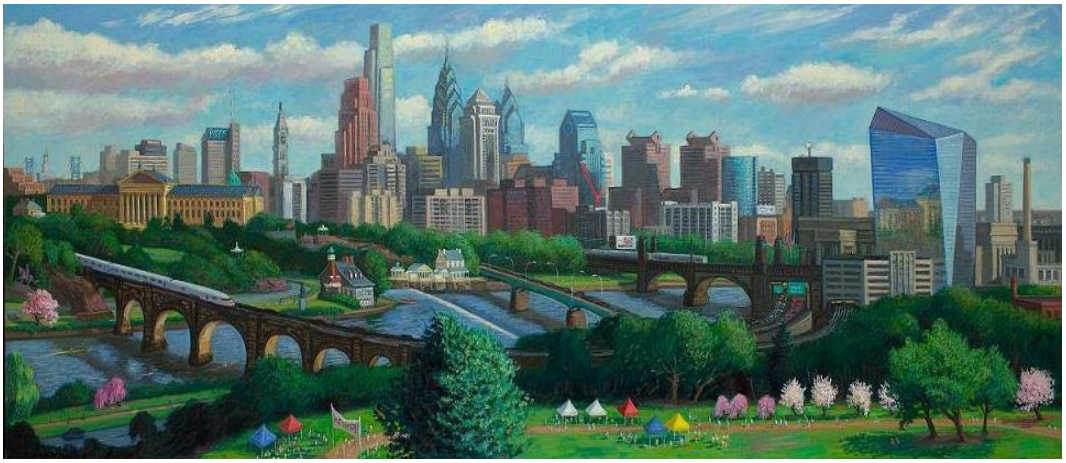
Creating a Sustainable City: Philadelphia's Green City Clean Waters Program

Jeffrey Featherstone
Marc Cammarata
Howard Neukrug
William Devine



"Skyline with Cira Center" Courtesy of Charles Cushing

Introduction

Old American cities, like old cities everywhere, are challenged to maintain and upgrade their aging water and sewer infrastructure. They face increasing regulatory requirements to improve performance and meet environmental standards despite declining funding from national and state sources. Traditional infrastructure replacement programs can be cost prohibitive for old cities. Philadelphia has embarked on a major green infrastructure investment program in its pursuit to become America's most sustainable city.

Philadelphia's "Green City Clean Waters Program" (GCCW) seeks to integrate water resources management into the socioeconomic fabric of the City by creating amenities for its workers and residents. It is the centerpiece of a larger City effort to promote sustainability through improved stormwater management. Through a municipal investment of over $2 billion and an innovative stormwater billing program, the GCCW expects to transform the City of 1.6 million into a vibrant, green and sustainable one.

Stormwater Management in the United States

Stormwater management has been on the forefront of pollution regulation for over 25 years in the United States. By the mid 1980s, it became apparent that stormwater and urban runoff were the primary sources of our water-body pollution nationwide (Congress 2009). The forerunners of stormwater management regulation are the

Phase I and Phase II Stormwater Rules. The rules are regulatory programs that were promulgated by the Environmental Protection Agency (EPA).

In 1990, the EPA passed Phase I of a two-part stormwater regulation that aims to reduce the pollution caused by urban runoff. Phase I addresses larger cities like Philadelphia; Phase II, which was adopted in 2000 and revised in 2005, broadens the rules and includes smaller cities. The regulations are statutorily supported by the federal Clean Water Act. These stormwater regulations are based upon a permitting program that restricts the amount of stormwater effluent originating from urban development. This permitting system is part of the National Pollutant Discharge Elimination System (NPDES), which aims to ameliorate point source pollution. The rules target construction sites and the associated pollution triggered by stormwater runoff from such sites. The EPA Phase I and II Rules have set the standard for progressive stormwater management, pollution discharge abatement, and watershed restoration within the United States. (EPA 2011)

More recently, stormwater management has been used to address another environmental problem. Combined sewer systems are sewers that were designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. During periods of heavy rainfall these systems overflow and discharge excess wastewater directly to nearby streams. These combined sewer overflows (CSOs) are a major pollution concern in many U.S. cities, including Philadelphia.

