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October 3, 2013

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Via e-mail and U.S. Mail

Re: Notice of Intent to Modify the 14 New York City Department of Environmental Protection (NYC DEP) State Pollutant Discharge Elimination System (SPDES) Permits

Dear Ms. Diehsner:

On behalf of Natural Resources Defense Council and our over 14,000 members in New York City, as well as our 37,000 members throughout New York State, please accept these comments on the draft State Pollution Discharge Elimination ("SPDES") permits for New York City's fourteen wastewater treatment plants (the "Draft Permits").[1] These comments focus primarily on issues related to combined sewer overflows ("CSOs"). Since the CSO-related permit provisions are the same for all of the Draft Permits (except Oakwood Beach, which has no CSO outfalls), our detailed comments below refer to the section and page numbers from the Bowery Bay permit; those comments apply to the corresponding provisions in all of the other Draft Permits (except Oakwood Beach).

Additionally, we note that, for each of the Draft Permits that authorizes discharges from a municipal separate storm sewer system ("MS4"), the draft permit and fact sheet state that the permit's MS4 provisions will be superseded upon issuance of a new, individual SPDES permit that addresses MS4 discharges throughout the City, which the Department of Environmental Conservation ("DEC") is currently preparing. This MS4 permit is long overdue. As NRDC highlighted in our August 13, 2010 comments on the "administrative renewal" of these fourteen SPDES permits, the MS4 provisions in each of the permits must be modified because they manifestly fail to "require controls to reduce the discharge of pollutants [from MS4 outfalls] to the maximum extent practicable," 33 U.S.C. 1342(p)(3)(B)(iii), and to include any additional

[1] These comments are timely submitted, as per the announced October 3, 2013 deadline. *See* Environmental Notice Bulletin, (July 31, 2013), available at http://www.dec.ny.gov/enb/20130731_not2.html.

requirements "necessary to insure compliance with water quality standards adopted pursuant to state law," ECL § 17-0811(5).[2]

Specifically, our August 13, 2010 letter noted that:

> [W]ith the exception of floatables control, the permits contain virtually no provisions for the control of construction or post-construction runoff. For example, the permits do not have any provisions addressing [many of the technology-based effluent limitations required in] a "Phase I" MS4 permit, as per 40 C.F.R. § 122.26(d)(2)(iv) (which is incorporated by reference into state law by 6 NYCRR § 750-1.11(a)(9))….These omissions and others were identified in a 2005 EPA audit….

In that same comment letter, we also noted that:

> [I]t is not clear whether DEC is holding the City accountable for compliance with the existing requirement in each of its permits that, "if storm water is shown to significantly contribute to the contravention of water quality standards (including on a near field basis), the permittee must submit a description of additional proposed BMPs and/or control techniques in order to reduce the discharge of pollutants from the MS4." Modeling studies submitted to DEC in connection with the city's development of a Combined Sewer Overflow ("CSO") Long Term Control Plan conclude that separate stormwater contributes to violations of water quality standards in some areas….Since the existing permit terms have proven insufficient to ensure the City's MS4 discharges do not cause or contribute to violations of water quality standards, the permits should be modified to include any and all provisions as necessary to do so.

We are hopeful that DEC will soon be issuing public notice a draft New York City MS4 permit, and would welcome the opportunity to discuss the contents of that permit with DEC and the New York City Department of Environmental Protection ("DEP"), even in advance of such notice. However, given the extensive delays in developing meaningful MS4 permit requirements for New York City, and that fact that the Draft Permits would continue to authorize MS4 discharges until such time as the a separate MS4 permit is issued, NRDC reserves the right to challenge the issuance of these permits on the basis that they authorize MS4 discharges without the legally required technology-based and water quality-based effluent limitations.

Our specific comments concerning CSOs follow below. We would welcome the opportunity to discuss these issues directly with relevant staff from DEC and DEP.

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[2] A copy of our August 13, 2010 comments is enclosed as Attachment 1).

<u>Specific comments on CSO issues</u>

1. **<u>DEC should revise CSO Best Management Practice ("BMP") #12 to incorporate stricter controls on runoff from new development and redevelopment.</u>**

In the Draft Permits, CSO BMP #12 provides as follows:

> Control of Run-off - All sewer certifications for new development shall be consistent with NYCDEP rules and regulations and shall require on-site detention or retention to not exceed the existing sewers fronting the property. Only allowable flow will be permitted to discharge into the combined or storm sewer system.[3]

Comparable language appears in the currently effective versions of the SPDES Permits.

As DEC and DEP have recognized through the inclusion of green infrastructure requirements in the City's CSO Administrative Consent Order ("CSO Order"), reducing the volume of runoff flowing into the sewer system is an essential – and cost-effective – element of CSO control. The CSO Order establishes an enforceable target of using "green infrastructure" to capture the equivalent of one inch of runoff from 10% of the impervious surfaces served by the City's combined sewer systems, by December 31, 2030, with interim targets for 2015, 2020, and 2025.[4] The *NYC Green Infrastructure Plan*, on which the 10% target is based, anticipates that the application of DEP's new stormwater regulations for development and redevelopment projects will be responsible for achieving most of the 10% target.[5]

To maximize the control of runoff from new development and redevelopment into the combined sewer system, BMP #12 should be strengthened in several ways:

a. **BMP #12 should require DEP to ensure compliance with, at a minimum, the performance standards in DEP's *updated* stormwater regulations.**

DEP adopted its new stormwater regulations in 2012.[6] The regulation is stricter than provided by the Draft Permit's CSO BMP #12. Whereas DEP regulations, consistent with the Draft Permit language, previously limited the discharge of runoff into combined sewers to the "allowable flow" (a term of art defined in DEP regulations), DEP's new regulations impose

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[3] Bowery Bay Draft Permit, p. 18, § VII.12.

[4] *See* CSO Order Part IV (available at http://www.dec.ny.gov/docs/water_pdf/csomod2012.pdf).

[5] The *NYC Green Infrastructure Plan* (p. 139) anticipates that if 10% of impervious area citywide were targeted for GI retrofits over the next 20 years, over 80% of the necessary acres would comprise "on-site development" (*i.e.*, not in the public right of way), and 54% of the acres would come from private on-site development, through the application of DEP's intended stormwater management rule. (The *Green Infrastructure Plan* is available at http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_LowRes.pdf.)

[6] *See* http://www.nyc.gov/html/dep/html/environmental_reviews/stormwater_release_rates.shtml.

much stricter standards.[7] In addition, the new DEP regulations apply not only to "new development," as referenced in the Draft Permit language, but also to "alterations" to existing development. The new DEP regulations also require that any stormwater management systems installed to comply with the regulation "must be properly maintained throughout the useful life of the system and maintenance records maintained, until replacement as approved by DEP."[8]

In light of these improvements to DEP regulations, BMP #12 in the Draft Permits should be modified to require DEP to ensure that, at a minimum: (i) sewer certifications for all new developments and alterations of existing developments (as the term "alteration" is defined in DEP regulations) limit the discharge of runoff into combined sewers pursuant to the performance standards in DEP's *current* regulations; and (ii) all stormwater management systems installed to comply with such performance standards are properly maintained throughout the useful life of the system. BMP #12 should also require DEP to maintain documentation that such requirements are satisfied and to certify compliance annually to DEC.

b. BMP #12 should require DEP to develop and adopt a *more stringent* regulation for the control of runoff that, *inter alia*, maximizes the use of retention practices, rather than detention practices.

When DEP first proposed its updated stormwater regulations, NRDC and others – including a majority of the members of DEP's own "Green Infrastructure Steering Committee" – commented that the rules should require the use of stormwater retention practices, rather than detention practices, wherever feasible, because retention practices are more effective at reducing CSO discharges than detention practices.[9] Although DEP had acknowledged in the *Green Infrastructure Plan* that retention is more effective than detention,[10] its final regulation requires only the detention of runoff.[11]

Therefore, in addition to requiring that DEP enforce its existing regulation, the Draft Permit should also set a deadline for DEP to adopt (and then enforce) stronger regulations that maximize the use of retention practices, rather than detention practices. Specifically, BMP #12 should require DEP to adopt and enforce a rule that require new development and alternations of existing development to use infiltration, evapotranspiration, and rainwater harvesting, in any feasible combination, to retain the first inch of rainfall without discharge into the combined

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[7] 15 R.C.N.Y. § 31-03(a)(1)-(2).

[8] 15 R.C.N.Y. § 31-04(a)(8).

[9] *See*, NRDC letter to DEP, dated 11/30/2011; Letter from K. Bone, *et al*. to DEP, dated 11/18/2011. (Copies of both of those letters are enclosed as Attachment 2 and Attachment 3, respectively.)

[10] *See, e.g.*, *NYC Green Infrastructure Plan*, p. 21 (estimating that detention is 60% less effective than infiltration).

[11] 15 R.C.N.Y. § 31-03(a)(1)-(2). (The rule provides regulated parties the option to receive credit towards regulatory compliance if they choose to utilize retention practices. *See id*. at § 31-03(a)(3)-(4).)

sewer system.[12] Discharge (at the maximum release rate specified in DEP's current regulations) should be allowed only when no combination of those methods is feasible to manage the entire first inch of rainfall.[13] In support of this comment, we attach to this letter, and incorporate by reference, the detailed comments and analysis on this point that we submitted to DEP in 2011.[14]

BMP #12 should also be revised to require DEP to make certain other revisions to its stormwater regulation, consistent with the comments NRDC submitted on DEP's proposed rule. Specifically, DEP should be required to revise the regulation to:

- treat smaller sites (*e.g.*, from 5,000 s.f. to 1 acre) comparably to larger sites, *e.g.*, by defining a maximum release rate on a c.f.s.-per-acre basis; and
- apply the performance standards more expansively to projects classified as "alterations," including to alterations that replace one impervious surface with another;

Again, in support of these specific comments, we attach to this letter, and incorporate by reference, the detailed comments and analysis we submitted to DEP in 2011.[15]

Additionally, in light of DEP's finding that detention is less effective than retention at reducing CSO discharges, the permit should require DEP to further modify its regulations to require that any portion of the first inch of runoff that is managed by detention methods must be "offset" by off-site mitigation (or payment of a fee-in-lieu) that retains an equivalent or greater amount of runoff from another site.[16]

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[12]Permit terms should allow DEP the option of allowing developers to satisfy a portion of this one-inch retention requirement by retrofitting another property to retain runoff, provided that conditions are imposed to ensure that the off-site compliance results in net pollution reductions within the same drainage area. As an example, the MS4 permit for Washington, DC authorizes that city to develop rules to implement this approach to compliance with a 1.2-inch retention standard. (That permit is available at: http://www.epa.gov/reg3wapd/npdes/dcpermits.htm.)

[13]This basic approach -- requiring the use of all feasible stormwater retention methods to manage runoff from a specific design storm – is generally reflected in DEC's Stormwater Management Design Manual. It is also reflected in many Clean Water Act permits for municipal separate storm sewer systems (MS4s) and state and local regulations around the country, including in the Northeast and Mid-Atlantic states. For example, see:

- Pittsburgh city ordinance (http://library.municode.com/index.aspx?clientId=13525&stateId=38&stateName=Pennsylvania (in left-side menu, click through to Pittsburgh Zoning Code, Title 10, Chapter 1003, § 1003.04(d))
- Washington, D.C. MS4 Permit (http://www.epa.gov/reg3wapd/npdes/dcpermits.htm) (requiring that city to adopt regulations implementing a specific performance standard set forth in the permit)
- West Virginia MS4 General Permit (http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/permits/Documents/WV%20MS4%202009%20General%20Permit.pdf)

See also NRDC, *Rooftops to Rivers II* (Nov. 2011), at pp. 32, 37 (available at http://www.nrdc.org/rooftops).

[14] *See* Attachment 2.

[15] *See id.*, pp. 6-7.

[16] The MS4 permit for Washington, DC provides an example of a stormwater performance standard that includes requirements for off-site mitigation or payment of a fee-in-lieu when a retention standard cannot fully be satisfied on-site. (The Washington, DC MS4 permit is available at: http://www.epa.gov/reg3wapd/npdes/dcpermits.htm.)

In the alternative to mandating changes to DEP's regulations at this time, DEC should, at a minimum, revise BMP #12 to require DEP to annually evaluate the adequacy of its current stormwater regulations and report to DEC and the public on its findings; the permits should also expressly reserve DEC's authority to require more stringent controls on runoff, based on such evaluations and on any other relevant information. DEP has already committed – to both DEC and NRDC -- to annually re-evaluate the stormwater regulation to determine if it needs to be strengthened.[17] However, it appears that DEP has not undertaken any such re-evaluation.[18] Thus, it is important that the permit expressly require these periodic evaluations.

2. **<u>DEC should revise the CSO BMPs to require DEP to convene a peer review panel of experts to evaluate and make recommendations on the implementation of DEP's green infrastructure program.</u>**

As noted above, DEP's green infrastructure program is a key element of its compliance with the CSO Order and, in turn, compliance with the SPDES Permits.[19] Recognizing the complex technical issues involved with implementing green infrastructure practices at a city-wide scale, DEP committed nearly two years ago – to both DEC and NRDC -- to promptly form "a panel of independent, qualified experts to review green infrastructure design."[20] In making this commitment, DEP stated that "[a] strong foundation in defensible, replicable results, complemented by rigorous peer review, will make our program even more effective."[21]

We commend DEP for this commitment. However, to our knowledge, DEP has not yet established such a peer review panel. Therefore, to ensure that DEP keeps this commitment, it is important the CSO BMPs in the Draft Permits be revised to expressly

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[17] *See* Letter from DEP Commissioner Strickland to L. Levine, NRDC, dated 12/21/2011, a copy of which is enclosed as Attachment 4 (stating that DEP "will be performing internal reviews of the rule, . . . which will be reflected in the annual reports [required pursuant to the CSO Order]. . . . We will use those annual reports as an opportunity to reflect on challenges in implementing the rule and potential amendments to the rule moving forward."). *See also* Responsiveness Summary for comments received during the public comment period associated with the 2012 Modified CSO Consent Order, p. 10 (Response 3.5) (stating that "DEP will track and report on the acreage managed under the [new DEP stormwater rule] in the annual report required to be submitted under Paragraph IV.C.2 of the [CSO] Order. The annual report will also report on challenges implementing the Rule and potential amendments to the rule moving forward. [Additionally,] [a]s part of the evaluation of alternatives in LTCPs, DEP will also evaluate how well the stormwater controls are working in combined sewer areas as part of an overall review of the Proposed Rule.") (available at http://www.dec.ny.gov/docs/water_pdf/csosum2012.pdf).

[18] For example, DEP's first annual report under the CSO Order makes no mention of any such reevaluation. *See* http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2013.pdf.

[19] The Draft Permits, like the currently effective SPDES permits, prohibit violations of certain water quality standards and provide that "[a]ny existing violations of these standards are addressed by compliance with the terms of [the CSO Order]." *See* Bowery Bay Draft Permit, Part VIII.

[20] *See* Attachment 4; *see also* Responsiveness Summary for comments received during the public comment period associated with the 2012 Modified CSO Consent Order, p. 10 (Response 4.3) ("DEP has also committed to accelerate the formation of a technical peer review group, consisting of experts in green infrastructure, hydrology and drainage, to review green infrastructure designs.").

[21] *See* Attachment 4.

require that DEP shall establish a peer review panel of independent, qualified experts to periodically review its green infrastructure program and shall report to DEC and the public on the panel's findings. The permits should set fixed deadlines for these independent reviews. We recommend that the permits should require DEP to convene the peer review panel no later than July 1, 2014; and to ensure that the panel reports on the findings of its first review no later than December 31, 2015, coinciding with the first major green infrastructure milestone under the CSO Order.

3. <u>DEC should revise the CSO BMP #15 to require that DEP must report on specific green infrastructure metrics annually.</u>

The Draft Permits require an annual report on the implementation of CSO BMPs.[22] DEC should revise this language to specifically require annual reporting on certain key green infrastructure metrics, as detailed below.[23]

a. Annual reports should specify the amount of impervious area, *within each individual sewershed*, that is managed with green infrastructure.

The CSO Order requires reporting on progress towards city-wide green infrastructure targets. However, since the city's CSO control efforts must ultimately achieve water quality standards compliance in each individual receiving waterbody, the permits should require DEP to report on green infrastructure implementation on a sewershed-by-sewershed basis, not only on a city-wide basis.[24]

b. Annual reports should include a breakdown of the amount of impervious area managed with green infrastructure through (i) city-funded capital projects, (ii) redevelopment projects built in compliance with the city's stormwater regulations; and (iii) voluntary retrofits on private property.

DEP's planning and budgeting for implementation of its green infrastructure obligations is based on certain assumptions regarding the amount of impervious area that will be managed without direct expenditure of city funds (*e.g.*, through application of the city's stormwater regulations to private development projects). Therefore, DEP should be required to closely track – and report on – trends in the development of green infrastructure through private redevelopment projects and voluntary private retrofits, to ensure that any unexpected trends are identified quickly.

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[22] Bowery Bay Draft Permit, p. 18, § VII.15.

[23] The CSO Order requires annual reports on green infrastructure implementation and identifies certain required minimum elements of those reports. *See* CSO Order, ¶ IV.C.2. The reporting requirements proposed here would complement, rather than modify, the CSO Order's reporting requirements.

[24] We acknowledge that, although not expressly required by the CSO Order, DEP's first annual report (at p. 22) did provide green infrastructure data on a waterbody-by-waterbody basis. *See* http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2013.pdf. It is important to ensure that DEP continues this practice in future years.

