, Tunnels & Expansions	132	$546	$4.14
Grey Strategy Total	**284**	**$665**	**$2.34**

* Cost-Effective Grey Investments under the Grey Strategy do not include the interceptor and bending weir option (55 mg reduction) included under the Green Strategy, as they are not necessary with the 26th Ward WWTP wet weather expansion.



GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES


Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Existing and Planned Installations
Community Gardens w/ rainwater harvesting (9)
Parking lots (2)
ROW swales and tree pits (12)
Rain barrels (15)
Rooftops (6)

NEWTOWN CREEK

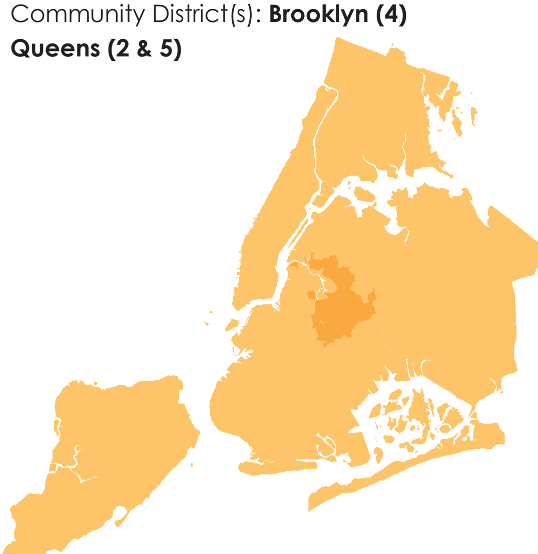
Total Watershed Drainage Area:	**7,441 acres**
Combined Sewer Contributory Area:	**6,032 acres**
Combined Sewer Contributory Impervious Area:	**4,524 acres**
Opportunity Area for Source Controls:	**2,263 acres**

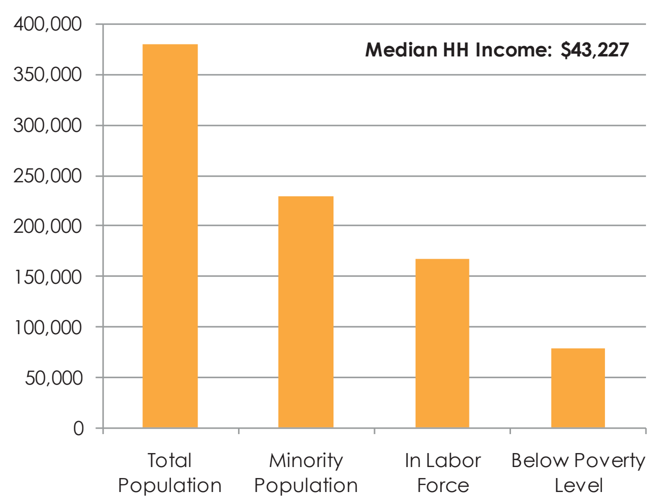
The goal is to manage stormwater from 10% of the impervious surfaces in the combined sewer contributory area. There are opportunities in 47% of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	254	5%
Vacant lots	85	2%
Right-of-way	1,534	32%
Planned ROW Projects	137	3%
Commercial corridors	12	0.2%
Other streets	940	19%
Other sidewalks	447	9%
Multi-family residential complexes	71	1%
Schools	130	3%
Parks	140	3%
Other public properties	50	1%
TOTAL	2,263	47%

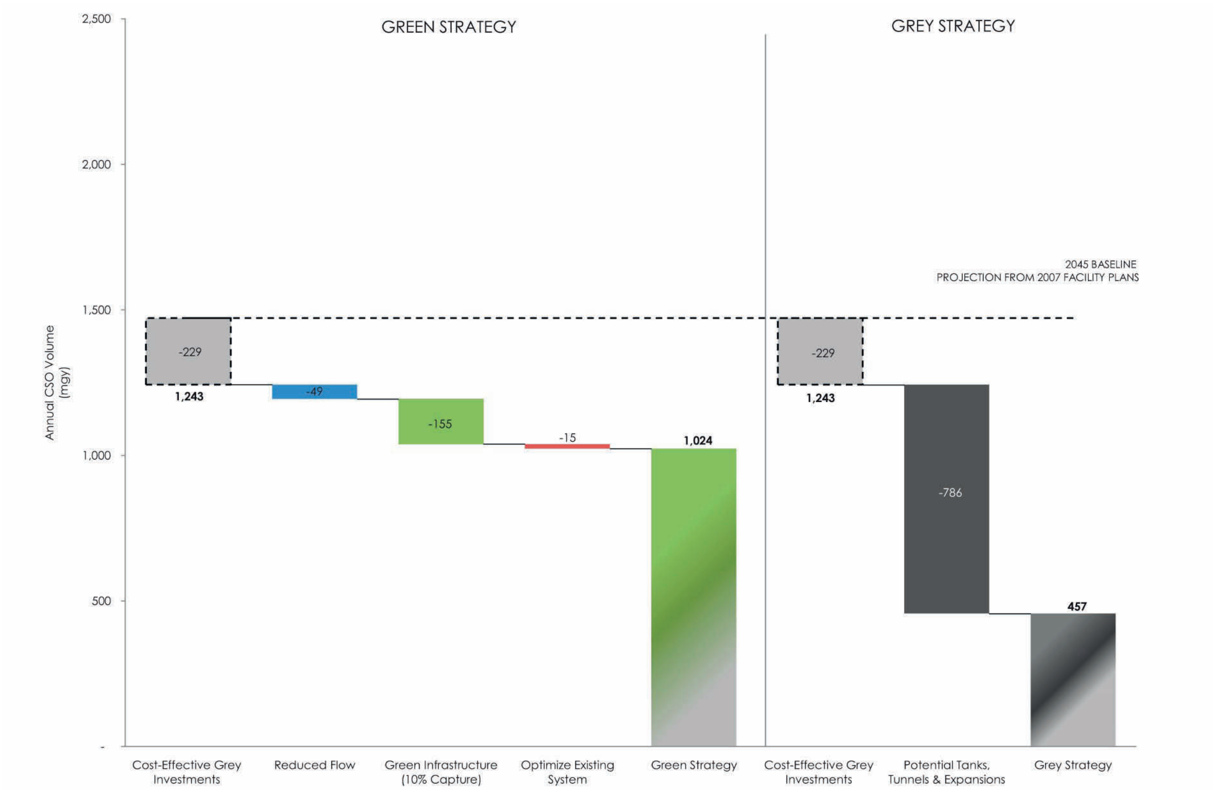
Wastewater Treatment Plant(s):	**Newtown Creek and Bowery Bay**
NYSDEC Classification(s):	**Class SD – Fish Survival**
Ecological Classification(s):	**No Designation**
Existing Water Uses:	**Commercial and Municipal Shipping and Barging**
Shoreline Uses:	**Industrial, Institutional, Commercial, Municipal**

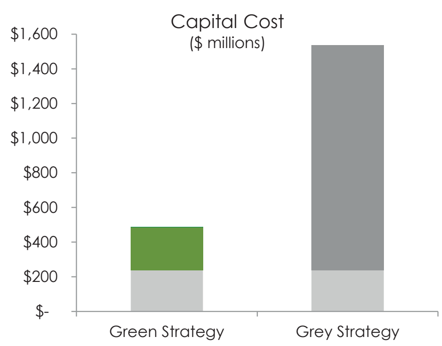
Borough(s): **Brooklyn and Queens**
Community District(s): **Brooklyn (4)**
Queens (2 & 5)

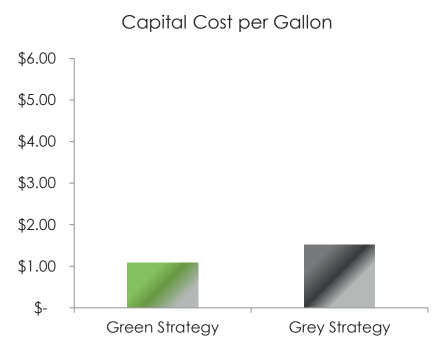




PERFORMANCE AND COSTS



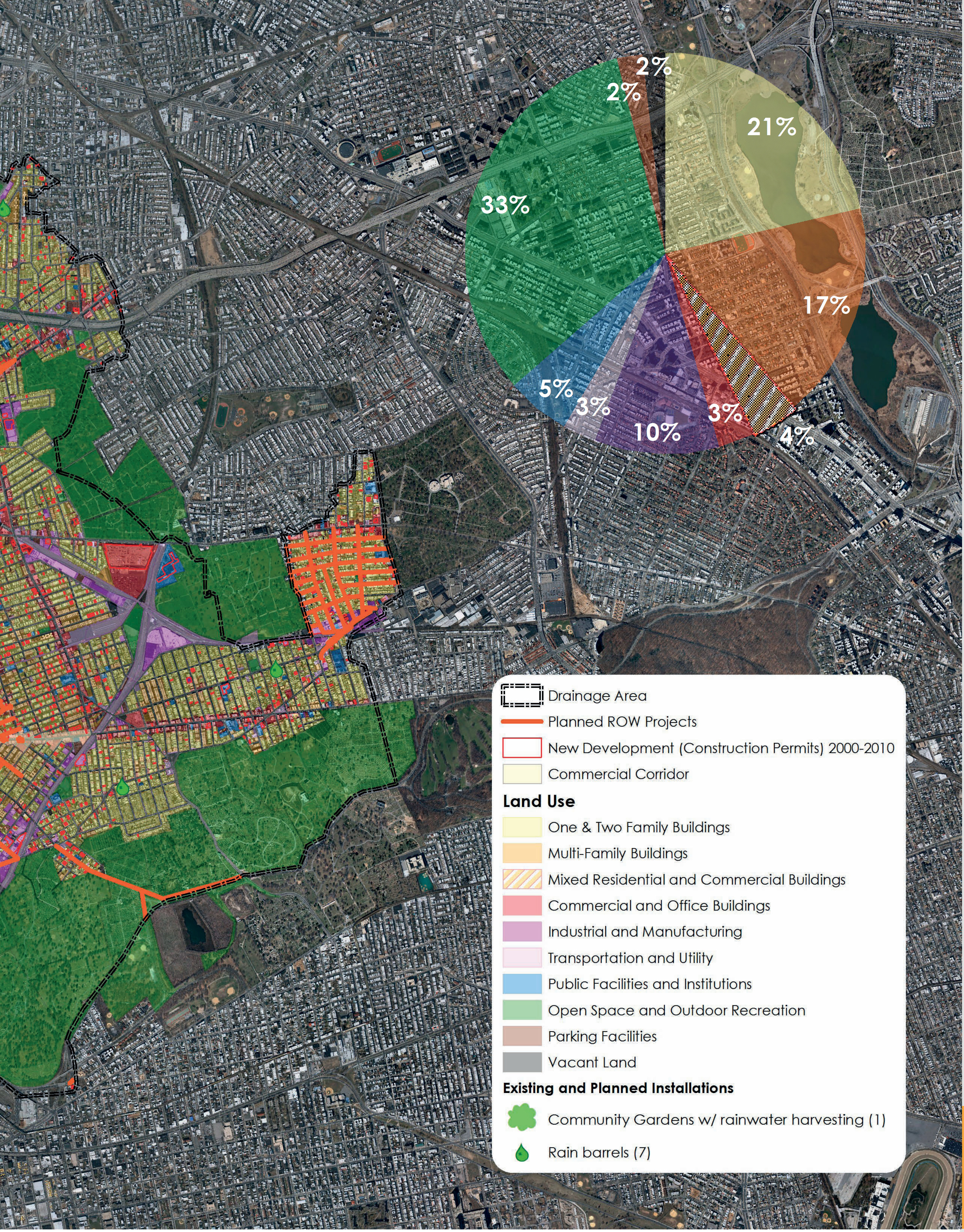




	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Throttling Facility, Expand Newtown Creek WWTP capacity to 700MGD, Bending Weirs, Dutch Kills Relief Sewer, Regulator Modifications	229	$236	$1.03
PLUS Reduced Flow	49	$0	$0.00
PLUS Green Infrastructure (10% Capture)	155	$249	$1.60
PLUS Tide Gate Repair and Interceptor Cleaning	15	$0.05	$0.003
Green Strategy Total	**448**	**$485**	**$1.08**
Cost-Effective Grey Infrastructure Investments	229	$236	$1.03
PLUS Potential Tanks, Tunnels & Expansions—Newtown Creek CSO Retention Tunnel	786	$1,300	$1.65
Grey Strategy Total	**1,015**	**$1,536**	**$1.51**

GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES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Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Commercial Corridor
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Existing and Planned Installations
Community Gardens w/ rainwater harvesting (1)
Rain barrels (7)

PAERDEGAT BASIN

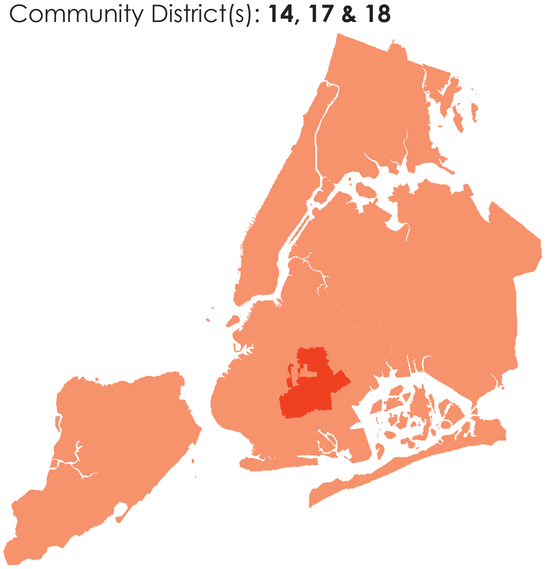
Total Watershed Drainage Area: **6,824 acres**
Combined Sewer Contributory Area: **5,192 acres**
Combined Sewer Contributory Impervious Area: **4,725 acres**
Opportunity Area for Source Controls: **2,037 acres**

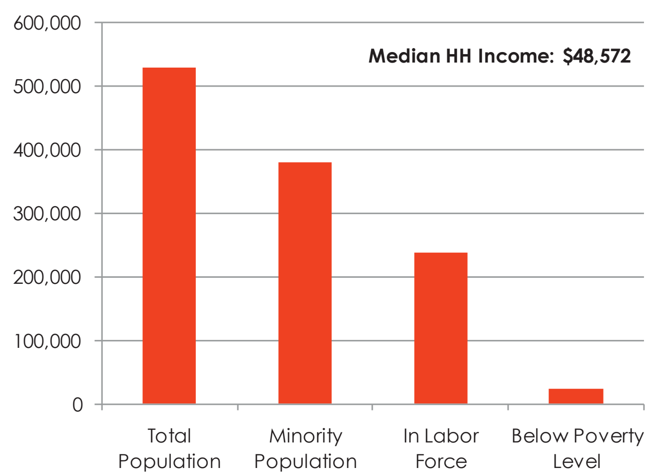
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **43%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	177	4%
Vacant lots	49	1%
Right-of-way	1,495	31%
Planned ROW Projects	16	0.3%
Commercial corridors	4	0.1%
Other streets	1,016	21%
Other sidewalks	459	10%
Multi-family residential complexes	63	1%
Commercial development with parking lots	6	0.1%
Schools	115	2%
Parks	61	1%
Other public properties	69	1%
TOTAL	2,037	43%

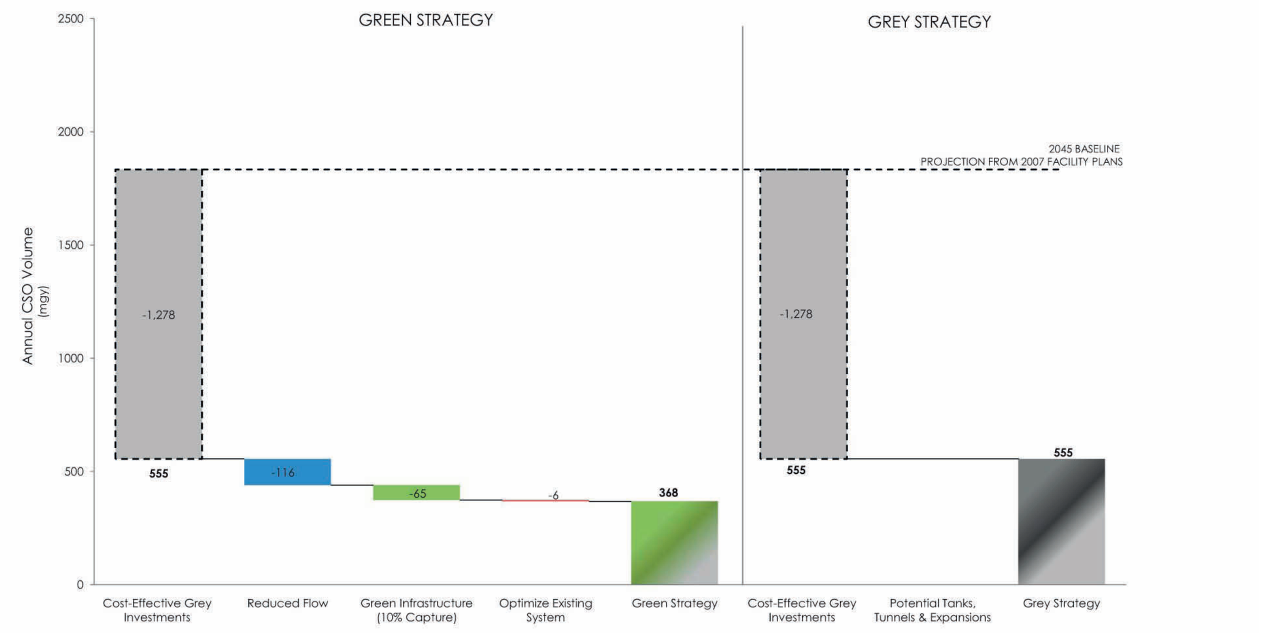
Wastewater Treatment Plant(s): **Coney Island**
NYSDEC Classification(s): **Class I – Secondary Contact, Boating and Fishing**
Ecological Classification(s): **Special Natural Waterfront Area (DCP)**
Existing Water Uses: **Recreational Boating and Fishing**
Shoreline Uses: **Commercial, Municipal, Recreational, Parkland and Open Space**

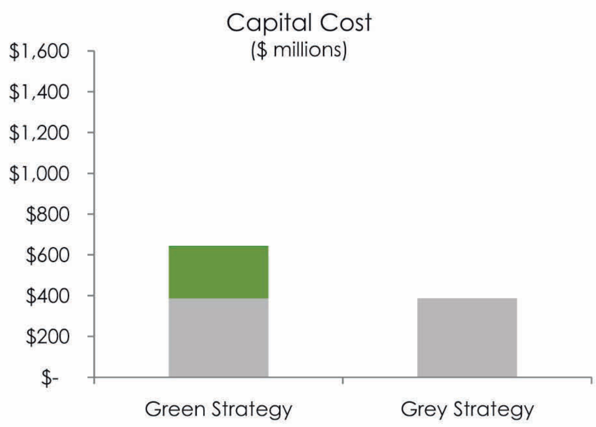
Borough(s): **Brooklyn**
Community District(s): **14, 17 & 18**

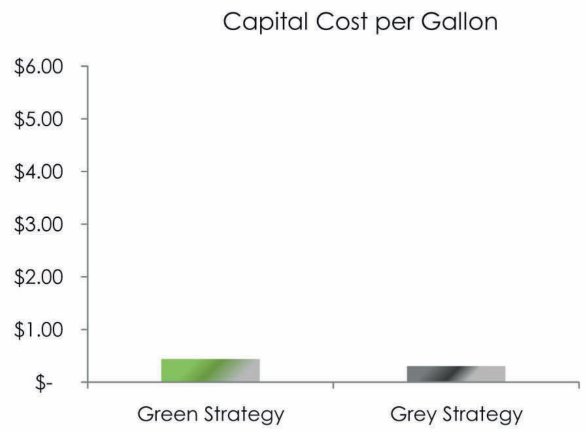




PERFORMANCE AND COSTS



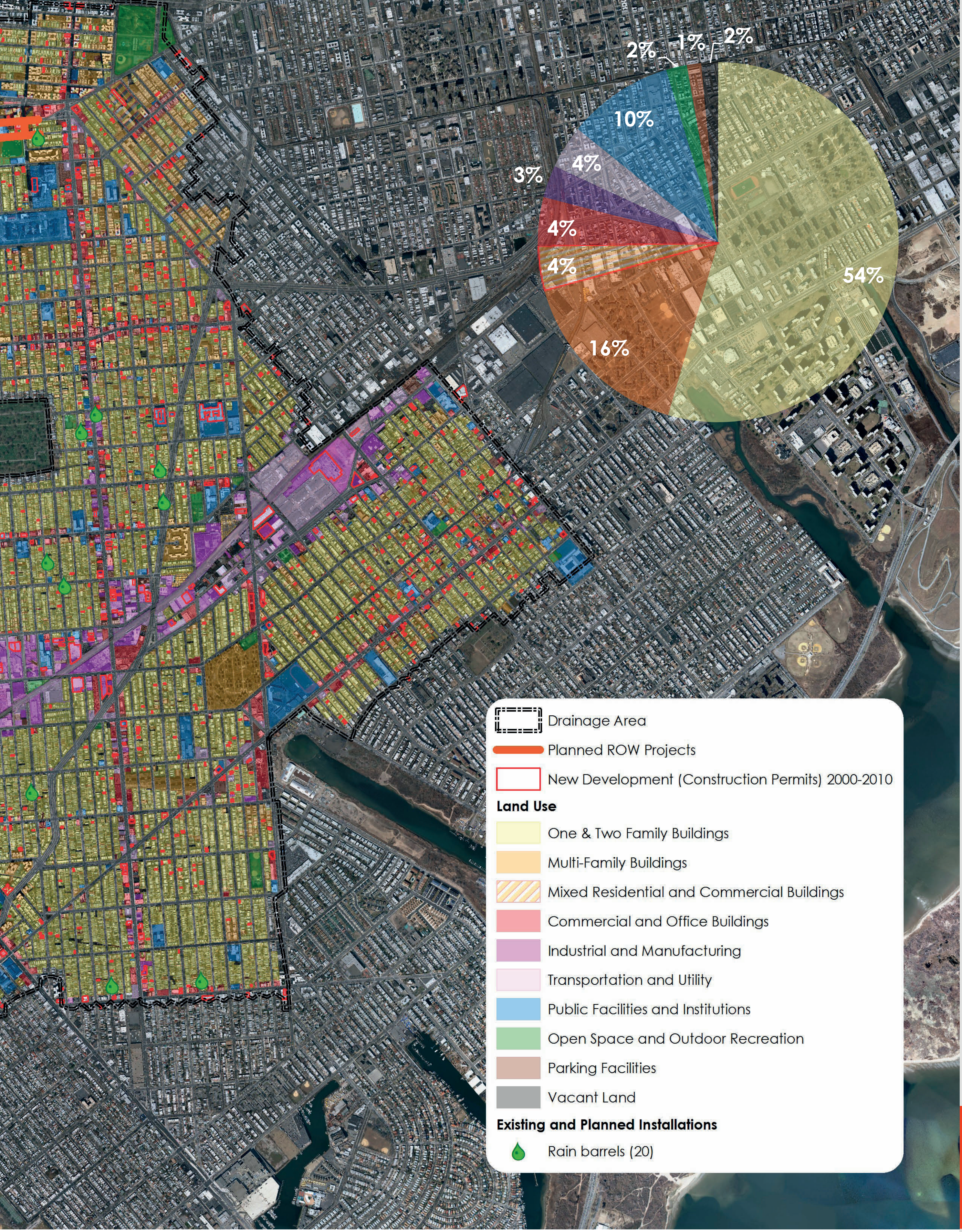




	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—CSO Facility	1,278	$387	$0.30
PLUS Reduced Flow	116	-	-
PLUS Green Infrastructure (10% Capture)	65	$256	$3.94
PLUS Tide Gate Repair and Interceptor Cleaning	6	$0.03	$0.01
Green Strategy Total	**1,465**	**$643**	**$0.44**
Cost-Effective Grey Infrastructure Investments	1,278	$387	$0.30
PLUS Potential Tanks, Tunnels & Expansions	NA	NA	NA
Grey Strategy Total	**1,278**	**$387**	**$0.30**

GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES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54%
16%
Drainage Area
Planned ROW Projects
New Development (Construction Permits) 2000-2010
Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Existing and Planned Installations
Rain barrels (20)

WESTCHESTER CREEK

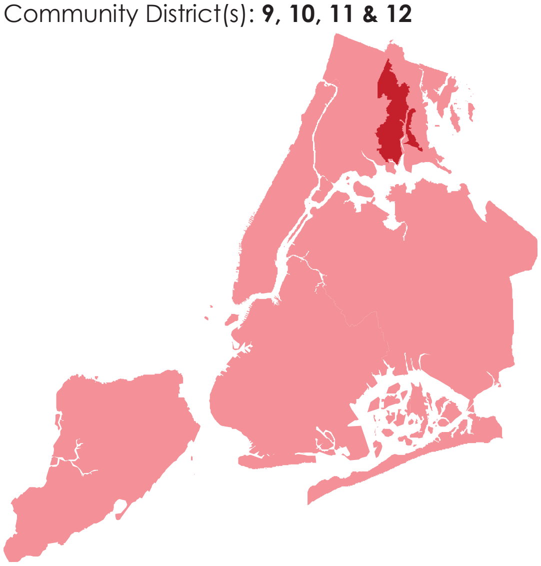
Total Watershed Drainage Area:	**4,952 acres**
Combined Sewer Contributory Area:	**4,243 acres**
Combined Sewer Contributory Impervious Area:	**3,480 acres**
Opportunity Area for Source Controls:	**2,287 acres**

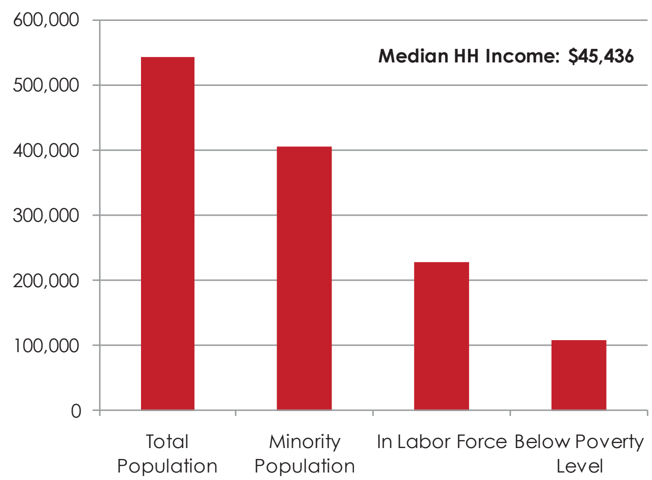
The goal is to manage stormwater from **10%** of the impervious surfaces in the combined sewer contributory area. There are opportunities in **51%** of the combined sewer contributory area.

Opportunities in Combined Sewer Contributory Area	Acres	% of Watershed
New development/redevelopment	**189**	**4%**
Vacant lots	**92**	**2%**
Right-of-way	**1,222**	**27%**
Planned ROW Projects	**24**	**1%**
Other streets	**850**	**19%**
Other sidewalks	**348**	**8%**
Multi-family residential complexes	**267**	**6%**
Commercial development with parking lots	**68**	**2%**
Schools	**61**	**1%**
Parks	**209**	**5%**
Other public properties	**179**	**4%**
TOTAL	**2,287**	**51%**

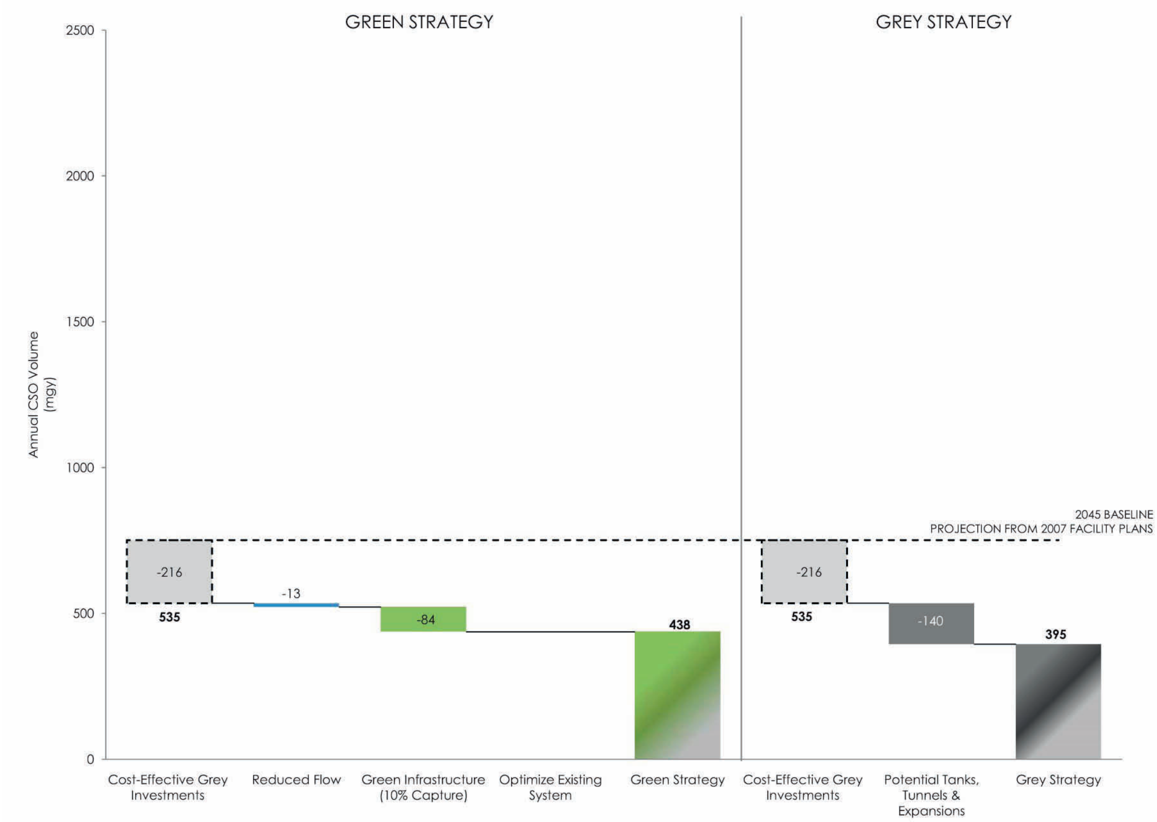
Wastewater Treatment Plant(s):	**Hunts Point**
NYSDEC Classification(s):	**Class I – Secondary Contact, Boating and Fishing**
Ecological Classification(s):	**Special Natural Waterfront Area (DCP)**
Existing Water Uses:	**Commercial Barging, Recreational Boating**
Shoreline Uses:	**Commercial, Industrial, Institutional, Residential, Recreational, Parkland and Open Space**

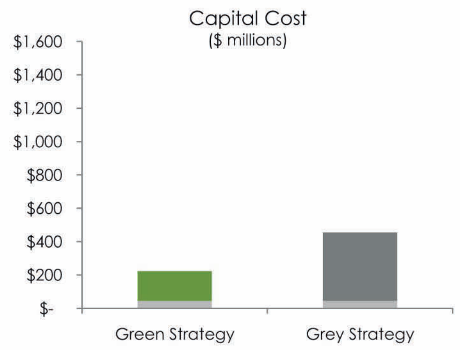
Borough(s): **Bronx**
Community District(s): **9, 10, 11 & 12**