The EPA regulates CSOs through its own CSO Control Policy (EPA 2011). This policy contains four fundamental principles to ensure that CSO controls are cost-effective and meet local environmental objectives:

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

Under this policy, municipalities with CSO's are required to implement Nine Minimum Controls as part of a Long Term Control Plan (LTCP):

1. Characterization, monitoring, and modeling of the combined sewer system
2. Public participation
3. Consideration of sensitive areas
4. Evaluation of alternatives to meet Clean Water Act requirements using either the "presumption approach" or the "demonstration approach"
5. Cost/performance considerations
6. Operational plan
7. Maximizing treatment at existing wastewater treatment plant
8. Implementation schedule
9. Post construction compliance monitoring program

Green City Clean Waters Program

Progressive stormwater regulation has advanced at the municipal level and Philadelphia is a leader in the United States. Operating within the Philadelphia Water Department's (PWD) Office of Watersheds is a new program, planned to reduce the occurrences of CSO discharges into the city's rivers and streams. The Green City Clean Waters (GCCW) program aims to reduce CSO discharges by combining a system of regulation toward point-sources of urban runoff, with a rejuvenation of stormwater infrastructure.

The PWD has ardently accepted the responsibility to restore the city's watersheds. The agency (2011) has taken the position of "watershed champion." This drive to implement a "comprehensive, environmental approach to resource management" is spurred by a preponderance of evidence revealing the grave state of the watershed ecology. The evidence comes in the form of governmental reports at the federal, state, and local levels. According to law professor Joel Eison (1995), "Stormwater conveyances "short-circuit [the] hydrologic cycle, with disastrous results."

The PWD seeks to employ innovative technology to control the CSO problem. Green infrastructure or low impact development is believed to be vital in managing stormwater and urban runoff. In order to properly assess the costs and external benefits of low impact development, the PWD has implemented a "triple bottom line analysis" of the environmental, economic, and sociological impacts of the GCCW program. It is anticipated that the increase of green infrastructure will benefit the community in ways not possible with traditional infrastructure. The program will create green space, raise property value, and absorb CO2 emissions. The inclusion of the triple bottom line analysis by the PWD illustrates the progressive nature and benefits of low impact development within the GCCW program.

Stormwater management and regulation is an intricate and ever-evolving process. It is comprised of a combination of policy, regulation, innovation, and public participation. It is the primary goal of the PWD to "leverage existing mandates and obtain buy-in with the regulating agencies for new initiatives." The PWD endeavors to influence and inspire legislative bodies to promulgate new regulations backed by scientifically-supported data, in order to improve overall water quality. The PWD anticipates that this governmental alliance with the EPA and Pennsylvania Department of Environmental Protection (PADEP) will yield success in the restoration of watershed ecology, as well as spearhead the new role of "progressive public utility" throughout our nation's municipalities (PWD 2011).

GCCW finds its roots in the PWD's CSO Long Term Control Plan (LTCP) which was instituted in 1997 (PWD 2011). This original plan was comprised of three major tenants: traditional technology-based capital improvements, comprehensive watershed planning, and ongoing implementation of the certain minimum controls. The minimum controls were originally developed by the PADEP in 1995. These were basic measures taken by the PADEP and PWD in order to reduce runoff pollution in receiving waters.

The PWD developed hydrologic and hydraulic models (H&H) in order to establish and support permitting requirements. Tier I modeling simulated the H&H response of the PWD's collection system during wet-weather events. These calibrated models were employed to determine CSO discharge frequencies and volumes. Tier II modeling simulated the LTCP. Based on the modeling, in 2007, the City of

Philadelphia and PWD decided to re-evaluate their LTCP. The PWD had already adopted new stormwater management regulations in 2006. The agency realized the importance of tighter regulation, but also understood that alternative management techniques were necessary. This led to the development of a comprehensive plan that took into account the symbiotic relationship between land, air, and water ecology. This "multi-media" approach toward pollution abatement became the basis for the LTCP Update or LTCPU. The final result of the LTCPU is a hybrid of economic and ecological revitalization. The merging of the multi-media LTCPU with a restorative capital-improvements plan has become GCCW (PWD 2011).

On June 1, 2011, the GCCW program was formally sanctioned by the regulatory bodies when Philadelphia and the PWD signed a Consent Order and Agreement with the Pennsylvania Department of Environmental Protection (PADEP 2011). This document formalizes and commits the PWD to implement the revised LTCPU. The agreement sets performance standards and milestones to be achieved over the next 25 years, and includes a mix of traditional measures (treatment plant upgrades and lining sewer pipes) and greened acres stemming from the GCCW program. Table 1 presents these performance standards and milestones. The PWD is also required to submit annual reports and a set of deliverables. The agreement allows the GCCW plan to carry legal influence to comply with the LTCPU.