Specifically, the permits should require that annual reports include a breakdown of the amount of impervious area managed with green infrastructure through (i) city-funded capital projects, (ii) redevelopment projects built in compliance with the city's stormwater regulations; and (iii) voluntary retrofits on private property .[25] This will enable DEC and the public to understand whether DEP must adjust its own capital planning, or enhance its focus on incentivizing voluntary retrofits on private property that is not undergoing redevelopment, in order to stay on course to meet the CSO Order's green infrastructure targets.

c. **Annual reports should include a breakdown of the amount of impervious area managed with *retention* practices versus *detention* practices.**

As described above (see comment #1.b), retention practices are more effective at reducing CSO discharges than detention. Accordingly, to support adaptive management in the implementation of DEP's green infrastructure program, annual reports should be required to break down the total amount of impervious area managed into area managed by retention practices vs. detention practices. Excessive reliance on detention may indicate the need for mid-course corrections.[26]

d. **Annual reports should report on the <u>net</u> amount of impervious area managed by green infrastructure, rather than simply the amount of new green infrastructure installed, in order to account for any loss of open space and/or vegetated cover in the city.**

Reducing CSO discharges through the use of green infrastructure requires both creating new capacity to absorb stormwater runoff <u>and</u> preserving existing capacity that exists in open spaces and other vegetated areas of the city. Although the City has, under the Bloomberg Administration, engaged in many efforts to create new green spaces in the City, a recent, peer reviewed study by researchers at the U.S. Forest Service and SUNY-ESF concluded that, from 2004-2009, New York City actually <u>lost 5.5% of its tree and shrub cover</u> (equal to 1.2% of the city's total area), and <u>increased impervious cover by 2.3%</u> (equal to 1.4% of the city's total area).[27]

These startling findings underscore the importance of tracking not only new green infrastructure created specifically for the purpose of stormwater management, but also tracking any replacement of existing pervious areas with new impervious area. Such land use changes would detract from the benefits of DEP's green infrastructure efforts, and may require recalibration of CSO models used to determine compliance with Clean Water Act obligations and/or increased investment in new green infrastructure to offset losses. (Ideally, of course,

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[25] DEP's first annual report (at p. 22) did not provide this breakdown. *See* http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2013.pdf.

[26] DEP's first annual report (at p. 22) did not provide this breakdown. *See* http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2013.pdf.

[27] *See* Nowak, D. and E. Greenfield, "Tree and impervious cover change in U.S. cities," *Urban Forestry & Urban Greening*, 11 (2012) 21-30. A copy of this study is enclosed as Attachment 5.

tracking the loss of existing pervious areas would lead to better land use policies in the City that would prevent these losses.)

For these reasons, the permits should require that annual reports not only include statistics on how much existing impervious space is retrofitted with green infrastructure practices, but also data on how much existing pervious or vegetated space is lost to development, and where such losses are located. The permits should also require DEP to report on the consequences of any such losses, with respect to the accuracy of CSO modeling and the projected benefits of its green infrastructure program.

4. **DEC should revise CSO BMP #2 to include critical water conservation requirements, which DEP has identified as "cost-effective" means of reducing CSOs.**

DEP's *Green Infrastructure Plan* states that:

> 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)…. ***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. [28]

It further explains:

> 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….***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 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***

[28] *Green Infrastructure Plan* at 4 (emphasis added).

> ***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….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.[29]

The plan states that "reducing water use is a cost-effective strategy for reducing CSOs"[30] and lists certain additional water conservation initiatives DEP planned to pursue, including:

- ***Track[ing] 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[ing] 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.
- Ensur[ing] that the rate structure incentivizes conservation while providing sufficient revenue for delivery and other essential services.[31]

These passages in the *Green Infrastructure Plan* make clear that DEP's overall approach to reducing CSOs relies on the assumption that current and future water conservation initiatives will ensure citywide water consumption remains constant, or decreases, over time. However, neither the Draft Permits, nor the CSO Order, include any requirements concerning water conservation.

To ensure that "consumption is meeting or exceeding the CSO modeling projections on which the Green Infrastructure Plan is based," DEC should revise CSO BMP #2 to include critical water conservation provisions, as detailed below.

The inclusion of water conservation requirements as part of the CSO BMPs is consistent with EPA guidance concerning the "Nine Minimum Controls" ("NMCs") under the federal CSO Control Policy.[32] EPA's guidance provides identifies water conservation measures as an

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[29] *Id.*at 45 (emphasis added).

[30] *Id.*

[31] *Id*. (emphasis added).

[32] The CSO BMPs that DEC includes in CSO permits are intended to implement the NMCs from the CSO Control Policy.

appropriate CSO BMP, explaining that "[w]ater conservation will reduce dry weather sanitary flow and increase the volume of combined sewage that can be retained in the CSS and treated at the POTW treatment plant."[33] Therefore, water conservation requirements are particularly appropriate for inclusion in the Draft Permits' BMP#2, which sets forth requirements concerning "Maximum Use of [the] Collection System for Storage."[34] Moreover, given DEP's identification of water conservation as a "cost-effective" means of reducing CSOs, the Draft Permits would be inconsistent with the CSO Control Policy's requirement to "[m]axim[ize] use of the collection system for storage," if they are not revised to include water conservation requirements.[35] This would render the permits legally deficient under the Clean Water Act ("CWA"), since, pursuant to CWA § 402(q), all CSO permits "shall conform to the [CSO] Control Policy."[36]

Specifically, the Draft permits should be revised to include the following water conservation requirements:

a. **The permits should require DEP to take such steps as are necessary to ensure that citywide water consumption remains at or below 1.1 bgd through at least 2030.**

As explained above, DEP's overall approach to reducing CSOs relies on the assumption that current and future water conservation initiatives will ensure citywide water consumption remains constant (at 1.1 bgd), or decreases, over time. DEP has already stated its intention to "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." The permits should not only require DEP to track water usage, but should also require DEP to take such steps as are necessary to ensure that citywide water consumption remains at or below 1.1 bgd through at least 2030.

b. **The permits should require DEP to complete implementation of its "Multi-Family Conservation Program by the deadlines established in its FY14 rate schedule.**

Although New York City began a transition to volumetric (*i.e.*, metered) billing for potable water many years ago, certain multi-family residential buildings are still billed based on a flat rate (referred to as "frontage" billing). For this set of customers, the City has adopted the Multi-Family Conservation Program ("MCP") "to promote water conservation in multiple-family housing, while giving Customers control over their water and wastewater costs."

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[33] USEPA, *Combined Sewer Overflows: Guidance for Nine Minimum Controls*, p. 8-3 (1995), available at http://www.epa.gov/npdes/pubs/owm0030.pdf. While the EPA Guidance recommends water conservation in connection with NMC #7 ("pollution prevention), it would seem to more appropriate fall under the category of NMC#2 ("Maximum use of the collection system for storage"), since, as acknowledged in DEP's *Green Infrastructure Plan*, reducing the dry-weather base flow would free up additional capacity in the collection system for wet-weather flows. NMC #2 in the CSO Control Policy corresponds to CSO BMP#2 in the Draft Permits.

[34] Bowery Bay Draft Permit, p. 15, § VII.2.

[35] USEPA, CSO Control Policy, Part II.A.3, available at http://www.epa.gov/npdes/pubs/owm0111.pdf.

[36] 33 U.S.C. § 1342(q).

Although it is unclear whether the MCP will be as effective at reducing water consumption as volumetric billing would be, the MCP is certainly a significant improvement over the status quo of simply charging these customers a flat rate with no incentive to reduce consumption.

The City's FY13 rate schedule (for July 1, 2012 – June 30, 2013) provided that all properties with 4 or more dwelling units that are billed pursuant to un-metered rates are, as of July 1, 2012, automatically enrolled in the MCP. Under the MCP, billing is still on a flat-rate basis, but property owners are required to promptly fix leaks and install meters (including automated meter readers) and to install certain high-efficiency fixtures.[37] The FY13 rate schedule set a deadline of Jan. 2014 for meter installation and 2015 for fixture installation.[38] However, the City's FY14 rate schedule (for July 1, 2013 to June 30, 2014) extended the deadlines for installation of meters and high-efficiency fixtures to Jan. 2015 and June 2016, respectively.[39] This is just the most recent of many instances, since the 1990s, in which the City has delayed the implementation of reforms to the frontage billing system.[40]

In light of the City's history of delays in implementing water conservation policies for multi-family residential buildings that are billed for water on a flat rate basis, the Draft Permits should be revised to require that the City enforce its <u>current deadlines</u> for meter installation and fixture retrofits under the MCP (*i.e.*, Jan. 2015 and June 2016, respectively), pursuant to the terms specified in the FY14 rate schedule.

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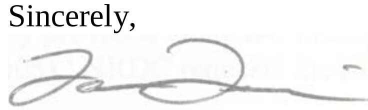
Thank you for your consideration of these comments. We would welcome the opportunity to discuss these issues directly with relevant staff from DEC and DEP. Please feel free to contact me directly at 212-727-4548 or llevine@nrdc.org.

Sincerely,



Lawrence Levine
Senior Attorney

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[37] For existing buildings, 70% of each type of the building's fixtures (i.e., toilets, showerheads and faucets) must be high-efficiency. For new buildings, substantial renovations, and upon turnover of vacant units, all such fixtures must be Water Sense compliant. There are also requirements concerning Energy Star clothes washers, which are both more energy-efficient and water-efficient than other clothes washers.

[38] *See* FY13 rate schedule, Part IV-2-G, available at http://www.nyc.gov/html/nycwaterboard/pdf/rates/fy2013_rates.pdf (cross-referencing the FY12 rate schedule, available at http://www.nyc.gov/html/nycwaterboard/pdf/rates/fy2012_rates.pdf).

[39] *See* FY14 rate schedule, Part IV-2-G, available at http://www.nyc.gov/html/nycwaterboard/pdf/rates/fy2014_rates.pdf.

[40] *See, e.g.*, http://waterwatchnyc.com/category/2012-water-sewer-rates/ and http://waterwatchnyc.com/2013/05/02/is-frontage-dead/.

encl.: Attachments 1-5

cc (via email): Angela Licata, DEP (Deputy Commissioner, Sustainability)
Joan Matthews, EPA Region 2 (Director, Clean Water Division)

Attachment 1

40 West 20th Street
New York, NY 10011
(212) 727-2700
Fax (212) 727-1773

August 13, 2010

Ms. Lindy Sue Czubernat
Division of Environmental Permits
NYSDEC
625 Broadway, 4th floor
Albany, NY 12233-1750

Via email (lxczuber@gw.dec.state.ny.us) and U.S. Mail

Re: Proposed Renewal of the SPDES Permits for New York City's Fourteen Water Pollution Control Plants

Dear Ms. Czubernat:

On behalf of NRDC and its over 39,000 members in New York State, including 15,000 members in New York City, please accept the following comments on DEC's proposed renewals of the SPDES permits for New York City's fourteen Water Pollution Control Plants, which were noticed in the Environmental Notice Bulletin ("ENB") on July 14, 2010.

Based on the ENB Notice, and our conversation on July 16, 2010 about that notice, I understand that the proposed permit renewals are "administrative renewals" of the permits. I also understand that the nine permits marked with an asterisk in the ENB notice all have expiration dates that have already passed; and that these would be simultaneously renewed and modified effective Sept. 1, 2010, with the modifications consisting of those required by the Commissioner's Ruling of June 10, 2010 (which concluded a permit modification proceeding that began around 2002). I also understand that the remaining five permits currently have an expiration date of December 31, 2010; and that these five permits would be modified effective Sept. 1, 2010, with the modifications consisting of those required by the Commissioner's Ruling of June 10, 2010, and renewed effective January 1, 2011. I further understand, from conversations with Carin Spreitzer of DEC's Office of General Counsel, that DEC intends to do a "full technical review" of all 14 permits and then propose further modifications as per DEC's Environmental Benefit Permit Strategy ("EBPS modifications"), following the administrative renewals, within the next 5-year permit term.

The July 14th ENB notice invites the public to submit "substantive comments" on the permits. NRDC understands that DEC's policy is to take such comments into account both in DEC's "priority ranking" of the permits under the EBPS system, and in DEC's full technical review of the permits. NRDC's comments on substantive issues with the permit, and on two procedural matters, follow below.

1. The permits must be modified to comply with federal and state law requirements applicable to discharges from municipal separate storm sewer systems (MS4s).

The MS4 provisions in each of the permits fail to "require controls to reduce the discharge of pollutants [from MS4 outfalls] to the maximum extent practicable," 33 U.S.C. 1342(p)(3)(B)(iii), and to include any additional requirements "necessary to insure compliance with water quality standards adopted pursuant to state law," ECL § 17-0811(5). Most notably, with the exception of floatables control, the permits contain virtually no provisions for the control of construction or post-construction runoff. For example, the permits do not have any provisions addressing the following essential elements of a "Phase I" MS4 permit, as per 40 C.F.R. § 122.26(d)(2)(iv) (which is incorporated by reference into state law by 6 NYCRR § 750-1.11(a)(9)):

- "planning procedures including a comprehensive master plan to develop, implement and enforce controls to reduce the discharge of pollutants from municipal separate storm sewers which receive discharges from areas of new development and significant redevelopment"; and

- "a program to implement and maintain structural and nonstructural best management practices to reduce pollutants in storm water runoff from construction sites to the municipal storm sewer system."

Other omissions include (but are not limited to) the following required elements addressing stormwater pollution prevention for municipal operations (see under 40 CFR § 122.26(d)(2)(iv):

- "practices for operating and maintaining public streets, roads and highways and procedures for reducing the impact on receiving waters of discharges from [the] MS4"; and

- "procedures to assure that . . . existing structural flood control devices have been evaluated to determine if retrofitting the device to provide additional pollutant removal from storm water is feasible"

These omissions and others were identified in a 2005 EPA audit of the Tallman Island Water Pollution Control Plant's MS4 permit provisions.[1] The MS4 provisions in the other thirteen permits suffer from the same defects.

We further note that it is not clear whether DEC is holding the City accountable for compliance with the existing requirement in each of its permits that, "if storm water is shown to significantly contribute to the contravention of water quality standards (including on a near field basis), the permittee must submit a description of additional proposed BMPs and/or control techniques in order to reduce the discharge of pollutants from the MS4." Modeling studies submitted to DEC in connection with the city's development of a Combined Sewer Overflow ("CSO") Long Term Control Plan conclude that separate stormwater contributes to violations of water quality standards in some areas; for some waterbodies (such as Coney Island Creek), the city's CSO "Waterbody/Watershed Facility Plan Report" submitted to DEC have even argued that aggressive control of CSOs is not cost-effective because the main cause of water quality standard violations is actually MS4 discharges. Since the existing permit terms have proven insufficient to ensure the City's MS4 discharges do not cause or contribute to violations of water quality standards, the permits should be modified to include any and all provisions as necessary to do so.

2. DEC should re-rank the permits under the EBPS priority ranking system to reflect the need to revise the permits' MS4 provisions.

DEC should re-rank New York City's water pollution control plant SPDES permits to account for the need to substantially revise and update MS4 requirements and should expeditiously conduct a "full technical review" of the permits and propose permit modifications to strengthen the MS4 provisions consistent with state and federal law.

The most recent EBPS priority ranking sheets for the permits, which DEC staff provided to NRDC upon request, do not appear to reflect the need to modify the permits to comply with the Clean Water Act's MS4 requirements. The permits' priority rankings should account for this deficiency in the permits and DEC should propose the necessary permit modifications as soon as possible.

3. DEC should commit in writing that, upon the next proposed "EBPS modification" of the permits, the public will be afforded a full opportunity to comment and seek a hearing on any aspect of the permits.

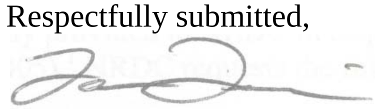
NRDC renews its request for DEC to confirm, in writing, that when DEC issues public notice of the next set of proposed EBPS modifications for each of the permits, the public will be afforded a full opportunity to submit comments raising any issues with any aspect of the permits – regardless of whether DEC proposes to modify such aspect of the permits – and will have the right to an adjudicatory public hearing if any issues raised in

[1] See Table 1 of "Municipal Separate Storm Sewer System (MS4) Audit, Tallman Island Water Pollution Control Plant, New York City, June 7 - 9, 2005" (prepared for EPA Region 2 by Science Applications International Corporation). A copy of that audit is attached.

such public comments are “substantive and significant” within the meaning of 6 NYCRR Parts 621 and 624. NRDC previously requested such written confirmation via emails I sent to DEC dated July 21 and July 22, 2010, each of which was either addressed to or copied to Ms. Spreitzer. Ms. Spreitzer called me on July 30, 2010, on behalf of DEC, and told me that the public would be afforded a full opportunity for comment and a hearing on any aspect of the permits, as described above, at the time of the next proposed EBPS modifications. During that phone conversation (and in my July 21-22 emails), I called Ms. Spreitzer’s attention to 6 NYCRR § 750-1.18(d), which could be read to suggest otherwise, and Ms. Spreitzer assured me that DEC commits to providing the opportunity for comment and a hearing, as described above, notwithstanding that provision of DEC’s regulations. Despite DEC’s willingness to offer this commitment to me orally, Ms. Spreitzer also informed me that DEC is either unable or unwilling to put this position in writing. On July 30, 2010, I sent an email to Ms. Spreitzer memorializing the conversation we had on that date and renewing my request, on behalf of NRDC, for a written commitment from DEC; to date, I have received no response. NRDC fully expects DEC will abide by its commitment and, as I explained to Ms. Spreitzer, we believe that such a result is, in any case, compelled by the Clean Water Act and state Environmental Conservation Law. We respectfully request that DEC confirm its commitment in writing, for the record.

Thank you for your consideration of these comments. We look forward to receiving DEC’s reply.

Respectfully submitted,



Lawrence M. Levine
Senior Attorney, NRDC Water Program

encl.

cc (by email): Jeff Gratz, USEPA Region 2

Municipal Separate Storm Sewer System (MS4) Audit
Tallman Island Water Pollution Control Plant, New York City
June 7 - 9, 2005

Prepared for:
EPA Region 2
290 Broadway
New York City, New York 10007

Prepared by:
Science Applications International Corporation
11251 Roger Bacon Drive
Reston, VA 20190

Table of Contents

Municipal Separate Storm Sewer System (MS4) Audit
Tallman Island Water Pollution Control Plant, New York City
June 7 - 9, 2005

1. INTRODUCTION

At the request of the U.S. Environmental Protection Agency (EPA) Region 2, a Municipal Separate Storm Sewer System (MS4) Audit was conducted on June 7 - 9, 2005, at the New York City Department of Environmental Protection (NYC DEP). The audit was specifically related to the Tallman Island Water Pollution Control Plant (WPCP). The audit team included Mr. Jerry Whittum and Ms. Carol Winston of Science Applications International Corporation and Ms. Christy Arvizu and Mr. Philip Li of EPA Region 2.