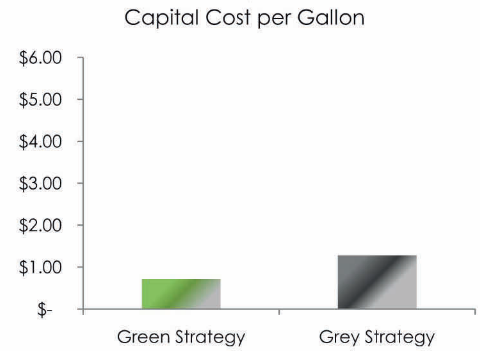




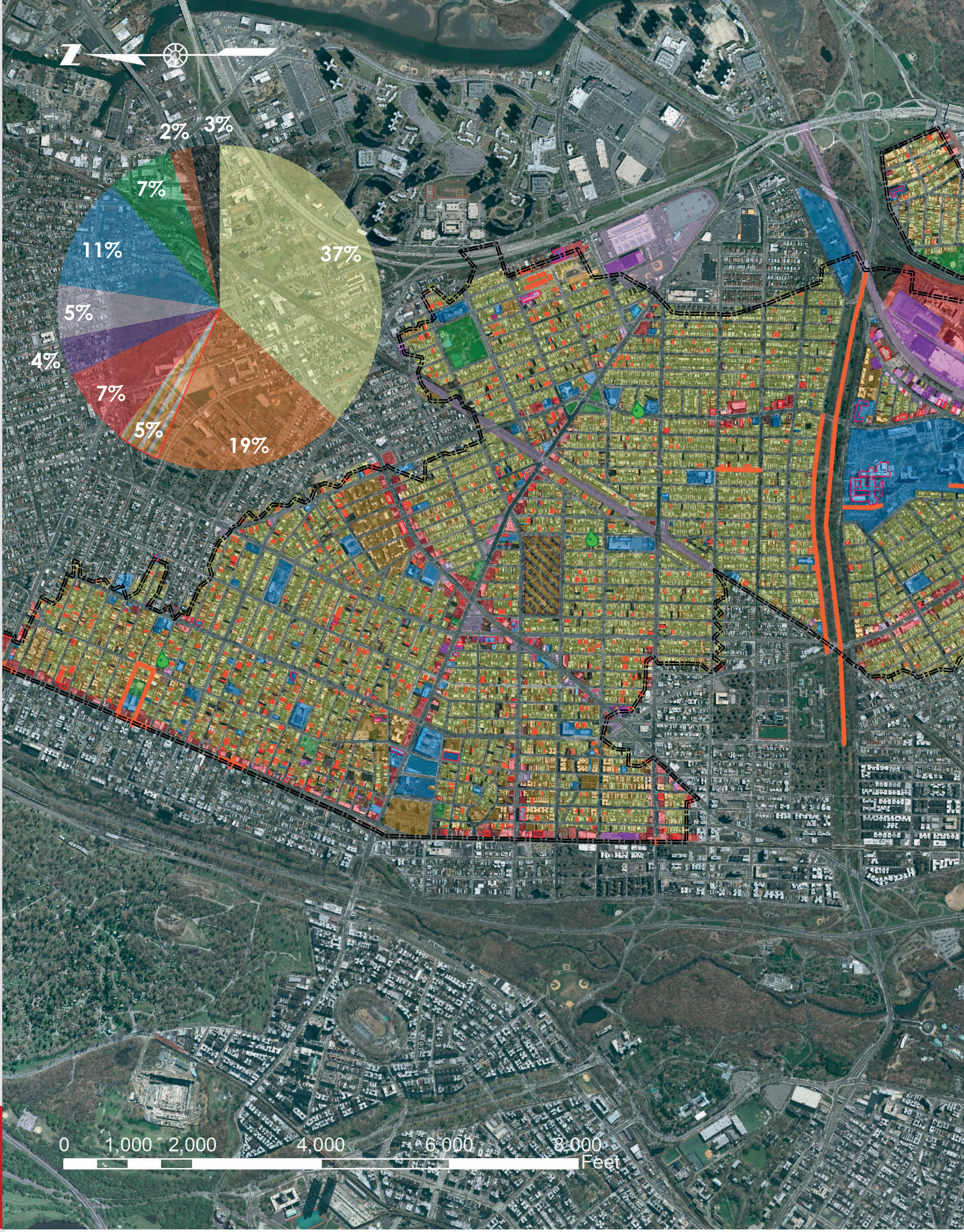
PERFORMANCE AND COSTS





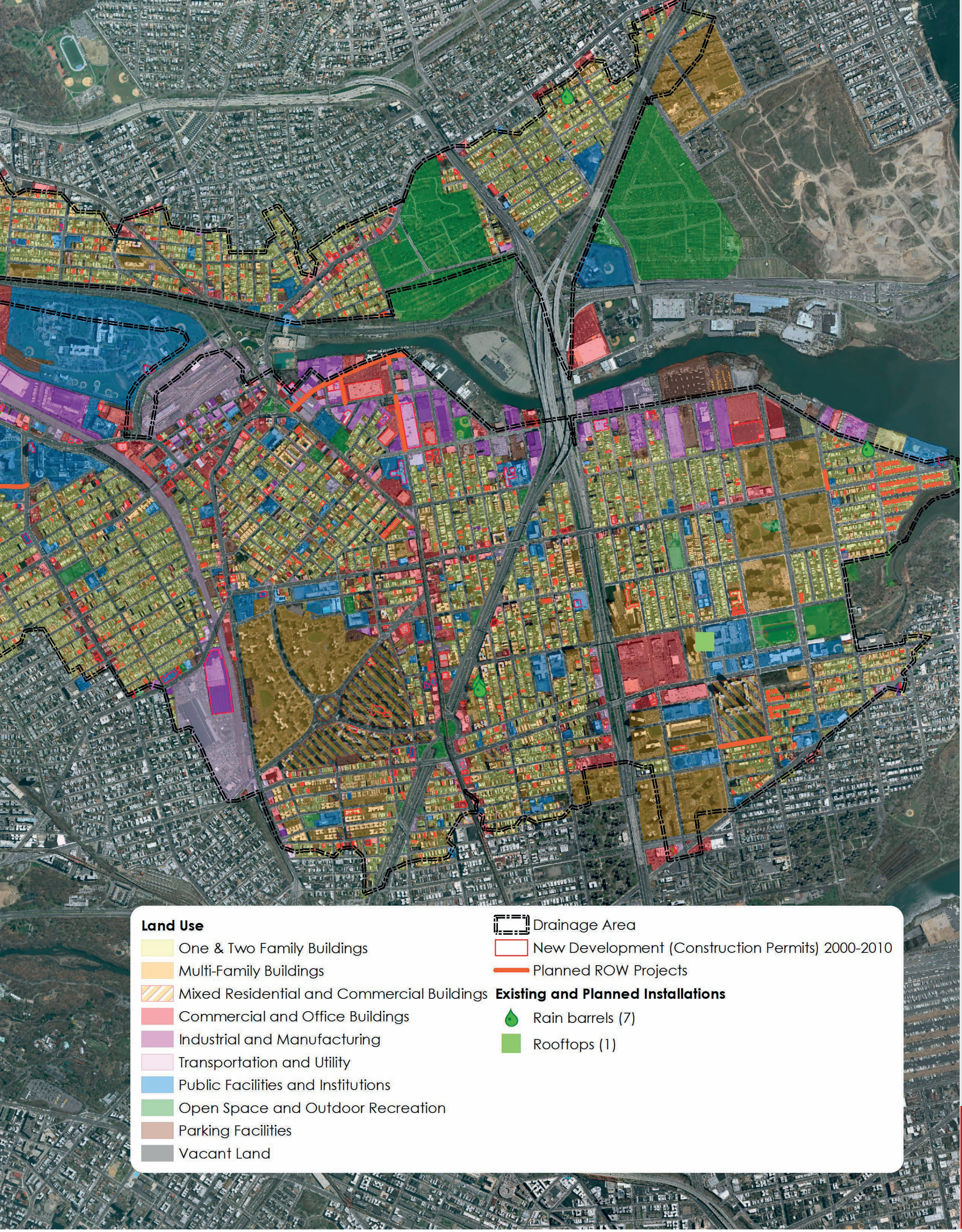


	CSO Volume Reduction (MG/yr)	Capital Cost ($M)	Capital Cost per Gallon
Cost-Effective Grey Infrastructure Investments—Hunts Point WWTP Improvements, Regulator Improvements	216	$46	$0.21
PLUS Reduced Flow	13	-	-
PLUS Green Infrastructure (10% Capture)	84	$178	$2.11
PLUS Tide Gate Repair and Interceptor Cleaning	NA	NA	NA
Green Strategy Total	**313**	**$223**	**$0.71**
Cost-Effective Grey Infrastructure Investments	216	$46	$0.21
PLUS Potential Tanks, Tunnels & Expansions—CSO Facility	140	$409	$2.92
Grey Strategy Total	**356**	**$455**	**$1.28**



GREEN INFRASTRUCTURE PLAN

OPPORTUNITIES


Land Use
One & Two Family Buildings
Multi-Family Buildings
Mixed Residential and Commercial Buildings
Commercial and Office Buildings
Industrial and Manufacturing
Transportation and Utility
Public Facilities and Institutions
Open Space and Outdoor Recreation
Parking Facilities
Vacant Land
Drainage Area
New Development (Construction Permits) 2000-2010
Planned ROW Projects
Existing and Planned Installations
Rain barrels (7)
Rooftops (1)

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

Institutionalizing adaptive management

The City's Green Infrastructure Plan will reduce CSOs by building Cost-Effective Grey Infrastructure, optimizing the existing wastewater system, and installing source controls to manage runoff from 10% of impervious surfaces in CSO watersheds.

The Green Infrastructure Plan is an example of adaptive management, an iterative decision-making process where incremental measures are matched with feedback mechanisms. Better decisions in successive rounds lead to a process and culture of continual improvement. This learning-by-doing framework is appropriate for contexts where there is considerable uncertainty. From DEP's point of view, adaptive management is a necessary approach to address CSOs because of the uncertainty of shifting requirements, climate, rainfall, population, land use, labor costs, material costs, and technology. At the core of this strategy is DEP's ability to model performance to support scenario planning, to measure performance to assess progress towards our management goals and interim milestones, and to monitor water quality to ensure that we are meeting our ultimate objectives.

Improving water quality modeling

DEP's ultimate goal is a water quality-based plan so that its investments can be focused where they are most needed. The LTCPs will be based on achieving water quality objectives in specific watersheds. The modeling results underlying this first installment of the Green Infrastructure Plan are preliminary and reflect CSO reductions rather than ambient water quality improvements, which DEP expects to show, but has not yet quantified.

By mid-2011, well in advance of the LTCPs, DEP will conduct additional modeling to understand the likely effects of the Green Infrastructure Plan on ambient water quality. DEP will complete additional water quality modeling for four watersheds within six months and will complete additional modeling for all of the 13 watersheds in one year.

Recalibrate the InfoWorks model using updated impervious data. The current InfoWorks model is based on estimates of impervious cover from aerial photography for limited areas of New York City. DEP now has detailed impervious data for all of the City, based on a satellite flyover in 2009 that took infrared images and captured the light spectrum emitted by vegetated and impervious areas. Additional flow monitoring has been conducted at ten locations, and ten more are planned to support recalibration of the model. Model recalibration may affect CSO total volumes and reductions for the various strategies presented in this first installment of the Green Infrastructure Plan.

Incorporate DEP's recently updated wastewater flow projections. The results presented in this report reflect a mix of baseline conditions (2005, 2008 and 2045). DEP is creating a consistent set of baseline data based on 2030 flow projections. This data will more precisely predict the effects of more modest flows from our consistently declining water use.

Model the effects of a combination of detention strategies and infiltration strategies. The modeling relied upon in this plan is based on infiltration strategies. A combined approach using detention technologies is more realistic given New York City soils, bedrock, groundwater, underground utilities, and ultra-urban environment. While detention strategies are more difficult to model, DEP has developed a methodology for doing so. DEP is also building a number of infiltration and detention technologies to determine the strategies that will work for New York City; the monitoring from these demonstration projects will be used to inform future modeling of green infrastructure.

Model ambient water quality. The more detailed modeling of predicted CSO reductions will be used to support modeling of the effects of the Green Infrastructure Plan upon water quality.

DEP will also model the hydraulic capacities of the sewer system in key drainage areas. In order to maximize the use of the existing system, DEP will assess the capacity of the interceptors and large lateral sewers in key drainage areas to determine their capability for retaining additional wet weather flow. This will help determine where additional cost-effective retrofits may be appropriate. This modeling will also help DEP determine if some flow can be diverted to less-sensitive CSO outfall locations.