Table 1 – Green City Clear Water Program Performance Standards and Milestones

Metric	Units	Baseline Value	Cumulative amount as of year 5	Cumulative amount as of year 10	Cumulative amount as of year 15	Cumulative amount as of year 20	Cumulative amount as of year 25
[plant name] WPCP upgrade Design	percent complete	0	TBD	TBD	TBD	100%	100%
[plant name] WPCP upgrade Construction	percent complete	0	TBD	TBD	TBD	100%	100%
Miles of interceptor lined	miles	0	2	6	14.5	14.5	14.5
Overflow Reduction Volume	million gallons per year	0	600	2,044	3,619	5,985	7,960
Total Greened Acres	Greened Acres	0	744	2,148	3,812	6,428	9,564
Equivalent Mass Capture - TSS	percent	62%	Report value	Report value	Report value	Report value	85%
Equivalent Mass Capture – BOD5	percent	62%	Report value	Report value	Report value	Report value	85%
Equivalent Mass Capture Coliform Bacteria	percent	62%	Report value	Report value	Report value	Report value	85%

Philadelphia's Stormwater Regulations

The PWD adopted new stormwater regulations on January 1, 2006. These stormwater regulations gave PWD the authority to monitor and control stormwater runoff on development sites. According to PWD, the requirement for preparing Post Construction Stormwater Management Plans represented the major progression of the new regulations from earlier ones adopted in the 1990s. These plans are prepared by developers, and encompass more than the typical peak rate controls that were previously required (PWD 2006).

The stormwater regulations (PWD 2006) incorporate the following technical components:

Water Quality: The first inch of precipitation over directly connected impervious cover must be recharged. Where recharge is not feasible or limited, then any remaining volume is subject to an acceptable water quality practice.

Channel Protection: The 1-year, 24-hour storm must be detained and slowly released over a minimum of 24 hours and maximum of 72 hours.

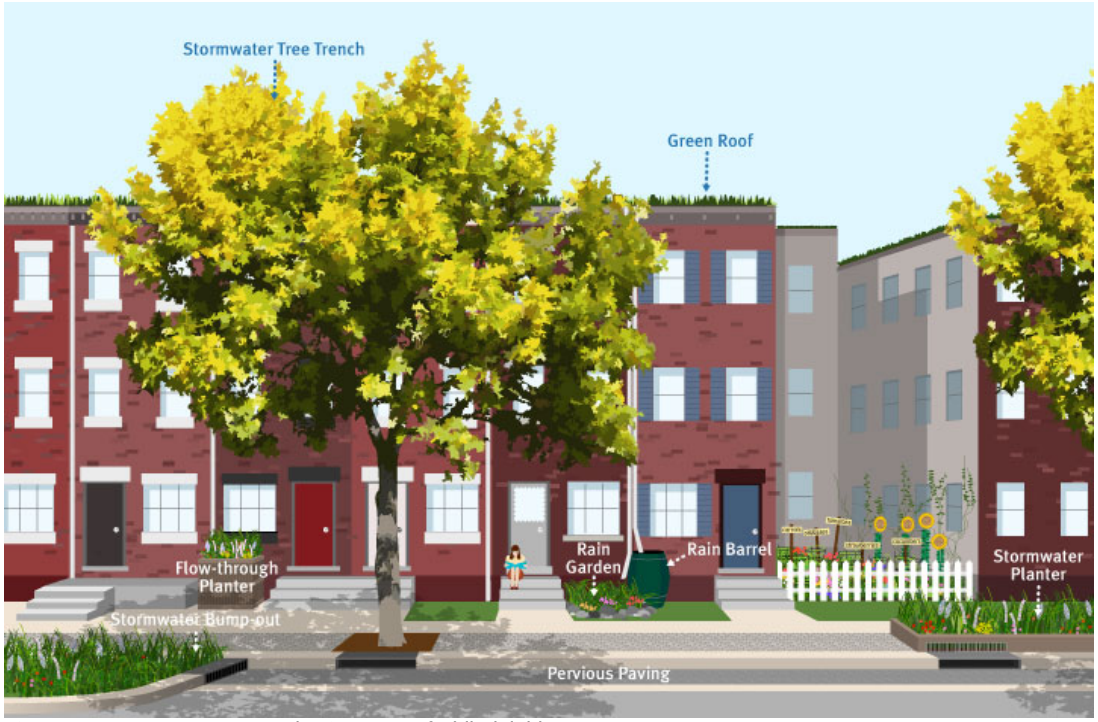
Flood Control: Watersheds that have been designated as part of a state stormwater planning effort known as Act 167 are to include the model results for flood management districts. Philadelphia has spearheaded this effort by providing funding to ensure the creation of regional, watershed-based stormwater plans for each of its watersheds. Philadelphia has also assisted its neighboring communities in stormwater management planning in response to Act 167.