Permit No. NY 0026239 was issued to the NYC DEP for the Tallman Island WPCP. The permit is effective from January 1, 2001 to January 1, 2006 (hereinafter called the 2001 Permit). The MS4 audit evaluated NYC DEP's implementation of its storm water program compared to the requirements in the 2001 Permit as well as an earlier version of Permit No. NY0026239 which was effective from September 30, 1988 to September 29, 1993 (hereinafter called the 1988 Permit). The report is organized as follows:

- General findings
- Specific sections which correspond to the program components included in either one or both of the 2001 and 1988 permits. Each section contains the specific permit conditions, findings, and required and recommended actions.

2. FINDINGS

A. General Findings

Responsibility for implementation of the storm water program is based within various organizations. It is uncertain whether active communication, coordination, and data sharing are occurring among these organizations. Such coordination and communication are critical to ensure that the storm water program is being effectively implemented.
Recommended action: *NYC DEP should enhance communication and coordination among all parties responsible for implementing the storm water program.*

The 2001 and 2003 Assessment of Controls Progress Reports required by the permit should reflect the current stormwater program activities and associated data. For example, some data presented in these reports did not appear to be correct or have enough information to adequately describe the activity.
Recommended action: *NYC DEP should ensure that Assessment of Controls Progress Reports required by the permit include accurate and complete information and data.*

The storm sewer maps being used by some NYC DEP staff are dated 1985, and staff indicated that these are the most recent maps of the MS4 system provided to them.

Recommended action: *NYC DEP staff should verify whether they have the most recent storm sewer maps for use in the storm water program implementation, and if not, obtain updated maps as expeditiously as possible.*

B. Source Identification

2001 Permit Requirements: None.

1988 Permit Requirements (Section 1.XI.A.3): NYC DEP was required to verify the locations of known and newly identified MS4 outfalls and major storm water structural controls, describe the land use activities, and estimate population densities and projected growth within the MS4 drainage area.

Findings: NYC DEP prepared the Source Identification Report in March 2001. This report included the items required in the 1988 Permit including major structural controls. During interviews, it appeared that NYC DEP staff were unaware of the existence and locations of structural controls within the Tallman Island drainage area. (Also see discussion in Section 2.I *New Development and Significant Re-development* of this report.)

Required actions: *None.*

Recommended actions: *NYC DEP staff working in the storm water program should become familiar with and knowledgeable of the major MS4 storm water structural controls. This is important for implementing the maintenance activities, spill response, and industrial components of the storm water program.*

C. Discharge Characterization

2001 Permit Requirements: None.

1988 Permit Requirements (Section 1.XI.B): NYC DEP was required to collect samples from the representative outfalls listed in the permit and submit a Supplemental Discharge Characterization Report.

Findings: NYC DEP collected and analyzed samples from the five required outfall locations representing Highway, Commercial, Heavy Industry, Low Density Residential, and High Density Residential runoff. The data generated from the study characterized the pollutant characteristics for each land use type. NYC DEP compiled and analyzed the data and developed and submitted a Storm Water Supplemental Discharge Characterization Report on May 1, 2002.

Required actions: *None.*

Recommended actions*:* *None.*

D. Monitoring Program

2001 Permit Requirements (Section I.XV.g): NYC DEP must develop and submit to NY DEC for approval a stormwater monitoring program and sampling schedule, which shall be no less than once per year, for pollutants present at representative MS4 outfalls, which describes the location of the representative MS4 outfalls or screening points to be sampled, why the location is representative, the frequency of sampling, the parameters to be sampled, and the sampling equipment.

1988 Permit Requirements (Section 1.XI.B): Within 90 days of completion of the Discharge Characterization, NYC DEP was required to submit a proposed stormwater monitoring program for representative data collection which described the location of MS4 outfalls or field screening points to be sampled, why the location was representative, the frequency of sampling, parameters to be sampled, and a description of sampling equipment.

Findings: The 2001 Permit has a due date of February 1, 2003, for submission of the stormwater monitoring program and sampling schedule. The stormwater monitoring program and sampling schedule, which was provided to the MS4 audit team, was submitted to New York Department of Environmental Conservation (NY DEC) on July 1, 2003.

In correspondence to NY DEC dated July 1, 2003, the NYC DEP stated that to provide sound data the sampling locations must capture runoff representative of the entire MS4. In correspondence to NY DEC dated December 28, 2004, the NYC DEP stated that three of the four proposed sampling locations had changed. The four new sampling locations appear to primarily represent residential areas as shown below:

- Outfall PR-603 - 91% residential and 9% commercial/industrial and a catchment area of 231 acres
- OB-614 - 99% residential and 1% commercial/industrial and a catchment area of 69.5 acres
- JAM-006 (north) - 27% residential and 73% commercial/industrial and a catchment area of 14.3 acres
- JAM-006 (south) - 55% residential and 45% commercial/industrial and a catchment area of 59.7 acres.

The City has collected the 2004 samples, but has not yet collected the 2005 samples. (See discussion of the *Shoreline Survey* and *Sentinel Monitoring* in Sections 2.E and 2.F of this report respectively).

Required actions: *None.*

Recommended actions: *NYC DEP should collect the 2005 samples as soon as possible.*

E. Shoreline Survey

2001 Permit Requirements: (Section I.XV.c): NYC DEP must complete a Shoreline Survey of at least 50% of the shoreline of New York City (NYC) as identified in consultation with DEC and submit a report to DEC which identifies and characterizes all dry weather discharges of untreated sewage from the NYC sewer system by April 1, 2003.

1988 Permit Requirements (Section 1.XI.D.1): NYC DEP was required to complete a shoreline survey of at least 50% of the NYC shoreline and submit a report to NY DEC which identified and characterized all new MS4 outfalls and untreated discharges from the NYC sewer system.

Findings: The NYC DEP is in the third cycle of its shoreline survey and has surveyed the entire shoreline twice previously. The NYC DEP had completed approximately 60% of the current shoreline survey by April 1, 2003, which was 10% more than required by that date. The NYC DEP expects to complete the remaining 40% of the shoreline survey by the required April 1, 2008 due date. The NYC DEP anticipates surveying more than the remaining 40% of shoreline during the current shoreline survey cycle.

The MS4 audit team observed NYC DEP monitoring and shoreline survey activities (see Appendix A).

Required actions: *None.*

Recommended actions: *None.*

F. Sentinel Monitoring

2001 Permit Requirements: (Section I.XIII.3): NYC DEP must perform a sentinel monitoring program at 80 ambient monitoring stations and establish a baseline number and/or range for fecal coliform for each station. Quarterly sampling is required at each monitoring station. Any statistically significant exceedance of a baseline number and/or range will require a shoreline survey investigation. The baseline numbers must be re-analyzed annually and changed if necessary.

1988 Permit Requirements (Section 1.XI.D.2): NYC DEP was required to perform quarterly fecal coliform sampling in a sentinel monitoring program at 98 ambient monitoring stations.

Findings: Due to adverse weather, a limited number of sample points were monitored in the first quarter of 2001. NYC DEP currently samples 80 ambient monitoring stations quarterly. Sample point S-59 routinely exceeds the fecal coliform baseline by excessive amounts. NYC DEP has investigated and determined the baseline exceedance is due to a raw sewage discharge by Westchester County. NYC DEP has no jurisdiction over Westchester County and has provided the information to NY DEC for follow-up.

Required actions: *None.*

Recommended actions: *NYC DEP should contact NY DEC regarding the status of the raw sewage discharge by Westchester County.*

G. Seasonal Pollutant Loads

2001 Permit Requirements (Section 1.XV.g): NYC DEP must submit a report that includes the cumulative estimates of seasonal pollutant loads and representative flow-weighted averages of storm water discharges from the major MS4 outfalls in the drainage area.

1988 Permit Requirements: None.

Findings: NYC DEP analyzed the data from its previously developed Estimate of Annual Storm Water Pollutants Loadings report to develop the required Estimate of Seasonal Storm Water Pollutant Loadings report which was submitted in January/February 2003. The Estimate of Seasonal Storm Water Pollutant Loadings report concluded that (1) most conventional pollutant concentrations increased during the warm season likely due to human activity, (2) metal pollutants increased during the cold season likely due to corrosion and abrasion of automobiles, and (3) Total Dissolved Solids and Total Suspended Solids increased in the cold season likely due to roadway ice control salting and sanding.

Required actions: *None.*

Recommended actions: *None.*

H. Sewer Use Regulations

2001 Permit Requirements (Section 1.XV.g): NYC DEP must reevaluate the need to amend the NYC Sewer Use Regulations, including the use of Best Management Practices (BMPs), and if necessary, the NYC DEP must submit a proposed plan in consultation with a Citizens Advisory Committee (CAC) along with a schedule for the completion of the plan in accordance with the time frames in the NY DEC-approved report *Proposed Program and Schedule to Monitor and Control Toxicants of Concern from Industrial Facilities and Waste Handling Sites Associated with Storm Water Discharges into the MS4* (hereinafter referred to as the Proposed Program for Control of Toxicants report).

1988 Permit Requirements (Section 1.XI.D.3): Upon completion of the Supplemental Discharge Characterization report, NYC DEP was required to evaluate the need to amend, if necessary, the NYC Sewer Use Regulations, including the use of BMPs. Within 90 days, NYC DEP was required, if necessary, to submit a proposed plan in consultation with a CAC, along with a schedule for completion of the plan.

Findings: NYC DEP submitted its Proposed Program for Control of Toxicants report to the NY DEC in October 2003. This report summarized Phase I of the program (data gathering from field inspections and facility survey forms to identify industrial and commercial facilities with the potential to impact storm water in NYC) and the proposed activities for Phase II of the program. However, the Proposed Program for Control of Toxicants report indicated that no specific schedule could be established for the proposed activities because they were dependent on "outside resources." City staff indicated this meant that the time frame could not be established because it partially depended on input from the stakeholders.

In its Proposed Program for Control of Toxicants report, NYC DEP presented plans to focus its program on two industrial and commercial sectors - the automotive sector (auto dealer, gasoline stations with and without auto repair services, fuel wholesaler, auto parts retailer and auto salvage) and the transportation sector (local and suburban transit, transportation equipment, motor freight, water and air transportation). Although these industrial and commercial sectors have the highest number of facilities and outdoor activities in the NYC MS4 drainage area, there were other sectors identified in Phase I which had storm water issues and do not appear to be addressed (e.g., heavy construction, food, industrial and commercial machinery and equipment). (Also see discussion in Section 2.M *Industrial Permits* of this report.)

Ms. Lily Lee, Acting Deputy Section Chief, Regulatory Planning Section, Bureau of Wastewater Treatment, presented a summary of NYC DEP's efforts in its Proposed Program for Control of Toxicants at a CAC meeting on January 21, 2004. Several stakeholders including trade associations were invited to the meeting. Example comments included the following:

- BMPs should be mandatory.
- NYC DEP should meet with the automobile and transportation representatives to solicit input.
- BMPs should be more aggressive while ensuring no unnecessary economic burden to businesses.

Based on the comments received during that meeting, NYC DEP is revising and proposing BMP options, which it plans to present at a CAC meeting in September or November of 2005. It appears unlikely that NYC DEP will have implemented this program by the end of the 2001 permit term (i.e., January 1, 2006).

The 2001 Permit indicates that the pollutants of concern for the Proposed Program for Control of Toxicants are: non-polar material, polychlorinated biphenyls (PCBs), tetrachloroethylene, arsenic, cadmium, copper, mercury, nickel, and lead (found in Footnote 1, page 37 of 41 of the permit). The Proposed Program for Control of Toxicants report does not specifically discuss these pollutants of concern.

Required actions: *In accordance with Footnote 1, Section I.XV.g of the 2001 Permit, NYC DEP's Proposed Program for Control of Toxicants must address the identified pollutants of concern.*

Recommended actions: *NYC DEP should do the following:*

> *(1) schedule the presentation for the BMP options for the Proposed Program for Control of Toxicants from industrial and waste handling facilities at the CAC meeting as soon as possible.*
> *(2) develop a schedule for implementing the selected BMP options.*
> *(3) revise the Proposed Program for Control of Toxicants to include a prioritization plan for addressing all the industrial and commercial groupings for which storm water issues were identified in Phase I of the project.*

I. New Development and Significant Re-Development

2001 Permit Requirements (Section 1.XV.g): None.

1988 Permit Requirements (Section 1. XI.D.4): NYC DEP was required to submit a report on the South Richmond Drainage Plan and its applicability to other areas of NYC.

Findings: NYC DEP's program is primarily based on the Bluebelt program which has been successfully applied to development in Staten Island. NYC DEP's Bluebelt program preserves and integrates natural drainage corridors (e.g., streams, ponds, and wetlands) into a system for conveying, storing, and filtering storm water. As part of the Bluebelt program, Mr. Jack Vokral, Division Chief, Bureau of Water and Sewer Operations (BWSO), indicated that NYC DEP conducted a major capital improvement program to build facilities where storm sewers end and natural areas begin (about 30 capital projects to date). These BMP facilities include constructed wetlands, storm water detention ponds, and stream restoration projects. More Bluebelt programs, which are being planned in the mid-Staten Island area, are in various stages of development. A brochure showing these areas was provided to the MS4 audit team.

Outside of the Bluebelt program, Mr. Jack Vokral indicated that there were very few storm water structural controls throughout the City. However, the Source Identification Report prepared in March 2001 included locations of structural controls for each NYC drainage area. For example, the Tallman Island WPCP drainage area listed seven controls including three detention basins in the College Park Industrial Park area. During the MS4 audit, the audit team observed the detention basins in the College Point Industrial Park. None of the NYC DEP staff were aware of the existence of these detention ponds at the time of the MS4 audit. The MS4 audit team observed the detention basin located north of 28th Avenue and between Ulmer Street and Linden Place (see Appendix B). The detention basin and fence needed minor repairs. A map provided by NYC DEP showed two basins extending south of 28th Avenue; however, the area contained commercial buildings.

Mr. Vokral was unaware of a review for storm water structural controls that would be included as part of a site plan review process, but indicated that if it were being performed, it was probably being done by the Department of Buildings. BWSO staff review Site Connection Proposals, which are required when connecting to the storm sewer system. They only review the actual connection to see if the storm water flow can be accommodated by the receiving storm sewer. The applicant has to demonstrate that the storm water flow will be within the limits of the receiving pipe, and if not, the applicant must provide on-site retention. If on-site retention is required, the Division of Review and Construction Compliance (within BWSO) reviews the design capacity of the on-site retention facility. During the closing conference, NYC DEP's Site Connection Proposal Form was provided to the MS4 audit team.

Required actions: *None.*

Recommended actions: *NYC DEP should do the following:*

(1) update its maps to show the current detention basin status.

(2) ensure that NYC DEP staff become familiar with the existing storm water structural controls within NYC and knowledgeable of their locations and conditions.

(3) address the minor repair of the detention basin and fence located north of 28th Avenue and between Ulmer Street and Linden Place.

J. Floatables Control and Maintenance Activities

2001 Permit Requirements [Section IX.7 - BMPs for Combined Sewer Overflows (CSOs)]: NYC DEP is required to implement the following BMPs to eliminate or minimize the discharge of floatables and settleable solids: catch basin repair and maintenance; catch basin retrofitting; booming, skimming, and netting; and institutional, regulatory, and public education.

1988 Permit Requirements (Section 1.XI.D.5): NYC DEP was required to conduct floatables control and maintenance as required under the CSO requirement found in Section III.B.5 of the permit (i.e., CSO - Water Quality Requirements). Section III.B.5 references the City's consent decree concerning its CSO abatement program.

Findings: NYC DEP's CSO abatement program includes a component for floatables control and maintenance activities. NYC DEP provided the MS4 audit team with a document entitled *Best Management Practices Annual Report for the Period January 1, 2004 - December 31, 2004* (hereinafter called the 2004 BMP Annual Report) prepared by the NYC DEP Bureau of Wastewater Treatment. This document contains a section on control of floatable and settleable solids which describes NYC DEP's catch basin repair and maintenance; catch basin retrofitting; and booming, skimming, and netting programs.

Catch basin repair and maintenance: The NYC DEP performs catch basin inspections on a three-year cycle as required in its permit (taken from the 2004 BMP Annual Report). The 2003 Assessment of Controls Progress Report indicates that as a requirement of the catch basin hooding program, all catch basins must be re-inspected every two years to confirm that the hoods are in place. It is unclear if this is different from the inspection schedule in the 2004 BMP Annual Report (i.e., the three-year inspection schedule).

The 2004 BMP Annual Report indicates that the schedule of inspections for catch basins began in October 2002 and that approximately 91,000 of the 140,000 catch basins in

NYC had been inspected through December 2004 (at a rate of about 3,500 to 4,000 per month). In addition, during 2004, approximately 44,000 catch basins were cleaned in response to inspections or complaints, or as part of scheduled cleaning.

Catch basin retrofitting: Information from the NYC DEP website indicates that hoods are being installed at all catch basins. The 2004 BMP Annual Report indicates that based on 1999 data, 8,203 catch basins required retrofitting to allow hood installation; this number was reduced to 2,798 by the end of 2003 and 2,129 by the end of 2004.

Booming, skimming, and netting: NYC has 20 boom sites and five net sites for floatables control corresponding to storm water and combined sewer drainage areas. The locations were strategically selected based on where most litter would accumulate. Inspections are conducted within 24 to 48 hours after storm events or at least weekly in the absence of storm events. Inspections may occur more often in areas where specific tide and wind conditions cause debris to accumulate. Floatable materials are retrieved by four City-owned skimmer vessels.

Public education: Mr. Charles Sturcken, Director, Public and Intergovernmental Affairs, NYC DEP, provided the MS4 audit team with a section from a report that describes DEP public education programs, including floatables reduction. NYC DEP's activities include school programs, public events, multimedia environmental education materials, volunteer programs, publications, promotional items, and the NYC DEP website. NYC DEP has a major public outreach program called Clean Streets = Clean Beaches. Program literature is distributed at public events and schools, and posters and advertisements are posted on buses and at bus stops and subway stations.