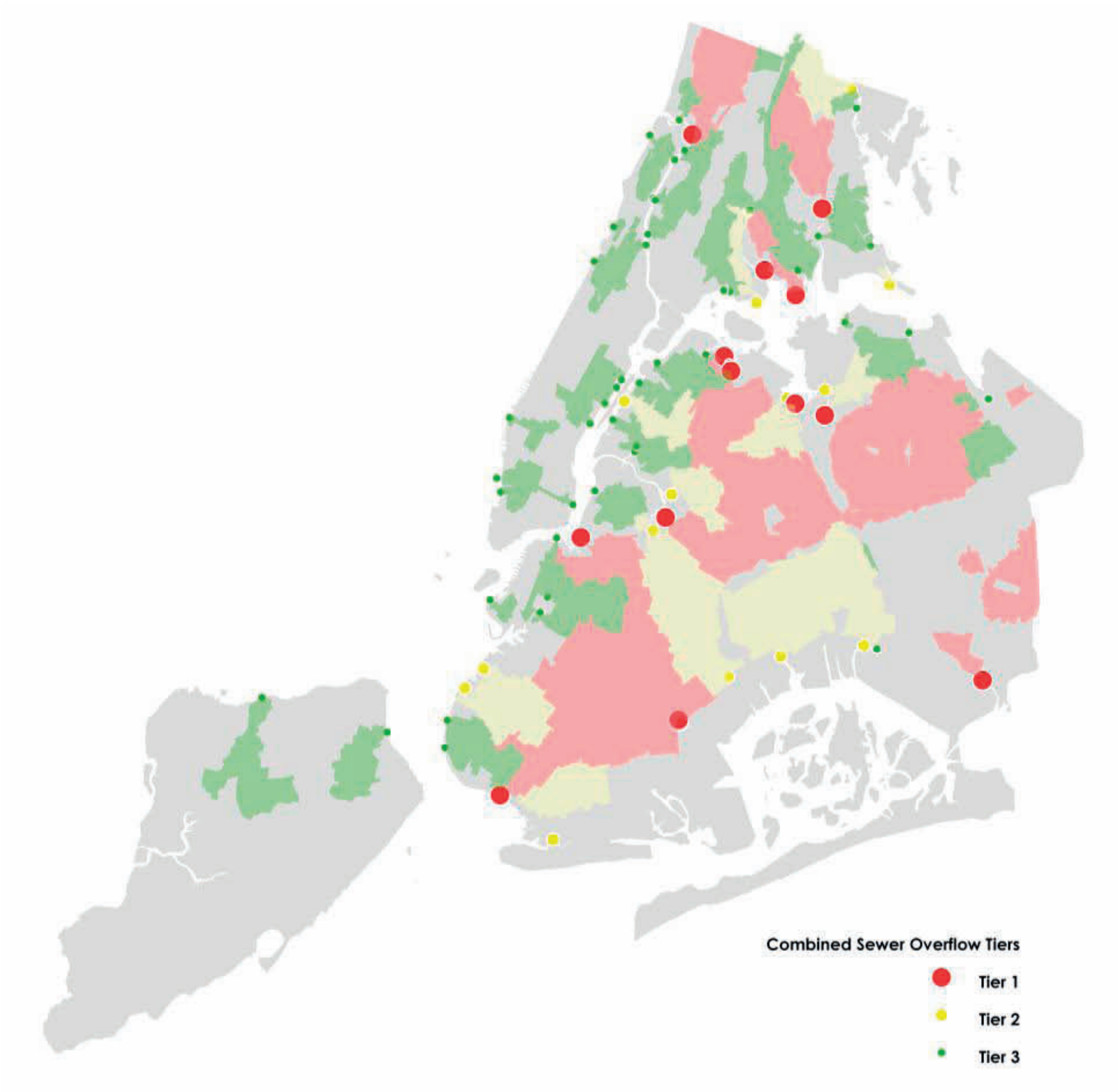
Measuring program performance and CSOs

The goal of this Green Infrastructure Plan is to improve ambient water quality by reducing CSO volumes throughout New York City. Direct and comprehensive CSO measurement poses a great challenge due to the large number and widespread distribution of the 422 combined sewer outfalls throughout the City (Figure 25). To date, DEP has developed three methods to monitor CSO events: telemetry at CSO outfalls, flows captured by WWTPs, and outflow from CSO retention facilities.

Figure 25: CSO Outfalls in New York City

Telemetry at CSO outfalls. DEP operates a computerized telemetry system that monitors the elevation of wastewater flows at 110 regulators throughout the interceptor sewer system. The telemetry system monitors the flow treated at DEP's 14 WWTPs; 83% of the citywide CSO flow was estimated based on modeling using this system. This coverage is possible because the 110 regulators monitored encompass all Tier 1, 2 and 3 outfalls, which service most of the land area in the City (see Figure 26).[4]

Figure 26: Tier 1, 2, and 3 CSO Outfalls and Associated Service Areas



4 Tier 1 outfalls comprise roughly 50% of all CSO volumes; Tier 2 outfalls account for an additional 25% of CSO volumes; and subsequent tiers offer diminishing returns on CSO monitoring: Tier 3 an additional 15%, Tier 4 an additional 5%, and Tier 5 the remaining 5%.

DEP is in the process of upgrading its Supervisor Control and Data Acquisition (SCADA) system to improve the monitoring of wastewater elevations in regulators. SCADA systems gather and analyze real-time data to monitor and control equipment, and are widely used in the telecommunications, water and wastewater utility, energy, and transportation industries. By gathering information, transferring it back to a central site, carrying out necessary analysis, and displaying the information in a logical and organized fashion, DEP's SCADA systems will allow for greater control. For example, DEP's SCADA operators will be able to open and close gates at regulator chambers in order for its interceptors to store excess flow during wet weather periods. Once the new SCADA system is complete, DEP will be able to evaluate whether there are reductions in potential CSO overflows related to specific strategies in drainage areas. DEP also has telemetry at its 95 pumping stations where it measures and reports for wet well elevation.

Flow captured by WWTPs. DEP monitors the hourly flow captured by wastewater treatment plants during wet weather. This allows the agency to evaluate the performance of WWTPs during individual storm events and also to understand the impact of CSO initiatives on the retention time within each of our interceptors. Our WWTPs can process up to twice their design capacity during wet weather periods, and hourly monitoring of the inflow enables DEP to compare the flow profile associated with storm events. For example, improved optimization of interceptors will allow more sewage to be processed and less CSOs discharged, thus reducing the number of hours where WWTPs register maximal inflows.

Outflow from CSO detention facilities. DEP currently operates CSO detention facilities at Spring Creek and Flushing Creek, and will begin operations at the Paerdegat Basin and Alley Creek CSO detention facilities in 2011. By monitoring the flow delivered through these CSO detention facilities DEP can assess whether the initiatives to store additional flow within the collection systems are leading to measureable improvements.

These three methods, together with sophisticated CSO models, allow DEP to monitor CSO events and assess the relative impact of its initiatives on CSO outflows. DEP's systems, however, cannot measure actual CSO volumes and current technology to meter the precise quantities of CSOs at outfall locations is limited.

Monitoring ambient water quality

For the past 100 years, DEP has been monitoring New York Harbor to evaluate the improvements from the construction and optimization of WWTPs and sewers. Since the Harbor Survey was started in 1909 with 12 monitoring stations around Manhattan, it has evolved into a tool that regulators, scientists, managers, educators, and citizens rely on to assess impacts, trends, and improvements in the harbor's water quality.

Today, DEP collects 20 water quality parameters from 57 stations across the Harbor, more parameters and locations than other municipalities in New York State. DEP conducts monthly testing at all 57 stations, with weekly testing during the summer season. DEP samples the waterways for dissolved oxygen to protect marine life and fecal coliform bacteria to protect human health. In addition to mandatory parameters, DEP measures 18 additional indicators in its testing regime, including water transparency, chlorophyll A (for algae blooms), temperature, and pH. DEP's water quality testing is supplemented with a shoreline water quality testing program conducted in partnership with the New York City Department of Health. These results are reported in DEP's *New York Harbor Water Quality Annual Reports*.

Harbor water quality has improved dramatically since the initial surveys, and monitoring enables DEP to manage its operations to maintain high water quality and to focus attention and resources on areas that need to be improved. Nonetheless, some small tributaries – the creeks, canals, basins that feed into New York Harbor – are periodically affected by pathogens from CSO events.

DEP will increase the number of monitoring sites at the mouths of key tributaries to gauge improvements in pathogen concentrations resulting from the green strategy.

Research and development for measuring CSOs

The industry standard is to use computer models to estimate future CSO volumes and associated pollutant loadings for purposes of making investment decisions, and such models have long been accepted by regulators. The sophisticated models used by DEP have been customized for more than a decade to reflect the City's unique infrastructure, as calibrated by flow metering. These models predict CSO flows depending on the sewer configurations of individual catchment and sub-catchment areas.

Actual monitoring is also critical to managing CSOs. Despite advancements in technology, however, measuring the flow of CSO volumes is difficult in combined sewer systems that are influenced by tidal waters. When tide gates are working, the end of the CSO outfall is closed during high tide; when they are not working, tidal flows can intrude into the regulator. These tidal conditions and other factors make it very difficult to rely upon flow meters.

DEP conducted a flow meter pilot study from January to April 2007 to assess four leading flow meters from different manufacturers. The meters were designed to monitor the volume of sewage flow at critical regulator sites in a range of flow conditions. The study concluded that none of the flow meters made reliable measurements within an acceptable range of accuracy. Since then, DEP has continued to track the efforts of other municipalities to measure CSOs, and not found any successful, independent efforts to identify reliable technology.

Accordingly, DEP will launch a focused and applied research effort to develop the best strategy and technology for quantifying and tracking CSO volumes. That effort will challenge the wastewater engineering and technology industry to develop, through a request for expressions of interest, an appropriate application.

5. ENGAGE AND ENLIST STAKEHOLDERS IN STORMWATER MANAGEMENT

Notification systems to reduce potential exposure

During the time that DEP's green infrastructure initiatives take root and other CSO control mechanisms are built, it is important to reduce exposure to potentially harmful waters. The City has several structural safeguards in place. The most important is the construction of public bathing facilities in areas that are not affected by CSOs because they are far from outfalls or are in areas with undisturbed shorelines and strong tidal flows. The City has over 14 miles of public bathing beaches with supporting amenities that hosted over 7.7 million visitors in 2009. The New York City Department of Health has a vigorous monitoring and advisory system to protect bathers from pathogen infection, and this system is integrated with the City's 311 system and an email notification system to provide information to the public.

The City does not recommend swimming in unofficial areas, which do not have lifeguards and may be located where there are dangerous riptides, currents, and boat traffic. In addition, unofficial swimming areas may be closer to CSO outfalls or in confined and altered waters that do not have a flow that is sufficient to remove contaminants. State water quality regulations reflect these appropriate uses in harbor waters, and restrict "primary contact recreation" to bathing beaches and similar areas. These standards provide another layer of institutional control against exposure to pathogens.

Nevertheless, there is a risk that some members of the public will be exposed to contaminants from CSOs through incidental contact with the water. DEP has installed signs on the water side and land side of all 422 CSO outfalls that can be read by the public. The current signs contain language that, although it has been approved by the DEC, is not as informative as it could be (Figure 27). To improve the notification program, DEP is replacing the current signs with new signs that meet DEC requirements and will be easier to read from a distance, will have clearer warnings for wet weather events that could cause CSOs, and will have graphic images to

Figure 27: Old and New CSO Signs

Old CSO Sign

New CSO Signs

convey unambiguous warnings about recreational use to English and non-English speakers alike. These replacements will be completed in the next two years.

In addition, DEP is updating its website so that members of the public can check to see where CSOs are likely. The website will include real-time rainfall gauges at the airports and Central Park as well as model predictions about the effect of rainfall on various waterbodies. This system cannot predict every overflow; it is particularly challenging to predict overflows caused by rainfall over a limited area that may not be captured by the official rainfall gauges. Nevertheless, members of the public will be able check the site before swimming, boating, or fishing to obtain general advice about whether CSO events are likely.

Public outreach, education, and engagement

As stormwater management systems become more decentralized, well-organized data systems and stakeholder participation are critical. At the outset, DEP will have to educate developers, the general public, and other stakeholders about their role in the management of stormwater. In partnership with DEC, this outreach effort will involve community boards, stormwater advocacy and green job non-profit organizations, Citizens Advisory Committees (CACs), civic organizations and other City agencies. The City will be sure to include environmental justice organizations and communities where the sustainability benefits of green infrastructure – cool shady streets, improved air quality, and energy savings – are especially needed. DEP will extend its educational outreach effort to encourage the community to build and maintain green infrastructure.