Non-Structural Site Design: Projects are required to maximize the site potential for stormwater management through appropriate placement and integration of stormwater management practices (SMPs).

PWD's stormwater regulations apply to any type of development that results in an earth disturbance greater than 15,000 square feet. Regulated activities are subject to various pre-construction, construction, and post-construction procedures, which consist of 1) the creation and implementation of a post-construction stormwater management plan, 2) compliance with state sediment and erosion control standards, and 3) non-structural project design and sequencing to minimize stormwater impacts (PWD 2006). Regulated activities are also subject to randomized inspections by PWD, which may result in a "Stop Work Order." Lastly, these regulated development sites are required to attain all necessary permits from all other pertinent government entities.

Stormwater Management Practices, as defined by PWD (2006), consist of "any man-made structure that is designed or constructed to convey, store, or otherwise control stormwater runoff quality, rate, or quantity." These practices can consist of traditional engineering techniques such as retention basins, or low impact development techniques such as bio-swales, green roofs, and rain gardens. While the stormwater management practices are designed to reduce stormwater pollution before, during, and after construction; the post construction management plan is a comprehensive proposal that is designed to implement controls for managing urban runoff after the development project is complete. The post construction plan is highly important, not only because it details and implements the methods of stormwater management on

the developed site, but it also leaves the signature of the developer upon the finished project.



"Stormwater Management Tools" Courtesy of Philadelphia Water Department

Another important element of the stormwater regulations is "sequencing to minimize stormwater impacts." In order to encourage green infrastructure, the developer is required to find practicable low impact development (LID) alternatives to surface discharge of stormwater (PWD 2006). The site developer must first prepare an "existing resource and site analysis" map and worksheet, which will display sensitive environmental areas and natural resources on site. The developer must then establish a natural buffer by preserving native species of plants and trees adjacent to any surface water body. Next the developer must prepare a draft of the project layout, showing avoidance of the sensitive areas identified in the analysis. The developer must then evaluate nonstructural stormwater management alternatives. During construction, the operator of the project must minimize earth disturbance, while also reducing impervious surfaces and directly connected impervious areas within the limits of said earth disturbance. Finally, the developer is responsible for the design of stormwater detention and retention structures. The developer is also required to adjust any site designs as necessary, in order to meet the requirements of the current regulations. Post-construction implementation of LID practices and stormwater easements will prepare the site for its intended function. These sustainable practices will pay dividends when stormwater impact fees are assessed.

The PWD is confident that as redevelopment flourishes within the city, these new regulations will continue to reduce the negative impacts of stormwater runoff. The PWD is implementing an extensive monitoring network to determine the effectiveness of the overall GCCW program and its various components. It also is advocating the widespread use of IID approaches that encourage the return of rainfall back to the hydrologic cycle (PWD 2011).

Parcel-Based Billing

Stormwater fees are an essential component of the PWD's program to reduce stormwater runoff. The fees provide a financial incentive for landowners to implement stormwater improvements on their properties. A key goal of the GCCW program is to replace one third of Philadelphia's impervious surfaces with low impact development. Formerly, stormwater fees or charges in Philadelphia were based on the water meter size of the property. By the mid-1990's, the PWD realized a gap between stormwater remediation costs and stormwater revenues collected by the city. In 1994, PWD assembled a citizen's advisory committee that was charged with revamping the stormwater billing structure. In 1996, the committee recommended that PWD transition from a water meter-based stormwater management charge to a property-based charge, particularly for larger, non-residential properties. Unfortunately, the city did not possess the technology required to analyze parcels at this time. Over the next ten years, the new billing plan met challenges from business interests and property owners and parcel-based fees languished.

After the stormwater management regulations were passed in 2006, the PWD set a new launch date for parcel-based fees for 2010 and on July 1 of that year the PWD initiated its parcel-based billing. The new fees are being targeted towards non-residential parcels of land and phased in over a four-year period until 2014.