The 2003 Assessment of Controls Progress Report lists the following enhanced boom monitoring procedures and maintenance and repair activities:

- ***Ebb tide boom inspections*** - When the tides are low, vessels cannot navigate to the areas where the booms are located. During favorable tidal conditions, the vessels are dispatched to inspect and pick up the litter with the skimmer vehicles. Collected litter and debris go to a transfer station and are ultimately disposed of in a landfill.
- ***Digital video recording of inspections*** - NYC DEP employs a contractor to perform operation and maintenance services for their skimmer vessels. The contractor videotapes the weekly inspections of boom locations. NYC DEP also has a third-party contracted project manager who is responsible for managing the operation and maintenance program.
- ***Boom replacements*** - NYC DEP determined that all floatables were not always being captured because of turbulence from the outfall discharge. They identified a boom which had a skirt about 14 inches below the water surface and replaced all the booms with this new design about three years ago. This design was significantly more effective and more durable than the previous design.
- ***Tide slide repairs and replacements*** - When inspecting the boom facilities, NYC DEP found situations in which the boom was damaged or disengaged from one side. The

inspectors usually have some spares and will replace the slide. If the inspectors can't replace the slide, they contact the office for follow-up.

- ***Employing a gate system at some booms*** - NYC DEP implemented a system where they put in place a second boom to prevent floatables from going back into the outfall during low tides.

Required actions: *None.*

Recommended actions: *NYC DEP should review the inspection schedule for catch basins described in the 2003 Assessment Report to ensure it is consistent with the inspection schedule described in the 2004 BMP Annual Report.*

K. Trackdown and Remediation

2001 Permit Requirements (Section 1.XV.g): If pollutants identified in the stormwater monitoring program are significantly and repeatedly contributing to a water quality violation, then the permittee must develop and submit for approval to NY DEC a trackdown program and schedule to identify the source of the discharge of these pollutants. NYC DEP was also required to submit a proposal for a definition of "significantly contributing to a water quality violation" to NY DEC by October 1, 2003.

1988 Permit Requirements (Section 1.XI.D.6): NYC DEP was required to propose a trackdown program and schedule to identify discharges of PCBs, pesticides, and herbicides if they were found to be significantly contributing to a water quality violation or a fish-consumption advisory as part of NYC DEP's stormwater monitoring program.

Findings: NYC DEP submitted a proposal for a definition of "significantly contributing to a water quality standard" on October 1, 2003. The proposal included levels for all the pollutants listed in the permit (Footnote 3) except non-polar material. For non-polar material, NYC DEP proposed determining what constitutes "significantly contributing to a water quality violation" after 36 months of stormwater monitoring (i.e., October 2006). NYC DEP has not received any response from NY DEC on this proposal.

NYC DEP has not initiated any trackdown and remediation activities for pollutants identified in the stormwater monitoring program. Activities conducted under the PCB trackdown and remediation have been completed, and no further activities are planned.

Required actions: *None.*

Recommended actions: *NYC DEP should contact the NY DEC to obtain comments or feedback on its proposal for a definition of "significantly contributing to a water quality standard."*

L. Construction Site Runoff

2001 Permit Requirements (Section 1.XV.g): None.

1988 Permit Requirements (Section 1.XI.D.7): NYC DEP was required to develop and submit to DEC for approval a Construction Site Urban Runoff manual. The permit also required NY DEP to continue to implement all activities outlined in the Part II Storm Water Permit Application until the development of this manual, at which time NYC DEP would reassess its oversight activities of construction sites.

Findings: In the 2003 Assessment of Controls Progress Report, NYC DEP stated that the requirement to develop and submit a Construction Site Urban Runoff manual was removed from the current State Pollutant Discharge Elimination System permit because NY DEC and NYC DEP agreed that there is already sufficient guidance on storm water management from other agencies.

Regarding the construction site runoff program, the Part II Storm Water Application was not reviewed as part of this audit, and therefore it was not determined if NYC DEP reassessed its oversight activities of construction sites. However, the MS4 audit team discussed NYC DEP's responsibilities for the construction sites runoff program. NYC DEP staff indicated that they attended a meeting with the NY DEC regarding regulation of construction site activities within NYC. Based on that meeting, NYC DEP staff understood that they would be notified by NY DEC of sites in NYC that submitted a Notice Of Intent (NOI) for coverage under the general permit for storm water associated with construction sites. NYC DEP was unable to provide documentation of this agreement.

NYC DEP indicated that they had not received any notifications of NOI submittals within the past two years. However, the MS4 audit team observed several large construction sites in the Tallman Island drainage area, of which NYC DEP was unaware because they had not received NOI submittal notification from NY DEC. The MS4 audit team observed a large commercial site located at 15th Avenue between 139th and 143rd Streets and a single family residential site located along the north side of Powell's Cove Boulevard from west of 3rd Avenue towards 151st Street (see Appendix C). The commercial site was in need of storm water BMPs to contain soils on site and protect off-site area drains.

Required actions: *None.*

Recommended actions: *NYC DEP should enact a formal agreement with NY DEC that ensures notification of all NOIs submitted for sites within NYC. NYC DEP should discuss with NY DEC the development of standard protocol for NYC DEP notification to NY DEC of observed construction site problems.*

M. Industrial Permits

2001 Permit Requirements (Section 1.XV.g): NYC DEP must update and submit to NY DEC by April 4, 2003, the inventory of industrial and waste handling facilities discharging to the MS4 that are engaged in activities specified by the SIC codes listed at 40 CFR 122.26(b)(14). The inventory must be organized by drainage area and include the name and address of each facility along with a description that best reflects the principal products or services provided (such as SIC code) by the facility. The inventory must also indicate which industrial facilities or waste handling facilities are regulated by NYC DEP's Industrial Pretreatment Program (IPP).

1988 Permit Requirements (Section 1.XI.D.8): NYC DEP was required to:

- incorporate storm water permit requirements into existing Pretreatment Program Permits for facilities where appropriate and perform annual storm water program inspections at these facilities
- for facilities not covered by NYC DEP's Pretreatment Program, submit a proposed program and schedule to monitor and control toxicants of concern from industrial facilities and waste handling sites associated with storm water discharges into the MS4. Priorities and procedures for inspections and establishing and implementing control measures for such discharges were required to be identified.
- provide a schedule to assess the effectiveness of the Spill/Slug Control Program for each facility covered under the Pretreatment Program.

Findings: Two documents related to an inventory of industrial and waste handling facilities were provided to the MS4 audit team: a letter dated January 18, 2002, which listed the number of industrial and waste handling facilities as 1,105 and Attachment 3 to the Proposed Program for Control of Toxicants report. The 2002 letter did not include any information about the 1,105 industries and Attachment 3, which was originally submitted to NY DEC on March 26, 2003, did not identify which facilities on the inventory were covered under the IPP.

Prior to the MS4 audit, NYC DEP provided to the MS4 audit team a list of three industrial and waste handling facilities that are located in the Tallman Island drainage area: Edward Fields, Inc. Comstar International Inc., and Con Edison. Based on interviews with NYC DEP staff, Edward Fields is no longer in business as of March 2005. In addition, the 2003 Assessment of Controls Progress Report included a list of industrial facilities which are in the MS4 drainage area, and thus will have storm water provisions in their IPP permits. Neither Edward Fields (which was in business at that time) nor Comstar International Inc. were included in this list. NYC DEP staff who prepared this report indicated that this was a technical problem with NYC DEP's database.

Review of IPP files for the Con Edison facility within the Tallman Island MS4 drainage area showed the following:

- The inspection report dated 7/21/03 had some questions in the storm water section of the checklist which were not completed. In addition, the question regarding whether the spill response procedures were adequate was marked "no." However, no follow-up action was indicated on the inspection report and no documentation of follow-up action could be found.

- The inspection report dated 11/4/04 had several questions in the storm water section of the checklist which were not completed (e.g., "activities that have the potential of exposure to precipitation and/or come into contact with contaminants", "does the establishment have a SPDES permit"). Also the question "was a logbook of spills/leaks of pollutants at area exposed to precipitation (or having the potential to enter the storm sewer) maintained properly at the time of the inspection" was marked "no." However, no follow-up action was indicated on the inspection report and no documentation of follow-up action could be found.
- The inspection report dated 6/03/05 had several questions not completed (e.g., "activities that have the potential of exposure to precipitation and/or come into contact with contaminants", "does the establishment have a stormwater permit", "does the establishment have a SPDES permit"). Also the question regarding whether the establishment posted emergency notification procedures at the facility was marked "no." No follow-up action was indicated on the inspection report and no documentation of follow-up action could be found. NYC DEP staff indicated that the NYC DEP inspector told the facility to post these procedures.

Regarding the questions of activities that have the potential of exposure to precipitation and/or come into contact with contaminants, Ms. Frances Leung, Acting Chief of the Permits and Inspections Section, Bureau of Wastewater Treatment, indicated that the Con Edison facility does not have such activities. However, the Storm Water Pollution Prevention Plan (SWPPP) prepared by the facility indicated that at the time the SWPPP was prepared, it had at least two activities with the potential to contaminate storm water - the concrete pad between settling basin grates and facility gates and the paved area at the facility entrance (Table 3-1 Potential Pollutant Sources).

Based on interviews of NYC DEP staff and document reviews, it appears that the NYC DEP's storm water program for industrial and commercial facilities is limited to the following:

- facilities covered under NYC DEP's IPP (e.g., two facilities in the Tallman Island drainage area)
- industrial and commercial sectors (e.g., automotive, transportation) being addressed in NYC DEP's Proposed Program for Control of Toxicants
- facilities with problems addressed through the Emergency Response Unit
- facilities in the dry cleaning, food services, and photofinishing sectors being addressed by the NYC DEP Pollution Prevention staff.

This leaves a large number of industrial and commercial facilities which can have a potential impact on storm water discharges not being addressed by NYC DEP's storm water program.

NYC DEP uses the IPP enforcement response program (ERP) for its response to industrial and construction and illicit discharge violations. It is uncertain whether the IPP ERP can be used effectively for the storm water program because of the type and nature of storm water violations (e.g., discharge of a batch process to the sanitary sewer compared to dumping of used motor oil down a storm drain). After the MS4 audit, NYC DEP faxed two documents:

- Attachment I, Enforcement & Compliance Section, Bureau of Clean Water dated November 18, 1993. The attachment listed increasing penalties associated with first, second, and third violations of specific types of violations (e.g., unauthorized discharge to catchbasin, storm sewer, or sanitary sewer). However, it did not include escalation of enforcement beyond increasing penalties (e.g., at what point other enforcement methods would be used).
- Enforcement Response Plan for the Bureau of Wastewater Pollution Control (Approved by USEPA on 4/26/00). This document is the ERP for NYC DEP's IPP. The document discusses the criteria for determining a proper enforcement response, legal authority to implement enforcement responses, and adjudication of Notices of Violation at the Environmental Control Board. The ERP also includes an Enforcement Response Guide which shows escalation of enforcement, but the Enforcement Response Guide is primarily focused on violations associated with the IPP.

Required actions: *In accordance with Section I.XV.g of the 2001 Permit, NYC DEP must submit an updated inventory of industrial and waste handling facilities discharging to the MS4 that are engaged in the activities specified in the SIC codes listed at 40 CFR Part 122.26(b)(14). Although an inventory was submitted on March 26, 2003, this inventory did not include identify whether the facilities were covered under NYC DEP's IPP as specified in Section I.XV.g. Thus, NYC DEP must either re-submit the inventory from March 2003 and specify whether the facilities were covered under the IPP or prepare a current inventory with all the required information.*

Recommended actions: *NYC DEP should do the following:*

(1) ensure that the industrial data presented in future Assessment of Controls Progress Reports are accurate.

(2) complete all questions on the storm water portion of the inspection checklist.

(3) ensure that follow-up actions for violations identified during a storm water inspection are taken and documented.

(4) review and revise as appropriate the IPP ERP to ensure that it clearly pertains to storm violations (e.g., illicit discharges). (Also see Section 2.P Spent Vehicle Fluids.)

(5) develop a prioritization plan to address all industrial and commercial sectors with the potential to impact the MS4, whether through the IPP, the Proposed Program for Control of Toxicants, or special initiatives that NYC DEP may conduct.

N. Spill Response

2001 Permit Requirements: None.

1988 Permit Requirements (Section 1.XI.D.9): NYC DEP was required to submit a description of procedures to prevent, contain, and respond to spills of materials prohibited by the

NYC Sewer Use Regulations that may discharge into the MS4 along with an implementation schedule for the procedures.

Findings: The City understands the requirement in the 1988 Permit for development of spill response procedures to apply only to industrial sites. Thus, the City has no written Standard Operating Procedures (SOPs) for response to spills outside of industrial areas such as spills on streets.

As mentioned above, spill response enforcement is conducted according to the IPP ERP. However, all facilities receive a clean record at the beginning of each new year. Thus, a low-level repeat offender has the potential to continue discharging spent vehicle fluids to the storm sewer twice per year indefinitely without any adequate enforcement action being taken.

Required actions: *None.*

Recommended actions: *NYC DEP should review its enforcement response policy to ensure that enforcement can be escalated in instances of noncompliance that extend beyond a one-year period.*

O. Catch Basin Stenciling

2001 Permit Requirements (Section 1.XV.g): None.

1988 Permit Requirements (Section 1.XI.D.10): NYC DEP was required to undertake an evaluation and provide an implementation plan and schedule for stenciling warning notices (e.g., Don't Dump Here) on catch basins within targeted areas of NYC.

Findings: NYC DEP used summer interns to conduct catch basin stenciling from 1993 to 1996. The stencil paint tended to flake off, and the program was discontinued. NYC DEP staff glued decals on selected catch basins from 1999 to 2001. The decals either came off or were stolen, and the program was discontinued.

Required actions: *None.*

Recommended actions*: NYC DEP should renew efforts to post warning notices at catch basins. NYC DEP may find benefit in conferring with other municipalities that have successful stenciling programs.*

P. Public Outreach

2001 Permit Requirements: None.

1988 Permit Requirements (Section 1.XI.D.11): NYC DEP was required to promote, publicize and facilitate public reporting of the presence of illicit discharges or water quality impacts associated with discharges from the MS4.

Findings: NYC DEP staff provided two examples of public outreach consisting of signs on telephone booths, city buses, and bus stations, and brochures handed out and mailed in water bills that address handling of used oils. The 2003 Assessment of Controls Progress Report provides additional public outreach efforts.

NYC DEP provided a brochure to the MS4 audit team entitled Grease Disposal Tips to Help the City's Environment. The brochure included a section called Contact Us which noted that to report illegal dumping into street storm drains, the person should call 311 Government Information and Services for NYC or write the NYC DEP. In addition, the NYC DEP website included a news release dated July 14, 1997, that announced a 24-hour toll-free hotline for reporting threats to water quality throughout the watershed. Citizens were asked to report incidents such as failing septic or other wastewater systems, illegal dumping, and illegal discharges of petroleum products and other hazardous materials.

Required actions: *None.*

Recommended actions: *None.*

Q. Spent Vehicle Fluids

2001 Permit Requirements: None.

1988 Permit Requirements (Section 1.XI.D.12): NYC DEP was required to define NYC's enforcement program against illegal dumping of spent vehicle fluids (i.e., used motor oil, antifreeze, and brake fluids) into the MS4.

Findings: Mr. Pravin Patel, Chief of the Pollution Prevention Section, Bureau of Wastewater Treatment, said that rather than an independent program, the spent vehicle fluids program is part of the spill response program. The program is complaint-driven, and 95% - 98% of the spent vehicle fluid incidences responded to by NYC DEP are generated by 311 calls. The 311 dispatcher notifies the NYC DEP communication center.

NYC DEP staff can issue a Notice of Violation ticket and, as needed, a Commissioner's Order to require clean up. Enforcement authority is through the IPP ERP.

Review of a spill response enforcement document dated April 29, 2005, File Number 10929.03, recipient Charles Taule, ESQ. included the following information:

December 2004	NOV	$250.00
March 12, 2005	NOV	$250.00
March 14, 2005	NOV	$250.00
March 15, 2005	NOV	$250.00
March 16, 2005	NOV	$250.00
March 17, 2005	NOV	$250.00
March 24, 2005	NOV	$350.00
		$1,850.00

Mr. Patel stated that all facilities get a clean record each 12-month period. At the end of a 12-month period (from the first offense), any new violation is treated as a first offense.

Required actions: *None.*

Recommended actions: *NYC DEP should do the following:*

(1) review its enforcement response policy to ensure that enforcement can be escalated in instances of noncompliance that extend beyond a one-year period.

(2) review and revise as appropriate the IPP ERP to ensure that it clearly pertains to storm violations (e.g., illicit discharges).

3. FEDERAL REQUIREMENTS FOR STORM WATER MANAGEMENT PROGRAMS

Table 1 below contains a comparison of the Federal requirements for a Storm Water Management Program to the permit conditions in the following two permits: Permit No. NY 0026239 (effective from 9/30/88 to 9/29/93 and Permit No. NY 0026239 (effective from 1/1/01 to 1/1/06).