Outreach and education

DEP will meet with community groups, environmental groups, and the general public to describe the agency's vision for the Green Infrastructure Plan, to explain our analysis and modeling assumptions, to identify opportunities for building green infrastructure, and to develop stewardship programs for maintaining green infrastructure. On June 28, 2010, DEP held an initial public meeting on the major findings in this report. DEP's website will also include related information, graphics, and provide an online system for the submittal of public ideas. These preliminary discussions with stakeholders will enable DEP, together with DEC, to further refine and develop a comprehensive outreach program.

This preliminary effort, including stakeholders' involvement and input, will carry over into outreach that is necessary for the formulation of LTCPs. DEP foresees a significant role for stakeholder involvement in the citywide LTCP development process and plans to establish a citywide CAC that will meet regularly. Other outreach efforts could include mailings, media notifications, water bill inserts, and a public service announcement to be played while 311 callers are on hold, featuring the DEP Commissioner talking about stormwater management. DEP will also use its dedicated education program and community liaisons who work with schools and are regularly involved in community board meetings and events.

In anticipation of those efforts, DEP has already revamped its website to include a comprehensive overview of the city's sewer system that explains how the system functions during wet weather and the issues surrounding stormwater and water quality. In the future it will provide multi-media information for a range of audiences to understand stormwater-related issues and the necessary steps to solve these issues. DEP sees the website as a critical tool for stormwater education as well as for distributing important information to the stakeholders and general public. The website would link to a citywide CAC.

Partnerships to build and maintain green infrastructure

Partnerships are critical to the successful implementation of green infrastructure. DEP is currently working on several fronts to enlist community-based organizations and local universities in the implementation of green infrastructure. As noted in this Plan, DEP issued $2.6 million in grants to local environmental groups and academic institutions to build research-based demonstration projects such as green roofs, permeable pavement, curbside swales, rain gardens, and restored wetlands.[5] Past grant programs have sponsored other demonstration projects and curriculum-based programs for long term maintenance and monitoring. DEP has also provided in-kind services such as water quality modeling and supplying materials. Finally, DEP will continue to share monitoring data from our demonstration projects and obtain data from outside groups.

DEP has also worked with other city agencies to build stormwater pilots on various types of public property. The City's Green Infrastructure Task Force will strengthen these relationships by provide planning, design, and funding for agency partners to incorporate stormwater management into their capital projects and standard designs, and to plan for long-term maintenance. The Task Force will also facilitate outside funding for green infrastructure construction and maintenance.

Green infrastructure conference

Cities around the world are adopting innovative environmental policies within a framework of sustainability to cope with climate change and to maintain population and economic growth. At the same time, wastewater utilities across the globe seek more intelligent ways to deliver services, regulators are focusing on nonpoint sources and other unexamined sources of pollution, and new technologies are being developed to assist in those efforts. To bring these strains together – and to develop practical solutions to our common problems – DEP will sponsor an international forum to focus on innovative ideas and strategies for urban green infrastructure and sustainable approaches to water quality. This conference will bring together scientists, engineers, planners, and policy makers to share their experiences and to develop practical solutions.

[5] In coordination with an environmental benefit program with DEC undertaken in connection with the settlement of an enforcement action taken by New York State and DEC for violations of New York State Law and DEC regulations.

NEXT STEPS

Begin immediate implementation of the Green Infrastructure Plan

The City is taking a number of concrete steps to begin early implementation of the Green Infrastructure Plan:

1. Preparing a Green Infrastructure Fund;
2. Creating 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;
3. Building green infrastructure demonstration projects on a variety of land uses;
4. Partnering with community groups to develop programs for the construction and maintenance of green infrastructure;
5. Launching a comprehensive program to increase optimization of the existing system, including drainage plans, hydraulic studies, the survey and rehabilitation of 136 miles of interceptor sewers in two years, the inspection and repair of tide gates, and programs to prevent grease from obstructing the sewers;
6. Developing a stormwater management standard for new construction and redevelopment that expands existing development;
7. Piloting sewer charges for stormwater for stand-alone parking lots;
8. Refining DEP models by including new impervious cover data and extending predictions to ambient water quality;
9. Identifying other funding for additional elements of the Green Infrastructure Plan; and
10. Replacing all CSO outfall signs to reduce potential exposure.

Incorporate green infrastructure and adaptive management into the existing regulatory structure

The Green Infrastructure Plan is a natural extension of the Clean Water Act, which is built upon a foundation of adaptive management principles. Such regulatory mechanisms as the five year cycle of discharge permits, the three year cycle of water quality standard reviews, the two year cycle of state Section 305(b) water quality assessments, the periodic state Section 303(d) impaired waters listings, and the planning process under Section 303(e), require iterative, incremental decision-making.

In another context – the Filtration Avoidance Determination under the Safe Drinking Water Act – the City, State, EPA and other partners have used an adaptive structure to protect the safety of New York City's drinking water with decentralized, cost-effective solutions. There, the Catskill and Delaware watershed partners have preserved forested areas and natural buffers, and have used landscape-based stormwater techniques, in a multi-year program across an entire watershed, to avoid centralized infrastructure that would not have been cost-effective. This approach can and must be used under the Clean Water Act.

In the context of CSO policy, consent orders and LTCPs should allow for learning by doing and for the maturation of green infrastructure designs and techniques. (See *Coordinating CSO Long Term Control Plans with Water Quality Standards Reviews*, EPA Guidance on Implementing the Water Quality Based Provisions of the CSO Control Policy (2001) ("An iterative, phased implementation of CSO controls fits well with the watershed approach.")).

The EPA recently held a forum on water policy. (See *Coming Together for Clean Water* (April 15, 2010, Washington, DC). One of its main topics was the watershed approach to clean water, which the EPA has long endorsed as one of four pillars of sustainable infrastructure. In the *Coming Together for Clean Water* forum, the EPA explained its preferred watershed approach in terms that almost exactly match New York City's approach in PlaNYC, the Jamaica Bay Watershed Protection Plan, the Sustainable Stormwater Management Plan, and now the Green Infrastructure Plan:

> The watershed approach provides a coordinated, holistic framework to water resources management that encourages locally led public and private sector efforts to address the highest priority problems within hydrologically defined geographic areas. To be ultimately successful, the watershed approach must fully embrace clear, unambiguous **goals**, program integration and **adaptive management**; **waterbody protection**, restoration, and enhancement; **planning and implementation**; and **regulatory** and **non-regulatory approaches**.

(http://blog.epa.gov/waterforum/discussion-document/) (emphasis added)

The City's Green Infrastructure Plan meets these criteria. First, it has clear goals. Meeting applicable state water quality standards is the ultimate performance standard under the Clean Water Act, and DEP will have to demonstrate attainment – or the lack of attainment due to other factors – in the LTCPs and in subsequent monitoring. In this report DEP has suggested a management goal: capturing the first inch of rainfall on 10% of the impervious areas in CSO watersheds through detention or infiltration techniques, at the end of a 20-year implementation period. Furthermore, DEP proposes to meet this goal by achieving 1.5% by 2015, another 2.5% by 2020, another 3% by 2025, and the remaining 3% by 2030.

Second, DEP's program includes adaptive management and watershed approaches. Adaptive management is explained in detail in the previous section. As to waterbody protection, the Facility Plans, anticipated LTCPs, and DEP's whole approach, are proceeding on a waterbody basis. Over the next year, DEP will refine its modeling and will extend its predictions to ambient water quality.

Third, the entire CSO program is focused on waterbody protection and implementation to meet water quality standards, where attainable. That yardstick allows DEP, with the advice and approval of DEC, to decide where to focus its investments. DEP's Cost-Effective Grey Infrastructure Investments are expected to meet current water quality standards in the Paerdegat Basin, Coney Island, Alley Creek, and East River and Open Waters watersheds. While some elements of the Green Infrastructure Plan will occur in every area, it may not be necessary to make public investments in green infrastructure in watersheds where there is likely to be attainment of water quality standards.

Instead, water quality and economic considerations are likely to drive DEP's initial investment of public funds in green infrastructure towards watersheds where attainment of water quality standards is not likely. Candidate watersheds include:

- The Hutchinson River, Westchester Creek, Flushing Bay, and Jamaica Bay and CSO Tributaries watersheds, where DEP is seeking to preclude the need for tanks, tunnels and expansions. (A tunnel is also proposed for Newtown Creek, but green infrastructure strategies need to be synchronized with Superfund and other planned water quality concerns improvements.)
- The Bronx River watershed, where DEP has not yet invested heavily in hard infrastructure and where there is significant public support for green infrastructure.
- The Gowanus watershed.

The prioritization of these and other watersheds will depend upon modeled predictions about meeting water quality objectives.

Fourth and finally, DEP has proposed non-regulatory approaches to complement the existing regulatory approaches to stormwater control. PlaNYC, the City's sustainability plan, sets forth a holistic program of planting a million trees, improving air quality, reducing greenhouse gases, encouraging green roofs, requiring green parking lots and, of course, improving water quality through a mix of traditional and green infrastructure. In 2008, the City published the *Sustainable Stormwater Management Plan*, the product of an interagency task force effort to identify innovative and flexible approaches to encouraging source controls of runoff. This Green Infrastructure Plan advances those ideas and provide a detailed implementation plan.

This holistic watershed approach must be incorporated into the existing regulatory structure to be fully realized. For over 20 years, DEP has made great progress working with DEC to meet the requirements of the Clean Water Act and the national CSO control policy. However, to make further progress, DEP will work with DEC, EPA, community leaders, and environmental stakeholders to reach a consensus about the direction and scope of the Green Infrastructure Plan and to memorialize that consensus.

The City submits this Green Infrastructure Plan to DEC for its consideration and incorporation into the CSO order and future LTCPs. The City believes that the most sustainable and cost-effective approach will include certain grey infrastructure projects, conservation, green infrastructure, and operational measures to control CSOs. This approach will take time to implement, but the City is starting immediately to take specific steps to create a greener, greater city by 2030.

INFOWORKS MODELING DETAILS

WWTP dry weather flows (MGD)

Year	26W	BB	CI	HP	JA	NC	NR	OH	PR	RH	TI	WI	Total 12 WWTPs	Total All WWTPs
2005	52	108	87	121	82	211	121	95	28	28	57	198	1188	1,237
2006	50	97	83	115	83	214	118	96	28	30	54	203	1171	1,223
2007	46	95	80	118	84	223	119	87	26	30	53	209	1170	1,221
2008	44	94	78	120	81	220	119	89	27	26	54	201	1153	1,203
2009	42	97	80	114	76	233	115	86	24	26	53	184	1130	1,175
New DEP Wastewater Projections														
2010	*47*	*98*	*82*	*118*	*81*	*220*	*118*	*91*	*27*	*28*	*54*	*199*	*1162*	*1,212*
2020	*47*	*102*	*83*	*118*	*84*	*222*	*121*	*92*	*28*	*28*	*56*	*201*	*1182*	*1,233*
2030	*48*	*107*	*85*	*120*	*88*	*225*	*124*	*94*	*29*	*29*	*58*	*204*	*1212*	*1,265*
2045 Flow Projections Used in the Facility Plan Modeling														
2045	*67*	*129*	*107*	*128*	*88*	*268*	*163*	*115*	*39*	*39*	*60*	*219*	*1422*	

Note: Blue indicates wastewater flows (dry weather) modeled in this plan. Green indicates 2030 flows that exceed modeled flows.