Non-residential customers are being assessed on a ratio of "Impervious Area to Gross Area" on the property. The advisory committee determined that 80% of the stormwater charge would be derived from the impervious area, while 20% of the charge will come from the gross area of the property. The PWD (2011) has estimated that the 500 largest non-residential properties within the combined sewer system cover 12.3% of the total impervious area. This displays the immense volumes of runoff generated by PWD's commercial customers. In 2006, PWD began the arduous task of analyzing the 40,000 non-residential parcels throughout the city and this effort was completed in 2010.

PWD has also taken measures to impose stormwater fees on properties that currently do not pay for water or sewer service. For example, many owners of parking lots are not provided water or sewer service. Since these parcels often generate a great deal of urban runoff, PWD is implementing the 80/20 impervious area/gross area formula to the owners of these parcels of land as well.

The billing program seeks to raise over $1-1.5 billion over 25 years. The implementation of updated stormwater fees will help to ensure funding for the GCCW program. Significant producers of runoff are now being assessed fees in relation to their contribution to stormwater runoff and the new fees will compel large landowners to implement sustainable SMPs.

Greenification and Triple-Bottom Line Analysis

The most enterprising element of the GCCW program is its promotion of "greenification" and the use of a triple-bottom line analysis. According to the PWD (2011), the vision of GCCW is to "protect and enhance our watersheds by managing stormwater runoff with innovative green stormwater infrastructure throughout our City, maximizing economic, social, and environmental benefits for Philadelphia." While there are numerous options for controlling CSO events and urban runoff, the

implementation of green or low impact development will provide many benefits beyond the sewer system.

***Greenification*.**--Living plants and trees can have a major impact on stormwater runoff. The soil in which the plant is growing can allow the stormwater to infiltrate and become part of the natural hydrologic process. The soil can also retain water, which can be evaporated by the sun. The plant itself may also have a great effect on managing the stormwater. First, the water that remains on the leaves and branches may evaporate before it even reaches the earth. Also, the plant itself will consume the water, and return it to the atmosphere via evapotranspiration.

In addition to managing water volume, soil and plants may also have a positive impact on pollution control. The plants and soil may act as a filter for the polluted water. This can also be true of permeable pavement, which can also filter impurities while allowing stormwater to return to the hydrologic cycle. Permeable pavement is also beneficial, because it may be used in areas that cannot sustain a rain garden or planter. This type of pavement can be utilized in most applications in which impervious pavement would be used. There are projects throughout Philadelphia that use pervious pavement for parking lots, alleys, streets, and sidewalks. Permeable pavement can also sustain trees and shrubs, which can enhance the aesthetics of a streetscape.

Green roofs are another major tool used in reducing stormwater runoff volume. Green roofs consist of multiple layers of material that insulate and waterproof the roof, while also allowing drainage. Different types of vegetation are planted on the top layer. Green roofs are separated into two classes, intensive and extensive.

"Green Roof" Courtesy of Philadelphia Water Department

Intensive green roofs will feature small vegetation such as a variety of grasses. These types of roofs are thinner and less heavy. They will mostly be employed to cover large areas, or in fluctuating climates. Extensive green roofs are deeper, heavier, and will usually boast heartier plants. Extensive green roofs can also benefit their property owner by doubling as an edible garden. Green roofs are optimally-effective in controlling stormwater, because they have the ability to retain water, and then release it slowly. They also promote evaporation and evapotranspiration.

***Triple-bottom line analysis*.**--Philadelphia aims to produce the maximum return for every dollar spent on CSO remediation. In order to realize the maximum socio-economic benefits in tandem with the desired environmental benefits, PWD

commissioned a triple-bottom line analysis. This type of analysis provided PWD with a plethora of data regarding traditional engineering, and low impact development approaches toward CSO controls.

Almost 50 years ago noted environmental planner Ian McHarg (1969) wrote these words describing Philadelphia:

> "The large modern metropolis may be thirty miles in diameter. Much, if not all of the land is sterilized…The rivers are foul; the atmosphere is polluted; the original configuration of the land is only rarely in evidence."
> -Ian McHarg

As described by McHarg, Philadelphia evolved into a necropolis over the past few centuries. The city had enclosed almost all of its natural tributaries, relegating them to sewers. The city had left only a few creeks exposed, and most receive CSO discharges.