Table 1. Comparison of Federal Requirements to Storm Water Management Program Components Required under Permit No. NY 0026239

Requirement from 122.26 (d)(2)(iv)	Permit No. NY 0026239 effective 9/30/88 to 9/29/93 (Previous Permit)	Permit No. NY 0026239 effective 1/1/01 to 1/1/06 (Current Permit)
(A) Description of structural and source control measures to reduce pollutants from runoff from commercial and residential areas that are discharged from the MS4. The description shall include:	(See below)	(See below)
– description of maintenance activities and a maintenance schedule for structural controls to reduce pollutants (including floatables) in discharges from separate storm sewers	Section XI.D.5 (floatables control and maintenance only)	Section IX.7 (floatables control and maintenance only)
– description of planning procedures including a comprehensive master plan to develop, implement and enforce controls to reduce the discharge of pollutants from municipal separate storm sewers which receive discharges from areas of new development and significant redevelopment	Section XI.D.4 (South Richmond Drainage Plan only)	No permit condition
– description of practices for operating and maintaining public streets, roads and highways and procedures for reducing the impact on receiving waters of discharges from MS4, including pollutants discharged as a result of deicing	No permit condition	No permit condition
– description of procedures to assure that flood management projects assess the impacts on the water quality of receiving water bodies and that existing structural flood control devices have been evaluated to determine if retrofitting the device to provide additional pollutant removal from storm water is feasible	No permit condition	No permit condition

Table 1. Comparison of Federal Requirements to Storm Water Management Program Components Required under Permit No. NY 0026239

Requirement from 122.26 (d)(2)(iv)	Permit No. NY 0026239 effective 9/30/88 to 9/29/93 (Previous Permit)	Permit No. NY 0026239 effective 1/1/01 to 1/1/06 (Current Permit)
– description of a program to monitor pollutants in runoff from operating or closed municipal landfills or other treatment, storage or disposal facilities for municipal waste, which shall identify priorities and procedures for inspections and establishing and implementing control measures for such discharges	Section XI.8(b)	Section XV.g (Sewer Use Regulations)
– description of a program to reduce to the maximum extent practicable, pollutants in discharges from municipal separate storm sewers associated with the application of pesticides, herbicides, and fertilizer which will include, as appropriate, controls such as educational activities, permits certifications and other measures for commercial applicators and distributors, and control for application in right-of-ways and at municipal facilities	No specific condition (pesticides and herbicides were included as part of Section XI.D.6)	No permit condition
(B) Description of a program, including a schedule to detect and remove (or require the discharger to the municipal separate storm sewer to obtain a separate NPDES permit for) illicit discharges and improper disposal into the sewer. The proposed program shall include:	(See below)	(See below)
– description of a program, including inspections, to implement and enforce an ordinance, orders or similar means to prevent illicit discharges to the municipal separate storm sewer system; this program shall address all types of illicit discharges	No permit condition	No permit condition

Table 1. Comparison of Federal Requirements to Storm Water Management Program Components Required under Permit No. NY 0026239

Requirement from 122.26 (d)(2)(iv)	Permit No. NY 0026239 effective 9/30/88 to 9/29/93 (Previous Permit)	Permit No. NY 0026239 effective 1/1/01 to 1/1/06 (Current Permit)
– description of procedures to conduct on-going field screening activities during the life of the permit, including areas or locations that will be evaluated by such field screens	Sections XI.D.1 and XI.D.2	Section XV.g (Stormwater monitoring prog.)
– description of procedures to be followed to investigate portions of the separate storm sewer system that, based on the results of the field screen, or other appropriate information, indicate a reasonable potential of containing illicit discharges or other sources of non-storm water	Sections XI.D.1, XI.D.2, and XI.D.6 (limited to PCBs, pesticides, and herbicides)	Section XV.g (Trackdown and remediation)
– description of procedures to prevent, contain, and respond to spills that may discharge into the municipal separate storm sewer	Section XI.D.9	No permit condition
– description of a program to promote, publicize, and facilitate public reporting of the presence of illicit discharges or water quality impacts associated with discharges from municipal separate storm sewers	Section XI.D.11	No permit condition
– description of educational activities, public information activities, and other appropriate activities to facilitate the proper management and disposal of used oil and toxic materials	Sections XI.D.10 and XI.D.12	No permit condition
– description of controls to limit infiltration of seepage from municipal sanitary sewers to municipal separate storm sewer systems where necessary	No permit condition	No permit condition

Table 1. Comparison of Federal Requirements to Storm Water Management Program Components Required under Permit No. NY 0026239

Requirement from 122.26 (d)(2)(iv)	Permit No. NY 0026239 effective 9/30/88 to 9/29/93 (Previous Permit)	Permit No. NY 0026239 effective 1/1/01 to 1/1/06 (Current Permit)
(C) Description of a program to monitor and control pollutants in storm water discharges to municipal systems from municipal landfills, hazardous waste treatment, disposal and recovery facilities, industrial facilities that are subject to section 313 of title III of Superfund Amendments and Reauthorization Act of 1986 (SARA), and industrial facilities that the municipal permit applicant determines are contributing a substantial pollutant loading to the municipal storm sewer system. The program shall:	(See below)	Section XV.g (Industrial Permits - requires an update of the industrial inventory)
– identify priorities and procedures for inspections and establishing and implementing control measures for such discharges	Section XI.D.8(a) - (d)	No permit condition
– describe a monitoring program for storm water discharges associated with the industrial facilities identified in paragraph (d)(2)(iv)(C) of this section, to be implemented during the term of the permit, including the submission of quantitative data on the constituents	Section XI.D.8(b)	No permit condition
(D) Description of a program to implement and maintain structural and non-structural best management practices to reduce pollutants in storm water runoff from construction sites to the municipal storm sewer system, which shall include:	Section XI.D.7	(See below)
– description of procedures for site planning which incorporate consideration of potential water quality impacts	Not included but may be in Part II Application	No permit condition

Table 1. Comparison of Federal Requirements to Storm Water Management Program Components Required under Permit No. NY 0026239

Requirement from 122.26 (d)(2)(iv)	Permit No. NY 0026239 effective 9/30/88 to 9/29/93 (Previous Permit)	Permit No. NY 0026239 effective 1/1/01 to 1/1/06 (Current Permit)
– description of requirements for nonstructural and structural best management practices	Section XI.D.7	No permit condition
– description of procedures for identifying priorities for inspecting sites and enforcing control measures which consider the nature of the construction activity, topography, and the characteristics of soils and receiving water quality	Not included but may be in Part II Application	No permit condition
– description of appropriate educational and training measures for construction site operators	Not included but may be in Part II Application	No permit condition
(v) *Assessment of controls*. Estimated reductions in loadings of pollutants from discharges of municipal storm sewer constituents from municipal storm sewer systems expected as the result of the municipal storm water quality management program. The assessment shall also identify known impacts of storm water controls on ground water.	Part XI.E.1	Section XV.g (Assessment of Controls and Seasonal Pollutant Loads)
(vi) *Fiscal analysis.* For each fiscal year to be covered by the permit, a fiscal analysis of the necessary capital and operation and maintenance expenditures necessary to accomplish the activities of the program under paragraphs (d)(2) (iii) and (iv) of this section.	No permit condition	No permit condition

Appendix A
NYC Monitoring and Shoreline Survey

NYC Monitoring and Shoreline Survey

6/9/05 Weather: clear, hot

Jerry Whittum, SAIC, Christy Arvizu and Phillip Li, EPA Region 2, and Sagar Chatterjee, NYC DEP Bureau of Wastewater Treatment, Pollution Prevention Section, observed the NYC monitoring and shoreline survey program.

Inspector statements/observations:

Monitoring:
1. A permanent GPS unit installed on the boat provides the ability to conduct repeated monitoring at the same locations (monitoring points).
2. The City can monitor 12 sample points per day. However, they must return to the dock to drop off samples during the day to ensure the fecal coliform 6-hour holding time is met.
3. The City has two large boats (approximately 26 feet long) for conducting the monitoring.
4. Samples are collected in pre-sterilized bottles.
5. The samples are held in a cooler and iced.
6. The bottles are labeled, and a chain-of-custody form is completed.

Shoreline Survey:
1. The City has smaller motorized rubber rafts (2-man) for conducting the shoreline survey.
2. The shoreline survey crew cruise at low speed along the shore looking for dry weather overflows. They also walk the shoreline during low tide.

My Concerns:
No concerns.

SAIC also observed a City floatation skimming vessel, an oil boom, and Combined Sewer Overflow (CSO) outfalls during the evaluation of the monitoring and shoreline survey.

Photo 1: Large boat used for conducting monitoring (in background).
Rubber raft for shoreline survey (in foreground).

Photo 2: Attaching a sample bottle to a dipper handle in preparation for collecting a sample.

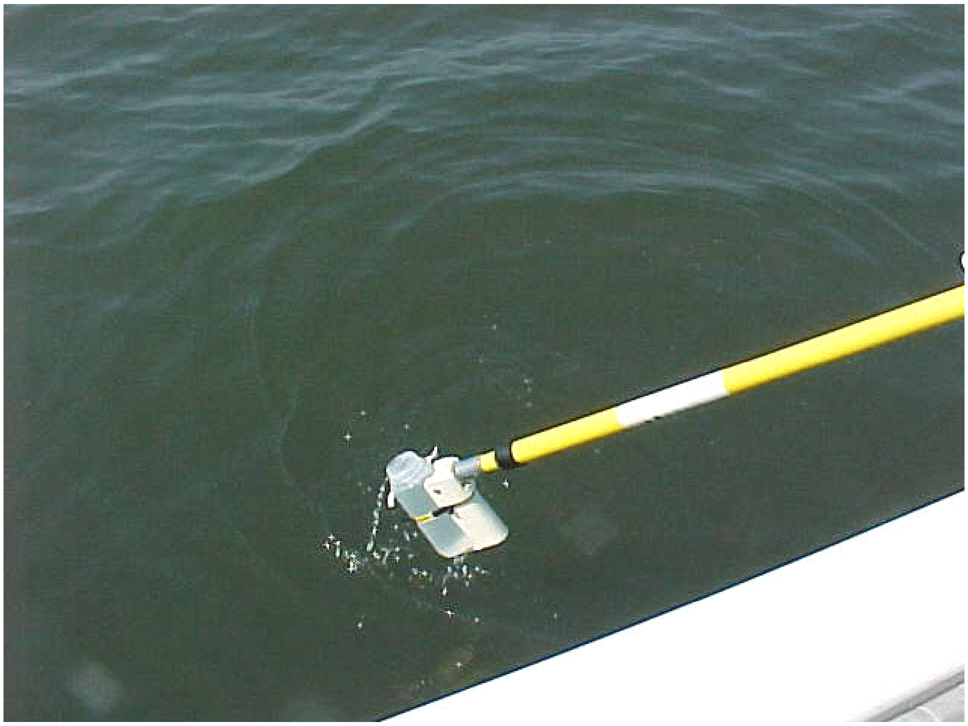


Photo 3: Collection of a fecal coliform sample at sentinel monitoring point S-2.

Photo 4: View of the crew conducting the shoreline survey.

Photo 5: View of a City floatation skimmer vessel.

Photo 6: View of an oil boom.

Photo 7: View of a CSO outfall.

Photo 8: View of a CSO outfall.

Appendix B
NYC DEP Detention Structure

NYC DEP Detention Structure

6/8/05 Weather: clear, hot

Jerry Whittum, SAIC, Christy Arvizu and Phillip Li, EPA Region 2, and Sagar Chatterjee, NYC DEP Bureau of Wastewater Treatment, Pollution Prevention Section, inspected the NYC Tallman Island drainage detention structure, located north of 28th Avenue, east of Ulmer Street, and west of Linden Place. The earthen detention structure was generally unknown to NYC DEP, Bureau of Wastewater Treatment staff. The structure was not identified by signage. The structure area was fenced, but the fence had a large unauthorized opening. Tall grass, shrubs, and trees lined the banks. The outlet structures were in a state of slight disrepair. A large area of standing water, likely a wetland, was located east of Linden Place. The Linden Place street was closed by a chain-link fence, and the street was abandoned.

Inspector statements/observations:
The map provided by the City showed a portion of the detention structure extending south towards Flushing Bay. Large commercial buildings were located over the detention structure areas shown to extend south. It is likely those portions of the detention structure had been placed in underground piping.

My Concerns:
The detention basin and fence were in need of minor repairs.

Photo 1: View north through fence from 28th Avenue.

Photo 2: View north of the twin outlet structures. Note the inlets to the outlet pipes have separated at the joints.

Photo 3: View north along the portion of the detention basin that parallels Linden Place.

Photo 4: View of wet area east of Linden Place.

Appendix C
NYC Construction Sites

NYC Construction Sites

6/8/05 Weather: clear, hot

Jerry Whittum, SAIC, Christy Arvizu and Phillip Li, EPA Region 2, and Sagar Chatterjee, NYC DEP Bureau of Wastewater Treatment, Pollution Prevention Section, inspected active construction sites located in the Tallman Island MS4 drainage area of NYC. The first construction site was a large commercial site located at 15th Avenue between 139th and 143rd Streets. A passerby stated that construction had started approximately five months prior. The site appeared to occupy more than 10 acres. The majority of the area contained completed buildings and paved parking areas. The buildings did not appear to be open for business, and landscaping was occurring. A small area at the northeast corner of the site was disturbed soil that was being graded by heavy equipment. The second construction site was a single family residential site located along the north side of Powell's Cove Boulevard from west of 3rd Avenue towards 151st Street. The site appeared to occupy more than 3 acres. The homes appeared to be completed, but not yet occupied. The area was fenced and boarded to restrict access. The NYC DEP Bureau of Wastewater Treatment appeared to have no knowledge of the construction sites.

<u>Inspector statements/observations:</u>
1. The large commercial construction site had no storm water BMPs installed to keep soils on site.
2. Soil was observed at and near three inlets located along 15th Avenue.

<u>My Concerns:</u>
1. The commercial construction site had active soil disturbance and did not have BMPs.
2. The City had no prior knowledge of the construction sites and did not know if the sites were permitted.
3. The City did not know if the sites had been and are being inspected.

Photo 1: View west of construction along 15th Avenue. Note no BMPs along site fence and soil had entered the avenue by three inlets.

Photo 2: View south, from 15th Avenue, of a street inlet, site soil at the inlet, and unstabilized soil in the background.

Photo 3: View south, from 15th Avenue, of second street inlet, site soil at inlet, and unstabilized soil in the background.

Photo 4: View southeast, from 15th Avenue, of bulldozer grading soil. Note the area had no visible BMPs.

Photo 5: View south, from 15th Avenue, of entrance to the construction site.

Photo 6: Sign located at second construction site at Powell's Cove Boulevard.

Photo 7: View west, from 3rd Avenue, of unoccupied homes at the construction site along Powell's Cove Boulevard.

Photo 8: View east along Powell's Cove Boulevard.

Attachment 2

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November 30, 2011

New York City Department of Environmental Protection
Office of Legal Affairs
Attention: Charles Shamoon, Esq.
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Julie Stein, Director
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Via email and U.S. Mail

RE: Comments on: (i) Proposed Amendments to Chapter 31 of Title 15 of the Rules Governing House/Site Connections to the Sewer System; and (ii) Draft *Guidelines for the Design and Construction of Stormwater Management Systems*

Dear Mr. Shamoon and Ms. Stein,

On behalf of NRDC and its 1.2 million members and online activists, including over 16,000 members in New York City, please accept the following comments on the Department of Environmental Protections ("DEP's") above-referenced proposed amendment to DEP regulations to establish a new stormwater performance standard for connections to the combined sewer system ("Draft Rule") and the related *Draft Guidelines for the Design and Construction of Stormwater Management Systems* ("*Draft Guidelines*"). Of necessity, we address both documents in a single set of comments, since the Draft Guidelines are essential to understanding the practical effect of the Draft Rule.

These comments have been informed by extensive consultation with Dr. Robert Traver, of Villanova University, a nationally recognized stormwater expert. Dr. Traver co-authored the seminal 2009 National Research Council report recommending that stormwater regulatory programs be re-oriented to promote practices that harvest, infiltrate, and evapotranspirate stormwater to prevent it from being discharged.[1] At NRDC's request, he has prepared a written review of the Draft Rule and *Draft Guidelines* (hereinafter, "Traver Memo"), which is attached hereto and incorporated-by-reference as part of NRDC's comments.[2]

We note at the outset that New York City has made great strides in recent years using green infrastructure techniques in projects built or funded by the city. DEP demonstration projects built within the last few years are proving that green infrastructure practices are highly effective at reducing the volume of runoff into the city's sewers, as they have likewise been shown to be in cities around the country. As detailed in NRDC's November 2011 report, *Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows*, green infrastructure is a cost-effective tool to reduce combined sewer overflows (CSOs), clean up local waterways, and improve the health and livability of neighborhoods.[3] We strongly support DEP's efforts to increase the use of green infrastructure practices, as an integral element of the city's CSO reduction efforts and its overall long-term sustainability plan.

The Draft Rule and *Draft Guidelines* must play a critical role in the success of the city's CSO efforts, particularly the implementation of the proposed modifications to the city's CSO consent order with the state Department of Environmental Conservation. The proposed order would, for the first time, formally incorporate green infrastructure into the city's Clean Water Act compliance efforts. The proposed order, and the *NYC Green Infrastructure Plan* on which its green infrastructure provisions are based, rely on the application of a new stormwater performance standard for development and redevelopment projects to realize most of the CSO reductions anticipated from green infrastructure.[4] Accordingly, as many commentors on the proposed consent order emphasized -- including a majority of the members of DEP's Green Infrastructure Steering Committee -- it is critical that the Draft Rule and *Draft Guidelines* be structured to maximize the use of volume reduction (*i.e.*, retention) methods wherever feasible, for projects on private as well as public property.[5]

NRDC and others have raised concerns with DEP throughout the development of the Draft Rule and *Draft Guidelines* -- including through DEP's Green Infrastructure Steering Committee,[6] comments on a "peer review draft" of the Draft Guidelines,[7] and various other

[1] National Research Council, *Urban Stormwater Management in the United States* (2009) (recommending that stormwater regulatory programs be re-oriented to promote practices that harvest, infiltrate, and evapotranspirate stormwater to prevent it from being discharged). <www.nap.edu/catalog.php?record_id=12465>

[2] A summary version of Dr. Traver's curriculum vitae is also attached.

[3] The report is available at www.nrdc..org/rooftops.

[4] The *NYC Green Infrastructure Plan* (p. 139) anticipates that if 10% of impervious area citywide were targeted for GI retrofits over the next 20 years, over 80% of the necessary acres would comprise "on-site development" (*i.e.*, not in the public right of way), and 54% of the acres would come from private on-site development, through the application of DEP's intended stormwater management rule.

[5] *See* Letter of 11/18/11 from 13 members of the DEP Green Infrastructure Steering Committee to G. Kline, NYSDEC.