1. 2045 flows used for waterbody and watershed Facility Plans are extremely conservative; 35 years out and based on an unreasonable new growth per capita of 161 gallons per capita per day (gpcd). This is more than twice the amount New York City is experiencing today.

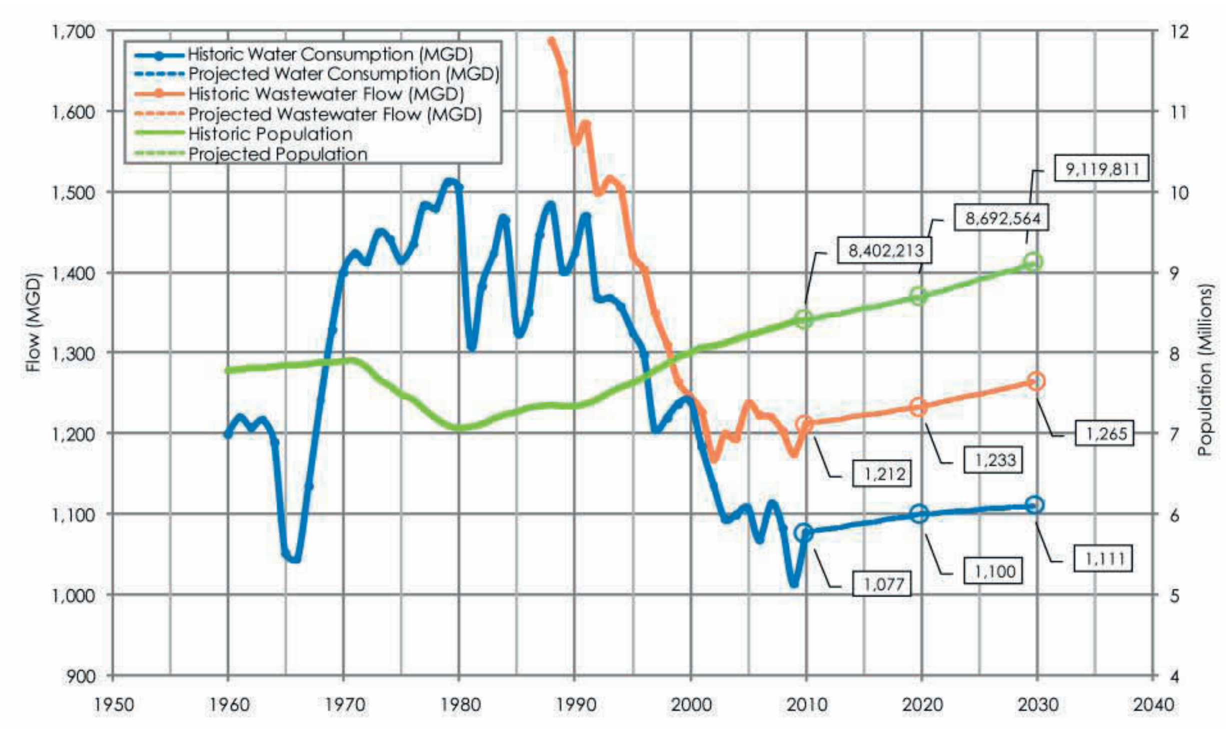
2. Therefore, for Green Infrastructure Plan modeling, DEP used 2005 flows (except Newtown Creek-used 2008 flows) as a conservative estimate of future flows. Water consumption and wastewater flows have declined considerably from 2005 levels. In 2005, wastewater flows were 62 mgd over 2009 levels.

3. Since completing its modeling for the Green Infrastructure Plan, DEP has completed new projections that show that, except for 4 plants, 2005 levels will not be reached until 2030 or beyond. For the 4 plants (shown in green), 2030 values are within 3-6 mgd of 2005/8 values.

4. DEP's new projections are based on new growth per capita of 78 gpcd, which was conservatively estimated.

5. Baseline maximum wet weather treatment plant capacity and sewer system delivery capacity are taken as the typical conditions that existed in New York City in 2003 prior to signing the CSO Consent Order as was the case for the modeling that supported the Facility Plans.

In-city water consumption & wastewater flows: historic and future projections



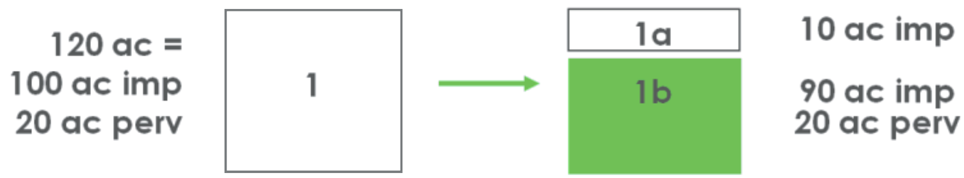
Water consumption and wastewater flows are projected to remain stable over next 10-20 years.

Green infrastructure modeling approach

- Controlled impervious surfaces through retention of first 1 inch of rainfall

Example:

- Catchment #1 is 120 acres (ac), including 100 acres impervious, 20 acres pervious:
    - Since the goal is capture of 10% of stormwater runoff: 10% x 100 acres = 10 acres
    - For the rest of the catchment = 90 acres impervious + 20 acres pervious = 110 acres
    - All other characteristics of subcatchments 1a and 1b are exactly the same (width of overland flow, slope, roughness, etc.)



- Rainfall for each subcatchment

  Created two rainfall patterns:
    - Rainfall pattern 1 = 1988 rainfall (base year)
    - Rainfall pattern 2 = same but removed first 1 inch of rain from each storm event

  #1a subjected to rainfall pattern 2

  #1b subjected to rainfall pattern 1 (including both its impervious and pervious portions)

Tide gate modeling approach

- Assess CSO reduction benefits of reducing inflow of tide water into combined sewer systems through leaking tide gates
- Reduce leakage to levels required to meet SPDES 400 mg/L chloride limit
- Assume sanitary sewage is reduced equally throughout system
- Assess CSO reduction benefits of removing sediments in combined sewer systems
    - Step 1 - Put measured sediment into model & calculate annual CSO
    - Step 2 - Remove sediment from model & calculate annual CSO
- Less sanitary sewage in system, more CSO to WWTP

	12-month average Cl mg/L	SPDES Limit 400 mg/l	Calc allow Q leak MGD	Existing DEP leakage estimate MGD	Potential reduction leakage MGD
Wards Island	430	400	5.3	9.1	3.8
North River	220	400	3.1	3.0	NA
Hunts Point	210	400	3.0	1.5	NA
26th Ward	360	400	1.1	1.1	NA
Coney Island	710	400	2.0	3.9	1.9
Owls Head	170	400	2.2	0.9	NA
Newtown Creek	660	400	5.6	12.1	6.5
Red Hook	640	400	0.7	1.4	0.7
Jamaica	210	400	2.1	1.0	NA
Tallman Island	320	400	1.4	1.5	0.1
Bowery Bay	380	400	2.4	2.9	0.5
Rockaway	1900	400	0.6	2.9	2.3
Oakwood Beach	170	400	0.7	0.3	NA
Port Richmond	420	400	0.6	1.0	0.4

Potential reduction of leakage flow to the plant based on leakage over SPDES limit of 400 mg/l chlorides. This reduction at the plant was modeled to determine annual CSO volume reductions.

Interceptor cleaning modeling approach

Sediment data assignment

- Multiple depths available for each interceptor segment
- IW model sediment depth calculated by averaging "Deposit Codes" in IW pipe segment

Interceptor	Amount of Sediment (cubic yards)	Annual CSO Reduction (Volume)	Annual CSO Reduction (Percent)	Already accounted for in the 2008 and WBWS modeling
26th Ward	484	6	1.8%	Yes
Jamaica	3072	411	24.5%	No
Tallman Island	499	41	1.3%	Yes

InfoWorks model

General

The InfoWorks model is a commercially available product from Wallingford Software (http://www.wallingfordsoftware.com). The model is used to analyze urban hydrology and hydraulics. The InfoWorks model is capable of using GIS data, of modeling continuous and event simulations, of incorporating real time controls, of modeling green and grey infrastructure, and of performing water quality tracking.

Urban hydrology & hydraulic modeling

- Infiltration models are based off of the Horton's infiltration model (see following page).
- Overland runoff routing is modeled using the Non-linear Reservoir Runoff Routing Model.
- Sewer flow routing models are governed by the Saint-Venant Equation. The latest data used in the model assumes that there are 25,000 catchments, 7,500 pipes, and 6,000 manholes and regulators. The model uses a sewer size of greater than 36 inches for all NYC sewers.

Horton's infiltration model

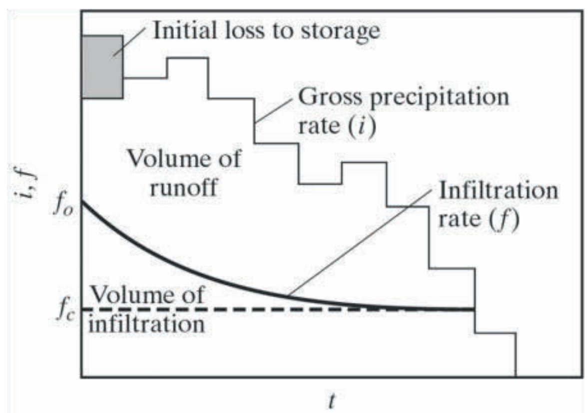
$f = f_c + (f_o - f_c)\ \exp(-kt)$

f_c = final rate value

f_o = initial rate value

f(t) = rate of water loss into soil

K = decay rate



Saint-Venant equations

Continuity equation

Conservation form (Q/A used)

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

Nonconservation form (V used)

$$V\frac{\partial y}{\partial x} + y\frac{\partial V}{\partial x} + \frac{\partial y}{\partial t} = 0$$

Momentum equation

Conservation form

$$\frac{1}{A}\frac{\partial Q}{\partial t} + \frac{1}{A}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$$

Local acceleration term; Convective acceleration term; Pressure force term; Gravity force term; Friction force term

Nonconservation form (unit width element)

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$$

Kinematic wave

Diffusion wave

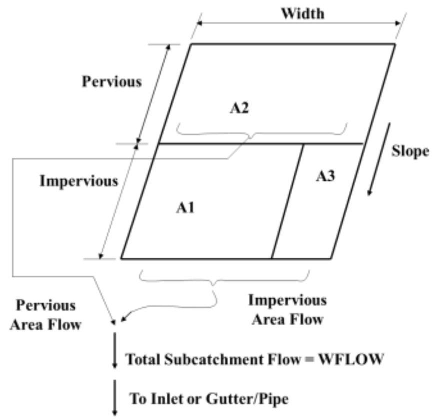
Dynamic wave

Process used in LTCP project

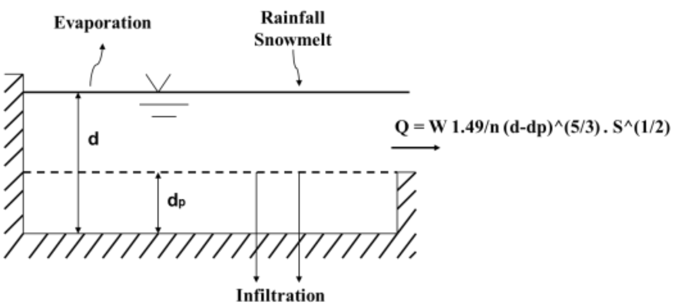
- f_o and f_c are set from SWMM literature, (e.g., 8-12"/hour for HSG A – sand)
- K is set as default, but f_o and f_c are adjusted during the hydrologic model calibration