While envisioning Philadelphia, city father William Penn said, "Let us build a fair city between two noble rivers; let there be five noble squares, let each house have a fine garden, and let us reserve territories for farming." As McHarg (1998) retorted, Penn's notion came before we discovered the efficient manner in which rivers carried sewage, or that city farmland was best-suited for buildings. The Philadelphia at the beginning of this century and the Philadelphia of the 17th century bear little resemblance. This is not the "garden city" that our founder envisioned.

"Green Street" Courtesy of Philadelphia Water Department

Returning to Penn's concept of a "green country town" has become a priority for Philadelphia. The city and PWD realized that while both traditional engineering and green infrastructure approaches to the CSO problem would be similarly expensive and effective to retrofit within an older urban system, the low impact approach may help pay for itself. The triple bottom line analysis was used in order to gain a "clearer appreciation of which option (or combination of approaches) may be most cost valuable to a community (PWD 2011). PWD is concerned with gaining a greater comprehension of the positive implications of green infrastructure and traditional approaches as they relate to the environmental, the economic, and social equity.

In August of 2009, the PWD released the final report of this analysis. It provides a thorough summary of results for different options and their corresponding impacts. The report details benefits on both a "city-wide" basis, as well as on an individual

watershed basis. The report includes comparison of benefits regarding the different approaches, in relation to socio-economic and environmental impacts. The report also provides a comprehensive summary of the external benefits provided by green development.

Table 2

Benefit Categories	50% LID Option	30' Tunnel Option
Additional creekside recreational user days	247,524,281	
Additional non-creekside recreational user days	101,738,547	
Reduction in number of heat-related fatalities	196	
Annual WTP per household for water quality and aquatic habitat improvements	$9.70-$15.54	$5.63-$8.59
Wetlands created or restored (acres)	193	
Green collar jobs (job years)	15,266	
Change in particulate matter ($PM_{2.5}$) due to increased trees ($\mu g/m^3$)	0.01569	
Change in seasonal ozone due to increased trees (ppb)	0.04248	
Electricity savings due to cooling effect of trees (kWh)	369,739,752	
Natural gas savings due to cooling effect of trees (kBtu)	599,199,846	
Fuel used (vehicles for construction an O&M) (gallons)	493,387	1,132,409
SO_2 emissions (metric tons)	(1,530)	1,452
NO_x emissions (metric tons)	(38)	6,356,083
CO_2 emissions (metric tons)	(1,091,433)	347,970
Vehicle delay from construction and maintenance (hours of delay)	346,883	796,597

Table 2 compares the estimated benefits of two options designed to achieve 85% mass removal of biochemical oxygen demand, total suspended solids, and fecal coliform. The complete separation of sanitary and storm sewers would be cost prohibited ($16 billion). The first option represents implementation of LID measures on 50% of the combined sewered land area within Philadelphia. The second option is a grey infrastructure system consisting of four 30' tunnels. The triple bottom line analysis indicates that the benefits of the GCCW program over a 40-year period far outweigh those for the grey infrastructure option. The analysis shows that for Philadelphia green infrastructure is an asset, while grey infrastructure would be a liability.

The incorporation of LID will reduce the volume of stormwater runoff, while increasing water quality. These factors will aid in the reduction of CSO discharge events, as well as reaching the goal of 85% mass pollution capture by 2036. LID accomplishes this, not by diverting and re-routing the hydrologic cycle, as so many other cities have done; instead GCCW seeks to reintroduce the natural hydraulic and hydrologic cycles within Philadelphia and provide many other economic and social benefits throughout this historic city.

Closing Remarks

Over the past ten years, it has become apparent that a strong relationship exists between stormwater, impervious surfaces, and the overall welfare of our cities. The PWD has pushed the envelope in CSO regulation with the GCCW program. The

agency has gone far beyond the required implementation of a LTCPU by implementing a truly comprehensive multi-media approach. Rather than focusing only on CSO remediation, PWD seeks to rehabilitate most of the watershed ecosystem. The GCCW program is now being combined with supplemental green programs implemented by other city departments, such as the Green Streets and Green Public Facilities Programs, to extend this comprehensive reconstruction of the city's watersheds. These other programs will help ensure the success of GCCW.

Other American communities and utilities will follow Philadelphia's lead. City officials in Pittsburgh are preparing to launch a similar program. It is important for all big cities to take responsibility for their damaged ecosystems. It is becoming clearer every day of the interconnectedness that exists between our cities and global ecosystems.

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Jeffrey Featherstone
Director, Center for Sustainable Communities, Temple University
United States of America