[6] *See*, *e.g.*, DEP Green Infrastructure Steering Committee, "Sept. 8, 2011 -- Agenda and summary minutes," available at http://www.nyc.gov/html/dep/pdf/green_infrastructure/green_infra_steering_committee_agenda_and_minutes_090811.pdf..

informal communications -- that the fundamental approach DEP had been pursuing for this rulemaking did not represent a "green infrastructure" approach to managing runoff on private property and at new city buildings. Unfortunately, this is still the case in the official public review versions of the Draft Rule and *Draft Guidelines* (notwithstanding some improvements around the edges, as compared to earlier versions that had been circulated informally).

The performance standard in the Draft Rule amounts to a distributed gray infrastructure approach, whereby developers would build decentralized, on-site storage capacity to capture runoff for delayed release into the city's sewer system. This "detention" approach would likely yield some CSO reductions (although DEP has yet to present any CSO modeling of the effects of on-site detention). But, as described in our detailed comments below, it would be less effective at reducing CSOs than a performance standard based on volume reduction. Further, the proposed approach would constitute a huge missed opportunity to literally "green" the city. Some aspects of the proposal may even have the unintended consequence of discouraging the widespread adoption of green infrastructure practices. As compared to a greener alternative, the proposed rule is likely to result in unnecessary costs for the city, DEP ratepayers, and property owners, because it fails to take full advantage of the cost-effective CSO reduction potential of using green infrastructure on private property.

We recognize that DEP has included in the Draft Rule and *Draft Guidelines* certain opportunities for developers to use infiltration and rainwater harvesting practices to obtain credit towards compliance with the proposed, detention-based performance standard. This is a step in the right direction, although it falls well short of an approach that <u>prioritizes</u> volume reduction, such as the standards now in place in many state and local jurisdictions (as well as for new federal facilities), which require the <u>retention</u> (*i.e.*, without discharge) of a certain amount of runoff, using any available combination of infiltration, evapotranspiration, and rainwater harvesting, wherever feasible. Further, as detailed below and in Dr. Traver's review, even the provisions for the optional use of green infrastructure, which DEP proposes, would still under-value the effectiveness of green infrastructure in ways that are likely to discourage many developers from choosing a green approach to compliance with DEP regulations.

In sum, NRDC is very concerned that the Draft Rule and *Draft Guidelines* do not require -- nor even create effective incentives for the voluntary use of -- current best practices for urban stormwater management. As a result, they fall short of their potential to contribute to necessary water quality improvements in our waterways and to literally "greening" the urban landscape of New York City.

We offer our detailed technical comments below. We respectfully request that DEP revise its proposed approach and issue a performance standard (and accompanying technical guidance) that supports a world-class green infrastructure program and makes good on PlaNYC's vision of a greener, greater New York City.

Despite the shortcomings of the current proposal, NRDC is hopeful that we can work with DEP and the Bloomberg Administration to design and implement a revised rule that could

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[7] *See, e.g.*, Letter of 8/8/11 from L. Levine, NRDC, to J. Stein, DEP, re: "Comments on July 2011 Draft of the *Guidelines for the Design and Construction of Stormwater Management Systems*."

become a national model of sustainability. We would welcome the opportunity to discuss our concerns with you, and would be happy to arrange a time for Dr. Traver to speak directly with technical staff at DEP.

Detailed Comments

1. The Draft Rule and Guidelines should be revised to establish a performance standard based primarily on volume reduction, rather than on limiting the rate of release.

The fundamental shortcoming of the Draft Rule and *Draft Guidelines* is that they are based on a maximum release rate (0.25 cfs/ac.), rather than on a requirement to reduce runoff volume. By DEP's own accounting, to reduce CSOs, volume reduction is more effective, on a gallon-for-gallon basis, than detention and slow release. (*See, e.g.*, NYC Green Infrastructure Plan, p. 21, estimating that detention is 60% less effective than infiltration.) Volume reduction is also superior in many other respects, including: improved pollutant mass load reduction (by keeping polluted runoff entirely out of the combined sewer system); non-water quality benefits such as air pollutant and heat island reduction and carbon sequestration, which are associated with vegetated green infrastructure; and relative ease of inspection and maintenance, as compared to underground detention systems. (*See* Traver Memo, p. 7) In many places, the Draft Guidelines expressly acknowledge these benefits of a green infrastructure approach based on volume reduction principles.

Infiltration, evaportranspiration, and harvesting practices, known collectively as "green infrastructure," are the optimal methods for urban stormwater management because they reduce the volume of runoff (and the pollution it carries) into the sewer system, while providing a range of additional, non-water quality benefits to our communities. This has been recognized by countless studies and codified in regulatory standards in many U.S. jurisdictions.[8] The *Draft Guidelines* explicitly describe the benefits of genuine green infrastructure and, in particular, vegetated source control practices. The document (p. 5) identifies "green infrastructure" as "a type of source control that moderates or reverses the effects of development by mimicking hydrologic processes of infiltration, evapotranspiration, and reuse." The introductory section of the document affirmatively states (p. 6; emphasis added) that "rain gardens and vegetated swales are *encouraged* in the design and construction of onsite source controls to provide stormwater retention through infiltration, vegetative uptake and evapotranspiration processes. The addition of vegetation provides other benefits for property owners and the surrounding neighborhoods, such as reducing the urban heat island effect, improving air quality, saving energy, increasing property value and mitigating climate change." Nonetheless, the operative provisions of the Draft Rule and *Draft Guidelines* do not prioritize the use of these approaches.

A performance standard based on limiting the volume of runoff, such as exists in many U.S. cities and states, as well as for federal buildings,[9] would promote the widespread use of these true "green infrastructure" approaches.

[8] See generally, NRDC, *Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows* (Nov. 2011), available at www.nrdc..org/rooftops.

[9] *See* examples at note 11, below. *See also, e.g.,*:

Therefore, DEP should revise the Draft Rule to require the retention of the first inch of runoff, through any combination of infiltration, evapotranspiration, and rainwater harvesting, wherever feasible. In cases where it is infeasible to retain all or part of the first inch of runoff (*i.e.*, due to site-specific constraints), an alternative, detention-based standard should be applied to whatever portion of the inch is not retained. (*See* Traver Memo, p. 8 (recommendation #2.a))

Previously, DEP has offered several reasons for not adopting this approach. While each one raises reasonable concerns, none of them -- alone or in combination -- is sufficient reason not to adopt a retention standard as the default approach in New York City. Specifically:

- DEP has argued that infiltration is infeasible in many places because of high water tables, steep slopes, shallow bedrock, non-porous soils, or high density development. It is true that each of these factors must be taken into consideration when determining the extent to which infiltration is feasible at any given location. However, none of these is a reason not to adopt a retention standard because <u>not all retention (*i.e.*, volume reduction) practices are based on infiltration</u>. As noted above, "green infrastructure" includes infiltration, evapotranspiration, and rainwater harvesting techniques. The latter two methods may often be suitable even where infiltration is not. (*See, e.g.*, Traver Memo, pp. 6-7)

- DEP has suggested that its experience with the failure of dry-wells indicates that infiltration systems are prone to failure. However, with respect to vegetated green infrastructure systems, this is simply an invalid comparison. As explained in Dr. Traver's memo (pp. 7-8), "experience with vegetated sites demonstrates that they are robust, and incorporate factors that maintain infiltration pathways to include freeze thaw, soil geomorphology and plant growth, with significant evapotranspiration losses. Note that none of these factors is present in dry well systems; therefore, any local experience with failure of dry-well systems in New York City should not be taken as an indication that vegetated infiltration systems are prone to failure." Moreover, maintenance is important for both gray and green infrastructure; indeed, it may be even more important, in some respects, for gray. (*See* Traver Memo, pp. 7-8 & Appendix B)

- DEP has suggested that a retention standard, with an "infeasibility" exception, would lead to a situation where 'the exception swallows the rule' because of the constraints mentioned above, such that DEP would be over-burdened with applications seeking to invoke the exception. First, as noted above, the constraints

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- EPA compendium of state standards: http://www.epa.gov/npdes/pubs/sw_state_summary_standards.pdf
- Philadelphia performance standard http://www.phillyriverinfo.org/programs/subprogrammain.aspx?Id=StormwaterManual

Notably, EPA explains that the requirement for federal facilities to reduce the volume of runoff "is intended to address the *inadequacies of the historical detention approach* to managing stormwater and promote more sustainable practices…." USEPA, *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects Under Section 438 of the Energy Independence and Security Act* (December 4, 2009), p. 3, available at www.epa.gov/owow/nps/lid/section438/.

are less severe than DEP suggests, because non-infiltration methods will be feasible in many instances where infiltration is not. Second, there are ways for DEP to minimize the administrative burden of handling requests for exceptions, such as (i) clearly defining the steps that must be followed to make a showing of infeasibility (such as in Philadelphia's stormwater manual[10]); and (ii) identifying areas of the city where infiltration is presumptively infeasible due to geologic or hydrologic conditions and exempting projects in these areas from performing any site-specific assessment of the feasibility of infiltration.

2. DEP should revise the Draft Rule to impose more environmentally protective requirements for relatively smaller sites, on par with larger sites.

The Draft Rule has the effect of subjecting smaller sites to less stringent requirements, but it is not at all clear that this is warranted. This leads to anomalous results, such as a scenario where the runoff for an individual one-acre impervious development project would be limited to 0.25 cfs of discharge into the combined sewer system but, if the impervious acre were divided evenly among four separate development projects, the summed runoff would be allowed to discharge at a rate of 1.0 cfs for the same amount of impervious surface (*i.e.*, 0.25 cubic feet per second from *each* of the four quarter-acre lots). This effect could substantially undercut the effectiveness of the rule at reducing CSOs. (*See* Traver Memo, pp. 1-3)

DEP should revise the Draft Rule to treat smaller sites (*e.g.*, from 5,000 s.f. to 1 acre) comparably to larger sites (*e.g.*, by defining any maximum release rate on a cfs-per-acre basis).

At a minimum, DEP should analyze, on a system-wide scale, whether the relaxed standards for smaller development sites is consistent with meeting CSO reduction goals, and revise the standard as needed to maximize CSO reductions. (*See* Traver Memo, p. 8, recommendation #1) Given that NYC anticipates over 20 billion gallons of CSO would remain even after implementing the capital projects specified in its proposed CSO consent order, additional CSO reduction from a more comprehensive stormwater rule will unquestionably be of value.

3. DEP should revise the Draft Rule to apply more expansively to projects classified as "alterations."

Initially, we note that there is a discrepancy between the rule for alterations, as it appears in the Draft Rule, and the rule as it is described in the *Draft Guidelines*. The Draft Rule (§ 31-03(a)) states that a maximum release rate applies to "alterations that increase impervious surfaces on a lot by more than 20 percent." However, according to the *Draft Guidelines* (p. 2), the maximum release rate applies to alterations that "increase impervious surfaces or building footprints on lots by more than 20% of existing impervious surfaces." We assume for purposes of these comments that the language in the Draft Rule is controlling, so we address our comments to that language.

[10] http://www.phillyriverinfo.org/programs/subprogrammain.aspx?Id=StormwaterManual

The basis for the 20 percent threshold in the Draft Rule has not been explained anywhere, to our knowledge. As the proposed rule is currently written, a lot that includes one acre of impervious space would be allowed to further develop 0.19 previously pervious acres on the same lot, without addressing the increased combined sewer loading. Also, as the proposed rule is currently written, unless a "new building" is being built, any size redevelopment project would be able to replace any amount of existing impervious area with new impervious area, without being subject to the new standard. (*See* Traver Memo, p. 3)

The effect of the 20% threshold is unknown without examining anticipated development patterns. Moreover, even for "alterations" where the rule does apply, it is difficult to understand whether the proposed standard is expected to maintain the current level of service or is to reduce the current volume / occurrence of CSO; since no runoff from existing impervious surface is targeted, it is questionable whether the proposed rule will reduce the current impact at all from these sites. (*See* Traver Memo, p. 3)

DEP should revise the Draft Rule to apply to "alterations" that replace one impervious surface with another (as do the stormwater performance standards in some other jurisdictions, such as Philadelphia[11]). DEP should also revise the Draft Rule to establish some threshold for alterations beyond which the new performance standard will be applied to the entire lot, not only to the portion of the lot undergoing alterations. DEP should also analyze whether 20% is the optimal threshold, and vet that analysis through public review.

At a minimum, DEP should analyze, on a system-wide scale, whether the 20% threshold for applying the performance standard to "alterations" and the lack of coverage for existing impervious surfaces is consistent with meeting CSO reduction goals, and then revise the standard as needed to maximize CSO reductions. (*See* Traver Memo, pp. 3, 8 (recommendation #1)) Given that NYC anticipates over 20 billion gallons of CSO would remain even after implementing the capital projects specified in its proposed CSO consent order, additional CSO reduction from a more comprehensive stormwater rule will unquestionably be of value.

4. If DEP adopts an approach that provides developers with an <u>option</u> to use volume reduction methods, rather than a <u>requirement</u> to do so wherever feasible, the Draft Rule and *Draft Guidelines* (as well as other city regulations, if necessary) should be revised to ensure the option is a meaningful one that ensures adequate credit for the volume-reducing functions of green infrastructure.

The following recommendations are offered to improve how DEP's proposal addresses green infrastructure <u>if</u> DEP preserves the basic approach of setting a detention-based standard, rather than adopting recommendation #1 above, which calls for a standard that requires volume reduction wherever feasible. Please note that we strongly recommend the volume reduction approach, for all of the reasons stated above.

[11] Philadelphia Water Dept. Regulations, Section 600.1(q) (defining covered redevelopment projects to include those where existing impervious surface is replaced with new impervious surface) (available at http://www.phillyriverinfo.org/WICLibrary/StormwaterRegulations.pdf).

a. The Draft Rule should be revised to state that the required stormwater detention volume "will be reduced" when a developer uses properly-designed systems that rely on infiltration and harvesting.

As proposed, the Draft Rule states that DEP "will consider requests" to reduce the required storage volume on that basis. As written, the Draft Rule creates far too much uncertainty as to whether DEP will approve green infrastructure-based approaches. There is no need to create this uncertainty. It may make a gray approach -- based on detention and delayed release -- the "path of least resistance" for applicants, discouraging the use of green infrastructure. (*See* Traver Memo, p. 6)

b. The Draft Rule and *Draft Guidelines* should be revised to state that the required stormwater detention volume will also be reduced when a developer uses properly-designed systems that rely on evapotranspiration to reduce runoff volume.

The Draft Rule makes no mention of evapotranspiration, despite the fact that it is recognized as one of three effective mechanisms for runoff volume reduction, along with infiltration and harvesting. The *Draft Guidelines* do, in effect, give credit for evapotranspiration for green roofs, by recognizing the void space in the growing medium and sub-layers of a green roof (where water is temporarily stored and ultimately evapotranspired, rather than released into the sewer system) as storage capacity that counts towards meeting the performance standard. (See pp. 29-30.) However, no such credit is provided for systems other than green roofs.

As explained in the Traver Memo (pp. 6-7), other vegetated green infrastructure at ground level -- such as a lined rain garden -- can work in the same way as green roofs, even in locations where infiltration is infeasible. The Draft Rule and *Draft Guidelines* should be revised to provide credit for such green infrastructure techniques. (*See* Traver Memo, p. 8, recommendation #2.b.) This basic approach -- providing regulatory credit for all feasible green infrastructure methods, not just infiltration -- is used in many Clean Water Act permits for municipal separate storm sewer systems (MS4s) and state and local regulations around the country,[12] as well as in the New York State Department of Environmental Conservation's Stormwater Design Manual.

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[12] For example, see:

- Pittsburgh city ordinance (http://library.municode.com/index.aspx?clientId=13525&stateId=38&stateName=Pennsylvania (in left-side menu, click through to Pittsburgh Zoning Code, Title 10, Chapter 1003)
- Washington, D.C. MS4 Permit http://www.epa.gov/reg3wapd/pdf/pdf_npdes/Wastewater/DC/DCMS4permit2011.pdf
- Montgomery County, MD local ordinance http://www.amlegal.com/nxt/gateway.dll/Maryland/montgom/partiilocallawsordinancesresolutionsetc/chapter19erosionsedimentcontrolandstormw?fn=altmain-nf.htm$f=templates$3.0#LPTOC2
- Aurora Illinois, Kane County ordinance http://www.co.kane.il.us/kcstorm/ordinance/adoptord.pdf

c. The Draft Rule and Draft Guidelines should be revised to provide an <u>alternative performance standard</u>, which is not based on release rates or the Rational Method, but rather is based expressly on volume reduction, for applicants that choose to use volume reduction methods at sites where such methods are feasible.

As detailed in the Traver Memo: (i) on a per-gallon basis, detention and slow release is less effective at reducing CSOs than volume reduction; and (ii) the Rational Method (on which the calculations in the *Draft Guidelines* are based) is not an appropriate hydrologic for volume reduction approaches. The combination of these two factors means that the Draft Rule and *Draft Guidelines* under-value the effectiveness of green infrastructure techniques at meeting DEP's CSO reduction objectives. By adopting a performance standard that does not account for the better performance of green as compared to gray, DEP would be artificially increasing the cost to property owners of using green infrastructure to achieve compliance.[13] (*See, e.g.*, Traver Memo at pp. 4-5) This discourages investment in green infrastructure, relative to the incentives that would exist if green infrastructure were appropriately valued in DEP's regulatory scheme (*i.e.*, if a property owner could (or were required to) achieve compliance by meeting a DEP performance standard based expressly on volume reduction). Even worse, developers facing new costs of complying with DEP's rule could entirely divert dollars that would have been spent on green space (*i.e.*, if green infrastructure were adequately rewarded under DEP's rules) into building subsurface storage tanks and rooftop detention instead.

To rectify this situation, DEP should revise the Draft Rule to establish a one-inch retention standard as an alternative performance standard, for those wishing to use volume reduction techniques to achieve compliance.[14] (*See* Traver Memo, p. 8 (recommendation #2.a)) Likewise, DEP should modify the Draft Guidelines to establish hydrologic design parameters for volume reduction systems based upon such a retention standard. (*See* Traver Memo, p. 8 (recommendation #2.c))

- West Virginia MS4 General Permit (http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/permits/Documents/WV%20MS4%202009%20General%20Permit.pdf)
- Federal facilities performance standard www.epa.gov/owow/nps/lid/section438

See also NRDC, *Rooftops to Rivers II* (Nov. 2011), at pp. 32, 37 (available at http://www.nrdc.org/rooftops).