SWMM overland flow routing model

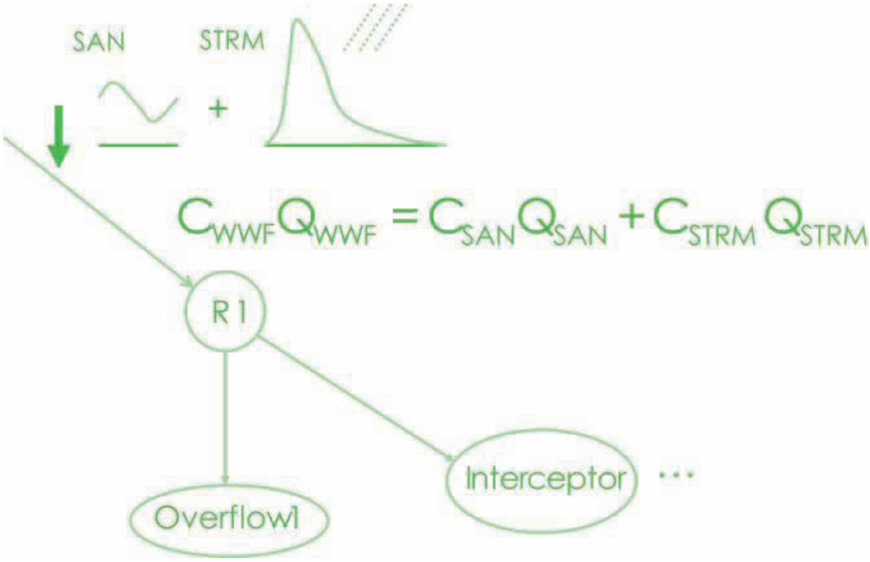
This model analyzes the processes through which the rainfall excess is transported to the point of interest. This transport occurs primarily in the form of overland flow (very shallow open channel flow). This model uses a simple reservoir routing model.



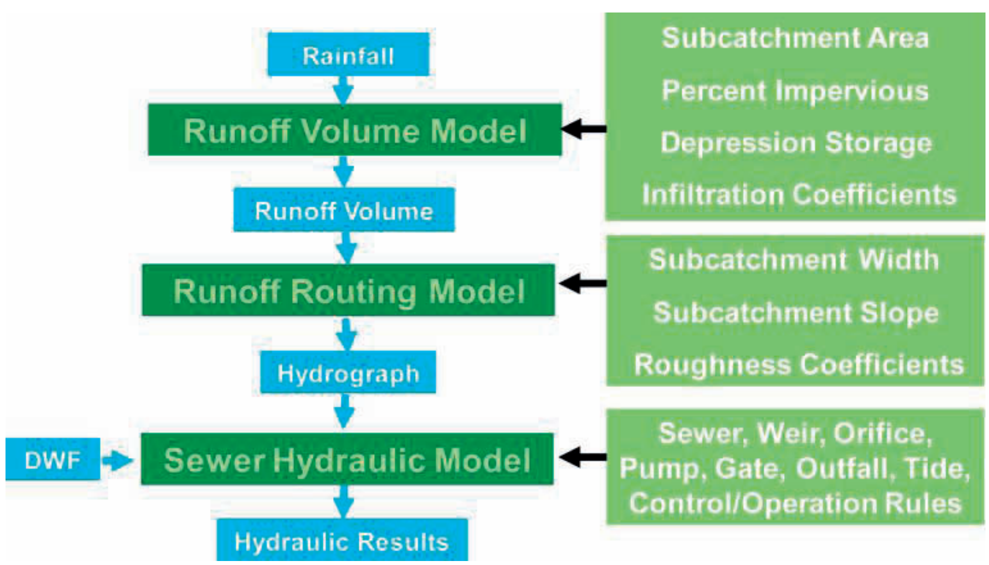
Non-Linear Reservoir Model of Subcatchment



Unique WQ methodology used in NYC



Model parameters reviewed during facility planning and green infrastructure evaluation



GREEN INFRASTRUCTURE COST ESTIMATE DETAILS - CITYWIDE

Scenario	Impervious Area to Be Addressed to Meet 10% Capture (Acres)*	ROW Portion (Acres)	Public Onsite Development Portion (Acres)	Private Onsite Development Portion (Acres)	CSO Reductions (MGY)	$/acre On-site	$/acre ROW	ROW Portion (Millions)	Public Onsite Development Portion (Millions)	Public Portion Total (Millions)	Private Portion Total (Millions)	Total Costs (Millions)
Alley Creek	223	54	85	85	37	$ 200,000	$ 720,000	$ 39	$ 17	$ 55	$ 17	$ 72
Bergen and Thurston	362	94	134	134	45	$ 200,000	$ 720,000	$ 68	$ 27	$ 95	$ 27	$ 121
Bronx River	350	95	128	128	75	$ 200,000	$ 720,000	$ 68	$ 26	$ 94	$ 26	$ 119
Coney Island Creek	104	31	36	36	6	$ 200,000	$ 720,000	$ 22	$ 7	$ 30	$ 7	$ 37
East River & Open Waters	2,313	-	-	2,313	548	$ 200,000	$ 720,000	$ -	$ -	$ -	$ 463	$ 463
Flushing Bay	607	182	212	212	214	$ 200,000	$ 720,000	$ 131	$ 42	$ 174	$ 42	$ 216
Flushing Creek	888	231	329	329	151	$ 200,000	$ 720,000	$ 166	$ 66	$ 232	$ 66	$ 298
Gowanus Canal	208	64	72	72	32	$ 200,000	$ 720,000	$ 46	$ 14	$ 61	$ 14	$ 75
Hutchinson	169	46	62	62	52	$ 200,000	$ 720,000	$ 33	$ 12	$ 45	$ 12	$ 58
Jamaica Bay & CSO Tributaries	822	230	296	296	49	$ 200,000	$ 720,000	$ 166	$ 59	$ 225	$ 59	$ 284
Newtown Creek	679	217	231	231	155	$ 200,000	$ 720,000	$ 156	$ 46	$ 203	$ 46	$ 249
Paerdegat Basin	709	220	245	245	65	$ 200,000	$ 720,000	$ 158	$ 49	$ 207	$ 49	$ 256
Westchester Creek	522	141	191	191	84	$ 200,000	$ 720,000	$ 101	$ 38	$ 140	$ 38	$ 178
TOTAL	**7,956**	**1,605**	**2,019**	**4,332**	**1,514**	-	-	**$ 1,155**	**$ 404**	**$ 1,559**	**$ 866**	**$ 2,426**

**Impervious area assumptions:* While the goal of the Green Strategy is to capture 1 inch of runoff from 10% of impervious areas in combined sewer watersheds, for the cost analysis, DEP conservatively assumed that 15% of the impervious area of each watershed would be needed to meet the 10% capture goal, pending further modeling. This is because the current modeling is based on capturing 1 inch of runoff based on infiltration techniques, while it is more likely that a combination of detention and infiltration technologies will actually be used to manage stormwater. Equivalent capture through detention technologies will require more land area. Combined detention and infiltration scenarios will be modeled in Phase 2.

GREEN INFRASTRUCTURE COST ESTIMATE DETAILS

Example of Stormwater Source Control Costs for Sidewalk Swales to Capture One Acre of Impervious Surface

CONSTRUCTION BUDGET ESTIMATE

Green Infrastructure Type: Sidewalk Swale

System Length =	40	ft	Drainage Area	2,200	sf
System Width =	5	ft	BMP AREA	200	sf
System Height =	4.5	ft	Storage Provided* =	183	cf
Excavation Depth (System Height+ 6" base) =	5	ft			

Materials	Quantity	Unit	Unit Material Cost	Total Material Cost
Disposal	37	CY	$ 35.00	$ 1,295
Install Sandy Loam Soils	19	CY	$ 78.00	$ 1,482
Select Granular Fill - Drainage Stone	1	CY	$ 32.00	$ 32
Root Barrier	52	LF	$ 9.50	$ 494
Curb Piece Installation and Sidewalk Repair	18	LF	$ 125.00	$ 2,250
Fence and Tree Guard Installation	50	LF	$ 55.00	$ 2,750
Trees	2	EA	$ 800.00	$ 1,600
Plantings and Mulch	200	SF	$ 4.25	$ 850
Equipment Rental Cost	10	days	$ 325.00	$ 3,250
Total Material & Equipment Cost				$ 14,003

Labor Time and Cost	Quantity	Unit	Daily Fee per Crew	Labor Estimate
Total Labor Estimate	10	days	$ 1,552.00	$ 15,520

Total Construction Cost per Swale		$ 29,523
Total Construction Cost per 1-Acre of Impervious Surface	20 (# swales needed to capture 1 acre impervious)	$ 590,460

Design, Construction Monitoring, and Contingency (20% of total)	$ 118,092
Total Cost for Streetside Swale with Design, Construction Monitoring & Contingency	**$ 708,552**

* Capacity is to capture one inch of rainfall and does not assume infiltration

Example of Stormwater Source Control Costs for Perforated Pipe on One Acre Property

CONSTRUCTION BUDGET ESTIMATE

Green Infrastructure Type: Perforated Pipe

System Length =	99	ft	Drainage Area	43,560	sf
System Width =	110	ft	BMP AREA	10,892	sf
System Height =	1.7	ft	Storage Provided* =	5,599	cf
Excavation Depth (System Height+ 6" base) =	2.2	ft			
Number of Pipe Rows =	62				

Materials	**Quantity**	**Unit**	**Unit Material Cost**	**Total Material Cost**
Disposal	901	CY	$ 25.00	$ 22,525
8" HDPE Perforated Pipe	6138	LF	$ 5.00	$ 30,690
Select Granular Fill - Drainage Stone	406	CY	$ 32.00	$ 12,983
Filter Fabric - top and sides	1314	SY	$ 1.50	$ 1,971
Manifold System Piping (8" HDPE)	221	LF	$ 5.15	$ 1,138
Manifold System Tees (8" HDPE)	124	EA	$ 114.00	$ 14,136
Equipment Rental Cost	28	days	$ 700.00	$ 19,600
Total Material & Equipment Cost				$ 103,044

Labor Time and Cost	**Quantity**	**Unit**	**Daily Fee per Crew**	**Labor Estimate**
Total Labor Estimate	28	days	$ 1,430.00	$ 40,040

Additional Materials	**Quantity**	**Unit**	**Unit Material Cost**	**Total Material Cost**
DEP Standard Catch Basin - Inlet to system (includes exc., frame, grate, and	5	EA	$ 2,500.00	$ 12,500
DEP Standard - Inlet to system (includes exc., frame, grate, and hood)	1	EA	$ 2,500.00	$ 2,500
Piping to existing combined sewer (6" Cast iron)	30	LF	$ 29.00	$ 870
Connect to existing combined sewer	1	EA	$ 1,640.00	$ 1,640
Clean-out / overflow	1	EA	$ 152.00	$ 152
Post-construction monitoring				$ 1,725
Total Additional Materials Cost				$ 19,387

Total Construction Cost for Perforated Pipe	$ 162,471

Design, Post-Construction Monitoring, and Contingency (20% of total)	$ 32,494
Total Cost for Perforated Pipe with Design, Post-construction Monitoring & Contingency	**$ 194,965**

* Capacity is based on capturing at least 5,580 cfs to achieve a release rate of 0.25 cfs for an acre property with a 0.9 runoff coefficient.
Green infrastructure sizing does not assume infiltration

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