[13] Alternatively, if a green infrastructure installation cannot be sized to entirely meet DEP's proposed standard in a given project (*e.g.*, due to site constraints), the developer would have to invest in both green and gray, if there is a desire to use gray -- but this may be less cost-effective than for the developer than simply sizing a gray system to manage 100% of the required storage volume. The result, again, is to discourage the use of green infrastructure -- even though, if DEP adopted a compliance standard based expressly on a volume reduction approach, that same project may be able to size a green infrastructure system to capture 100% of the volume required to be managed under such a standard.

[14] Again, as explained above (see comment #1), our ultimate recommendation is that such a standard be adopted as mandatory, wherever feasible, not merely as an alternative.

5. DEP should demonstrate the extent of CSO reductions that would result from the proposed approach and revise it as necessary to achieve CSO reduction goals.

DEP has not presented any modeling or other analysis to quantify the benefits for reducing CSOs of its proposed detention-based approach. It seems very likely there will be some benefit, for some storms. However, DEP has not presented any analysis of whether (and for what size and intensity of storms) the sewage treatment plants have capacity to receive and treat the delayed flow into the system, either under present or future hydraulic conditions in any given sewershed.

The *NYC Green Infrastructure Plan* stated that DEP would perform additional modeling of how the system would respond to widespread use of detention and delayed release practices.[15] This modeling is important not only to demonstrate whether an approach based on a maximum release rate would contribute significantly to CSO reduction, but also to determine what particular release rate and sizing requirements would obtain the optimal benefit.

In sum, DEP should analyze whether the proposed stormwater release rate is consistent with meeting CSO reduction goals. If the goals are not met, the proposed maximum release rate require revision.[16] (*See* Traver Memo., p. 8, recommendation #1) Given that NYC anticipates over 20 billion gallons of CSO would remain even after implementing the capital projects specified in its proposed CSO consent order, additional CSO reduction from a more comprehensive stormwater rule will unquestionably be of value.

6. DEP should revise the Draft Rule to apply a volume-reduction standard in separately-sewered and direct drainage areas, not only in combined sewer areas.

DEP has narrowed the scope of the Draft Rule from earlier iterations so that it applies only to combined sewer areas. Apparently, this was done in recognition of the fact that detention and slow release provides little or no water quality benefit in non-combined sewer areas. In addition to revising the Draft Rule to establish a retention standard (see comment #1), DEP should revise it so that the retention standard applies in separately-sewered and direct drainage areas, where reducing the volume of polluted runoff would directly reduce pollutant loadings to local waterways.

7. The Draft Rule and *Draft Guidelines* should require appropriate levels of inspection and maintenance, for both green and gray infrastructure.

We support DEP's inclusion of a general maintenance requirement in the Draft Rule. DEP should also ensure that specific inspection and maintenance requirements, for both green and gray infrastructure, are clear and appropriate to the circumstances. For example, green roofs do not need to be inspected after every storm, as is currently recommended in the *Draft Guidelines*, although appropriate inspection and maintenance of green systems is important.

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[15] *See, e.g., NYC Green Infrastructure Plan* at 139.

[16] Note that this analysis is relevant even if DEP adopts our recommendation in comment #1, since a volume reduction standard would still include, in cases where full compliance via retention is infeasible, a maximum release rate for the remaining runoff volume.

Moreover, it is important to establish clear requirements (not merely recommendations) for inspection and maintenance of grey systems, which appear to be lacking in the *Draft Guidelines*. (See Traver Memo, pp. 8-9, recommendation #2.d.)

8. DEP should ensure that any unnecessary obstacles to the use of green infrastructure that may are identified and eliminated.

Cities often find that local building, plumbing, zoning, and other codes contain requirements that may no longer serve the purposes originally intended, but which may present barriers to the use of green infrastructure techniques. DEP should commit to a follow-up rulemaking to identify and eliminate any such barriers in its own regulations. DEP should also, through its leadership of the inter-agency Green Infrastructure Task Force and in collaboration with the Mayors's Office of Long Term Planning and Sustainability, secure the commitments of other relevant agencies.[17]

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Thank you for your consideration of these comments. NRDC looks forward to further opportunities to discuss these issues with NYCDEP and other City agencies and officials. Please contact me at the number below with any questions.

Sincerely,

Lawrence M. Levine
Senior Attorney
Water Program
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encl. [Traver memo, with Appendices A & B and Traver c.v.]

cc (via email): C. Strickland
D. Ramia
D. Bragdon (OLTPS)
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[17] As but one example, we note that NRDC recently called on the Philadelphia Water Department to update that city's plumbing code to reflect current design techniques and available products. For example, the use of HDPE (high density polyethylene) pipe *in lieu* of ductile iron or concrete pipe is appropriate in many locations and could reduce private property construction costs but it currently restricted by Philadelphia's plumbing code.

To: Larry Levine, Senior Attorney NRDC

From: Robert G. Traver, Ph.D., P.E., D.WRE, Professor Civil and Environmental Engineering, Villanova University

Date: 30 November 2011

Subject: Review -NYC proposed stormwater performance standard and *Draft Guidelines for the Design and Construction of Stormwater Management Systems*

The scope of this project has been to review and make recommendations concerning the draft stormwater performance standard and associated *Draft Guidelines for the Design and Construction of Stormwater Management Systems* developed by the New York Department of Environmental Protection (DEP). In addition, the City of New York DEP document *Criteria for Determination of Detention Facility Volume* dated 9/28/2006 was included in the review as it is incorporated by reference into the *Guidelines*.

Fundamentally, the ongoing change to green infrastructure practices across the nation has brought new tools to an old challenge. Green infrastructure (GI) Best Management Practices add distributed volume reduction and water quality treatment components to the detention practices previously employed. Volume reduction directly reduces the volume entering the combined sewer system and thus directly reduces the volume to be treated and reduces the occurrence of overflows that bypass the collection and treatment system. This process is not the same as detention, and thus the challenge is to merge the new technologies with past practices to take full advantage of their attributes in order to create a sustainable systems. Over the last ten years there has been a tremendous leap forward in the engineering profession's understanding of how these GI control measures work based upon field research. While there is much more to be learned as to how to maximize their effectiveness, they have entered the mainstream and are considered engineered practices, joining the past practices of detention.

The *Guidelines for the Design and Construction of Stormwater Management Systems* is understandable and well organized. It is a good foundation for the final document. There are however two basic concerns. The first is in the effectiveness, coverage and applicability of the Stormwater Release Rate Criteria, and the second in the implementation of Green Infrastructure.

Stormwater Release Rate Criteria:

The stormwater release rate is defined as the greater of 0.25 cfs or 10% of the allowable flow. Note that the allowable flow is based upon the 5 year storm though the storm event modeled is the ten year event. At a hypothetical site in Brooklyn for example, the allowable flow as stated in the 9/28/2006 version of *Criteria for Determination of Detention Facility Volume* is Qall = 2.5 x A, where Q is flow in cubic feet per second (cfs) and A is area in acres. Thus, the new stormwater release rate for that site is the greater of 0.25*Area or 0.25 cfs. An example for a ¼, 0.5,1.0, and 2.0 acre impervious sites are shown in Table 1 below.

Table 1- Brooklyn Stormwater Release Rate Example

	Brooklyn Example				
Area (Impervious)	0.25	0.50	1.00	2.00	Acres
Allowable Flow (AF)	0.63	1.25	2.50	5.00	CFS
10% AF	0.06	0.13	0.25	0.50	CFS
Stormwater Release Rate (SRR)	0.25	0.25	0.25	0.50	CFS
"Greater of 0.25 or 10% AF					
SRR/ unit Area	1.00	0.50	0.25	0.25	CFS/AC

What this table shows first is the commendable reduction in release rates. For a new ¼ acre impervious site, the allowable flow is 0.63 cfs, so 10% of that is 0.063 CFS. As 0.25 is greater, that is the value used, not 10% of the Allowable flow. It also shows that when viewed from an impervious area perspective, the smaller sites have a much smaller reduction required compared to the larger site, though both are certainly much more restrictive then the past criteria. This is also shown in Figure 1 below. For areas 1 acre or above the requirements work out to be a simple value of 0.25cfs/acre, but for a .25 acre site the result is 1 cfs/acre. This leads to widely varying results, with potentially significant reductions of effectiveness toward meeting the goals of the program. For example, the runoff for an individual one acre impervious development project would be limited to 0.25 cfs of discharge into the combined sewer system from the site. But, if the impervious acre were divided evenly among four separate development projects, the summed runoff would be allowed to discharge at a rate of 1.0 cfs for the same amount of impervious surface (*i.e.*, 0.25 cubic feet per second from *each* of the four quarter-acre parcel). While still significantly lower than past practices, this is a 400% increase from the single site requirements. This also translates to a smaller over all site requirements for storage that is addressed later in this review. The one acre site would require stormwater management practices sized to capture approximately 1.1 inches, while each of the four properties would only need approximately .65 inches, a 40% reduction in storage requirements (Figure 2).

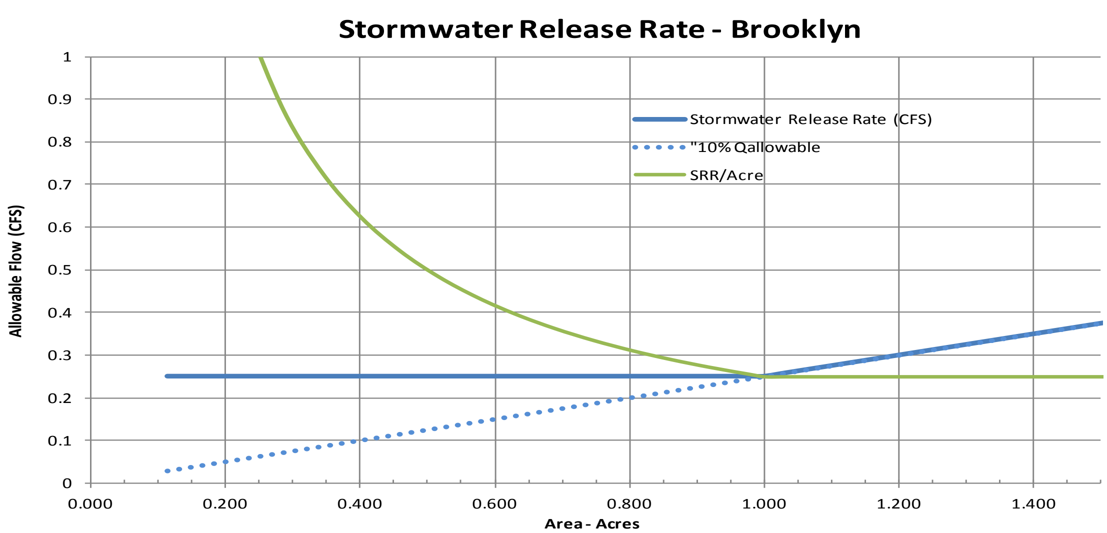


Figure 1- Brooklyn Stormwater Release Rate

It is very hard to understand whether this criterion will meet the desired CSO reduction goal. To answer this question an analysis of expected future development grouped by impervious footprint needs to be merged with the stormwater release rate criteria. The statement on page 3 of the draft that most of the runoff comes from larger buildings is very misleading. The relationship between runoff and impervious area is proportional, and several small buildings will have the same impact as one large one if the total impervious footprint is the same. The statement is made (page 7) that controlling the first inch of runoff from 10 % of the impervious area served by the combined sewer system would greatly reduce CSOs. If any significant proportion of the building permits (by impervious area) are less than an acre -- as it seems they would be in New York City -- the proposed standards should be reviewed and adjusted, as needed, to ensure the goals of the program are met. A spread sheet that was used in this analysis is included as Appendix A.

A similar comment may be made regarding the 20% impervious increase threshold required to trigger required action for redevelopments (also referred to in the *Guidelines* as "alterations"). It is stated on page 3 that proposed redevelopment projects that increase the impervious footprint by less than 20% are exempt from this standard (unless a new sewer connection is proposed), and only the increased impervious area is addressed. The immediate question is what sizes are most redevelopment requests? Does the 20% requirement aid substantially in reducing combined sewer overflows, or does it miss the mark? As the proposed rule is currently written, a parcel that includes one acre of impervious space would be allowed to further develop .19 previously pervious acres on the same parcel, without addressing the increased combined sewer loading. Also, as the proposed rule is currently written, unless a "new building" is being built, any size redevelopment project would be able to replace any amount of existing impervious area with new impervious area, without being subject to the new standard.

Additionally, it is not clear what analysis was done to set these criteria for redevelopment and, therefore, difficult to understand whether the proposed standard -- for projects where it does apply -- is expected to maintain the current level of service or is to reduce the current volume / occurrence of CSO. As no runoff from existing impervious surface is targeted, it is questionable whether this rule will reduce the current impact, without a model study of the impact. If the objective is to reduce the current impact, consideration should be given to extending the requirement to existing impervious surfaces for sites undergoing major alteration.

All of these questions regarding the redevelopment criteria should be addressed through analysis of expected future development patterns to include property size, coupled with the proposed stormwater release rate. The proposed standards should be reviewed to ensure the goals of the program are met.

<u>Green Infrastructure Approach:</u>

The proposed regulatory approach to the implementation of green infrastructure is to treat the volume reduction as a form of volume storage. This is made clear on page 1 with the statement "*The new performance standard is intended to reduce peak discharges to the city's sewer system during rain* *events by requiring greater on-site storage of stormwater runoff and slower release to the sewer system"*. The problem with this approach is it does not recognize or maximize the benefits available through green infrastructure, and may well discourage its use.

Criteria For Determination of Detention Facility Volume (9/28/2006)

These criteria are applied to green infrastructure throughout this document and, as such, is critical to the success of the program. The manual applies the peak flow rational method to develop a required storage volume. The method in essence varies the storm duration, calculating the impervious area peak flow based upon the surface condition and frequency storm intensity for the associated time. The flow rate is extrapolated over the storm minus the allowed release rate. The duration of the storm is varied, for example as the time increases, the intensity decreases, and vice versa. Through calculus, the time that creates the largest storage volume to assure the allowed release rate is met is selected.

The use of the rational method for hydrologic analyses to design stormwater BMPs is no longer supported by most stormwater professionals. The rational method is often used for peak flows for sizing inlets, culverts, etc.) but is rarely used as a hydrologic method that incorporates the volume and rate except for small highly impervious areas. Most current stormwater manuals do not recommend and in fact do not allow this method as it is not a hydrologic method, though arguably it can be useful to estimate runoff from small impervious parking lots, but definitely not for vegetated or storage / volume reduction practices.

As stated earlier, the method as developed in *Criteria For Determination of Detention Facility Volume* (9/28/2006) only considers the storage volume needed to maintain a set peak outflow, assuming a constant outflow. It does not credit the volume reduction approach and, is simply invalid for green infrastructure practices. Using a green roof as an example, the soil mantle void space is used to store the rainfall until it evapotranspires or slowly releases through an underdrain (not all green roofs have underdrains). The first volume of rain is reduced, thereby eliminating the rainfall from the waste stream. Only after the void space is filled would the rational method be valid, and the flow rate from this period would be much less then any release rate. Generally from both published studies (Minnesota) and conversations with green roof experts in New Zealand and Germany, if forced to use the rational method for rate, a "C" coefficient of approximately 0.3 is considered in the ball park. When this method is applied to the NYC criteria as shown in Figure 2 below, only a water storage of 1/3 of an inch over the impervious surface is needed to satisfy the published relationship for larger sites. The authors of the NYC *Guidelines* must have recognized this as they use an artificially `elevated "C" Value of 0.7 to raise the storage requirement to approximately 1.05". The value of rain gardens of 0.2 seems appropriate, but the Guidelines should clarify that 0.2 "C" value for "grassed areas" only applies to lawns or meadows, not grassy overlying compacted urban soils.

A consequence of requiring an artificial rational method approach with inflated "C" Values is that the *Guidelines* undervalues the effectiveness of green roofs and other green infrastructure techniques at meeting the proposed performance standard. This is counter to the statement made on page 21 in the NYC Green infrastructure Plan that detention of one inch is 60% less effective than infiltration (or evapotranspiration / reuse) of this volume. To be equivalent in reducing CSO, green infrastructure practices should be sized smaller than grey to achieve the same result. By not accounting for the improved performance, the cost of using green infrastructure is artificially increased (deeper green roofs, larger bioretention areas, etc.). This is not reflected in the required approach, thus the Green Infrastructure approach is not fully rewarded.

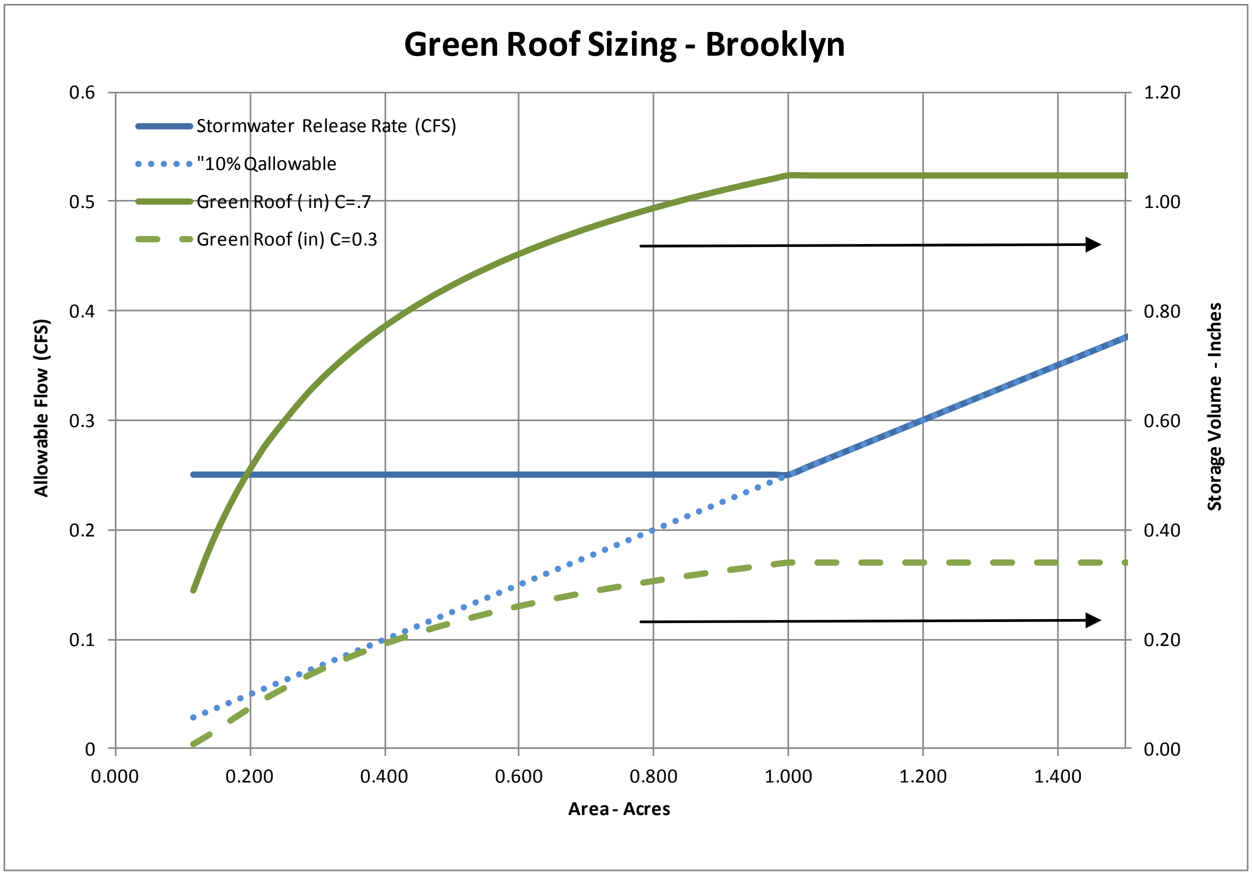


Figure 2- Brooklyn Green Roof Storage Volume - 5 Year Intensity

It clearly seems that it would be much simpler to set a performance standard requiring capture and removal of an inch over the impervious surface for volume reduction techniques (*e.g.*, green roofs, rain gardens, underground infiltration, and possibly rainwater harvesting). It would be essentially be equivalent or superior (for smaller areas) to the proposed stormwater release rate -- even without considering the expected superior performance of green volume reduction systems in regard to CSO reduction. Moreover, this would be more consistent with the statement (page 7) that controlling the first inch of runoff from10 % of the area would greatly reduce CSO volumes, since it appears that statement is derived from the NYC Green Infrastructure Plan, which based its analysis on modeling one inch of infiltration (*i.e.*, volume reduction). Additionally, when one starts with a falsely modified equation, it would not be able to be included in system wide hydrologic modeling, and it is difficult to understand how new knowledge can be included.

Finally, another apparent limitation of the *Criteria* is that the ten-year rainfall intensity relationship (I = 140/(t+15)) is encoded in the derivation. It is not clear when this relationship was developed, but it needs to be evaluated for changes in climate periodically, and the equations revised. Currently the *Criteria* document uses the 5-year six-minute intensity event to set the "Allowable Storm Flow", and then designs the facility for detention using the ten-year event. However, the *Criteria* document states that the 5-year storm should be used to determine the actual storm flow . This document should be revised to include any new performance standard that is adopted, and to ensure that it is based on an appropriate and up-to-date design storm.

Green Infrastructure Disincentives

The concept of slow release is that it will be delayed and move through the sewage treatment plant after the storm event. While the flows would be expected to receive both primary and tertiary treatment, this approach (even if it did reduce CSO volumes as much as a runoff volume reduction approach) is generally not as effective as green infrastructure -- either at reducing pollutant loads or achieving triple bottom-line benefits.

Unfortunately there are several disincentives to the use of green infrastructure throughout this manual. Many appear to be based on caution due to the lack of experience with the practices by the authors, and the overall focus on storage versus volume reduction. For example, for infiltration and reuse systems it states that department will "consider" inclusion of the reductions in the outflow due to infiltration (page 3). If an infiltration or reuse BMP is well designed and meets the criteria as set forth, why is this not an automatic inclusion? On page 3 it states that the applicant needs to conduct soil borings, and perform an insitu or laboratory infiltration trench, and then the department "will consider" approval. The fact that DEP need only consider granting credit towards regulatory compliance creates substantial uncertainty that would be enough to dissuade its use by developers and engineer designers. An option may be to permit a soil scientist to make the determination. Another example is on page one, where the *Guidelines* discuss the reduction of peak discharges through storage. There is no mention of the roles of evapotranspiration or infiltration, or volume reduction. Further, Section 2.6.2 (*Determine Available Storage Volume on Roof*) focuses on blue roofs and omits the void space storage volume of green roofs (although the latter does seem to be acknowledged in Section 2.4.2, on pp. 29-30).)

The draft *Guidelines* are laudable for acknowledging that green infrastructure is not limited to infiltration techniques, since the document also references rainwater harvesting. However, it omits consideration of the third mechanism by which green infrastructure reduces runoff volumes -- evapotranspiration. Importantly, evapotranspiration can be effective even where infiltration is infeasible, and it need not be measured or calculated directly in order to provide appropriate credit towards compliance with a performance standard. Measures such as rain gardens and vegetative systems can provide significant volume reduction in small events through temporary soil storage and evapotransporation, similar to green roofs, even in systems that cannot infiltrate (*e.g.*, lined rain gardens). Unfortunately, the use of lined rain gardens or planters or any non-infiltrative surface green infrastructure practice, with the exception of porous pavements, is simply missing from the *Guidelines*. Combination systems to include those that rely on non-infiltration vegetated features are not included.

This omission precludes the use of surface level green structures that are a main component of other cities programs.

It can be argued that green infrastructure should be incentivized in the system to increase the speed of meeting the desired goals. The NYC Green Infrastructure Plan's statement that, for an inch of rainfall, volume reduction is superior to detention would lead to this expectation. There are several additional factors that generally weigh in favor of volume reduction over detention. First, volumes that pass through primary and secondary treatment (*i.e.*, after on-site detention and delayed release into the sewer system) still contribute some pollutants to the waters. Volume reduction keeps the pollutants carried by that volume of runoff entirely out of the system. Second, slow release does not gain additional non-water quality benefits such as air pollutant and heat island reduction and carbon sequestration that are associated with vegetated green infrastructure. Third, it is difficult to determine whether storage/slow release systems are operational. They are usually below ground and out of site. The orifices used are by nature small and can clog. Without an inspection program, there is no certainty as to their operational capacity. Rain gardens, street planters, and in some situations green roofs are more readily visible and accessible (This is discussed further below in the section of this review that addresses maintenance issues.)

Maintenance of Green vs Grey Stormwater Systems

The attention given to Inspection and maintenance of volume reduction systems is laudable, and should be balanced across both green and grey infrastructure. There is a perception that grey systems do not require maintenance. For example on page 45, it states that pretreatment is not required and is a good idea where feasible. On page 48 an observation well is recommended, not mandatory. In contrast, for a green roof it is recommended, on p. 96, that the roof be inspected after every storm.

To investigate this perception that green infrastructure requires more maintenance than grey, and that grey requires little maintenance, a literature review of past maintenance experiences was undertaken (Appendix B). The conclusions of this literature search were that, clearly, BMPs that are not inspected and maintained should not be expected to perform to standard, whether they are grey or green. Sediment and poorly constructed outflows affect both grey and green infrastructure. The Australian studies point this out clearly with grey infrastructure, and bring out the challenges of greatly reducing outflows, and the danger of drowned outlets (which is not mentioned under drawbacks on page 37). The Maryland studies – which surveyed 258 sites – found that close to one half of the sites required maintenance action. Nine of the 47 subsurface infiltration sites (19%) had not drained within several days after a storm event (predominantly infiltration trench rock beds and dry wells), while five of the 31 underground detention sites (16%) had the same issue with ponding. The same study showed that a slightly higher percentage of underground detention facilities needed sediment removal, as compared to subsurface infiltration facilities. Note that this study was early in the implementation of green infrastructure, and does not include green roofs, or rain gardens. Experience with vegetated sites demonstrates that they are robust, and incorporate factors that maintain infiltration pathways to include freeze thaw, soil geomorphology and plant growth, with significant evapotranspiration losses.

Note that none of these factors is present in dry well systems; therefore, any local experience with failure of dry-well systems in New York City should not be taken as an indication that vegetated infiltration systems are prone to failure.

Studies at Villanova and other places referenced in the Appendix clearly define the issue for green infrastructure. Excessive solids when compacted with high depths of water can clog the infiltrating surface. Therefore designs should incorporate protection from this occurrence. One of the chief problems found in the Maryland studies occurred during the period immediately after construction. Grass seeding was the mechanism chosen to reestablish vegetation, and during this period high levels of sediment were allowed to enter the trenches. For vegetated areas, all BMPs need to be protected from such occurrences immediately after construction as illustrated on page 53, bullet 15. A rain garden built in Villanova that was protected immediately after construction has lasted for the past 11 years with no evidence of degradation with only landscape maintenance. Note that rooftop runoff for large buildings with slate roofs has been shown to have only minimal sediments in the runoff.

Recommendations:

My main recommendations are as follows:

1. DEP should analyze whether the guidelines, including the stormwater release rate, the relaxed criteria for smaller development sites, the thresholds for applying the rule to "alterations," and the lack of coverage for existing impervious surfaces are consistent with meeting CSO reduction goals based upon the climate and development patterns for NYC. If the goals are not met, the coverage and the criteria require revision.

2. The primary Green Infrastructure recommendation is to revise the NYC draft *Guidelines for the Design and Construction of Stormwater Management* Systems so as to include and encourage the use of volume reduction control measures to maximize the reduction in combined sewer overflows.

a) Create volume criteria that are not dependent on the rational method. Currently there are two storage volume equations listed, one for sites with a constant outflow and one for an orifice. Applying the constant outflow equation with the modified green roof "C" factor results in 1.05 inches of water storage in Brooklyn for impervious areas. A one-inch retention standard should be promoted as a third criterion. It is simple, easy to understand, design and review, is based upon the current approach, and more rigorous for areas of less than an acre. A superior approach would be to make the one-inch capture (infiltration, evapotranspiration or reuse) the default compliance requirement, with detention and delayed release implemented only when this standard could not be met. The criteria should reward performance, not provide an artificial advantage for lesser performance.

b) Introduce a section on rain gardens, tree planters, and other surface control measures

c) Revise the hydrologic design parameters for volume reduction systems (*i.e.*, green infrastructure)to be based upon the volume criteria discussed in point "a" above.

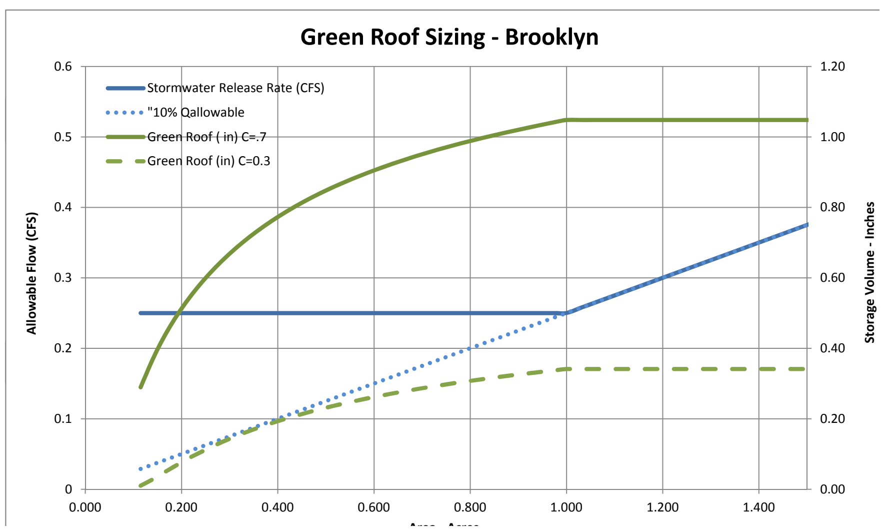
d) Review the manual to ensure the maintenance considerations are balanced for both green and grey infrastructure. For example, green roofs do not need to be inspected after every storm, as is currently recommended, although appropriate inspection and maintenance of green systems is important. Moreover, it is important to establish clear requirements for inspection and maintenance of grey systems, which appear to be lacking in the present draft.

Fundamentally, the document is well written and organized, with good detail. Due to this structure, it would be straight forward to revise this to address the points made previously, and would not require a massive rewrite.

Appendix A

			Brooklyn			Qo				Qo			
			Allowable Outflow			Green Roof C				Green Roof C			
Qo	Area	Area	Criteria	10% Criteria	SRR	0.70	Time	Vol Storage	hes/ Impervious Ar	0.30	Time	Vol Storage	hes/ Impervious Ar
	Sq Ft	Ac	(CFS)	(CFS)	(CFS)	Qo - CFS	Min	Cubic Feet	inches	Qo - CFS	Min	Cubic Feet	inches
Brooklyn	5000	0.115	0.287	0.029	0.25	3.11	10.98	120.55	0.29	7.26	2.01	4.03	0.01
	6000	0.138	0.344	0.034	0.25	2.59	13.46	181.15	0.36	6.05	3.63	13.18	0.03
	7000	0.161	0.402	0.040	0.25	2.22	15.74	247.73	0.42	5.19	5.12	26.25	0.05
	8000	0.184	0.459	0.046	0.25	1.94	17.86	319.04	0.48	4.54	6.51	42.42	0.06
	9000	0.207	0.517	0.052	0.25	1.73	19.86	394.22	0.53	4.03	7.82	61.12	0.08
	10000	0.230	0.574	0.057	0.25	1.56	21.74	472.65	0.57	3.63	9.05	81.94	0.10
	12500	0.287	0.717	0.072	0.25	1.24	26.08	680.01	0.65	2.90	11.89	141.40	0.14
	15000	0.344	0.861	0.086	0.25	1.04	30.00	899.86	0.72	2.42	14.46	209.03	0.17
	17500	0.402	1.004	0.100	0.25	0.89	33.60	1129.17	0.77	2.07	16.82	282.85	0.19
	20000	0.459	1.148	0.115	0.25	0.78	36.96	1365.96	0.82	1.82	19.02	361.57	0.22
	22500	0.517	1.291	0.129	0.25	0.69	40.11	1608.87	0.86	1.61	21.08	444.30	0.24
	25000	0.574	1.435	0.143	0.25	0.62	43.09	1856.90	0.89	1.45	23.03	530.38	0.25
	27500	0.631	1.578	0.158	0.25	0.57	45.93	2109.31	0.92	1.32	24.89	619.32	0.27
	30000	0.689	1.722	0.172	0.25	0.52	48.64	2365.50	0.95	1.21	26.66	710.74	0.28
	32500	0.746	1.865	0.187	0.25	0.48	51.23	2625.01	0.97	1.12	28.36	804.34	0.30
	35000	0.803	2.009	0.201	0.25	0.44	53.74	2887.46	0.99	1.04	30.00	899.86	0.31
	37500	0.861	2.152	0.215	0.25	0.41	56.15	3152.55	1.01	0.97	31.58	997.11	0.32
	40000	0.918	2.296	0.230	0.25	0.39	58.48	3420.02	1.03	0.91	33.10	1095.91	0.33
	42500	0.976	2.439	0.244	0.25	0.37	60.74	3689.64	1.04	0.85	34.59	1196.13	0.34
	43560	1.000	2.500	0.250	0.25	0.36	61.68	3804.57	1.05	0.83	35.20	1239.01	0.34
	45000	1.033	2.583	0.258	0.25826	0.36	61.68	3930.34	1.05	0.83	35.20	1279.97	0.34
	47500	1.090	2.726	0.273	0.27261	0.36	61.68	4148.69	1.05	0.83	35.20	1351.08	0.34
	50000	1.148	2.870	0.287	0.28696	0.36	61.68	4367.04	1.05	0.83	35.20	1422.19	0.34
	52500	1.205	3.013	0.301	0.30131	0.36	61.68	4585.39	1.05	0.83	35.20	1493.30	0.34
	55000	1.263	3.157	0.316	0.31566	0.36	61.68	4803.74	1.05	0.83	35.20	1564.41	0.34
	57500	1.320	3.300	0.330	0.33	0.36	61.68	5022.10	1.05	0.83	35.20	1635.52	0.34
	60000	1.377	3.444	0.344	0.34435	0.36	61.68	5240.45	1.05	0.83	35.20	1706.63	0.34
	62500	1.435	3.587	0.359	0.3587	0.36	61.68	5458.80	1.05	0.83	35.20	1777.74	0.34
	65000	1.492	3.730	0.373	0.37305	0.36	61.68	5677.15	1.05	0.83	35.20	1848.85	0.34
	67500	1.550	3.874	0.387	0.3874	0.36	61.68	5895.50	1.05	0.83	35.20	1919.96	0.34
	70000	1.607	4.017	0.402	0.40174	0.36	61.68	6113.86	1.05	0.83	35.20	1991.07	0.34
	72500	1.664	4.161	0.416	0.41609	0.36	61.68	6332.21	1.05	0.83	35.20	2062.18	0.34
	75000	1.722	4.304	0.430	0.43044	0.36	61.68	6550.56	1.05	0.83	35.20	2133.29	0.34
	77500	1.779	4.448	0.445	0.44479	0.36	61.68	6768.91	1.05	0.83	35.20	2204.39	0.34
	80000	1.837	4.591	0.459	0.45914	0.36	61.68	6987.26	1.05	0.83	35.20	2275.50	0.34
	82500	1.894	4.735	0.473	0.47348	0.36	61.68	7205.62	1.05	0.83	35.20	2346.61	0.34
	85000	1.951	4.878	0.488	0.48783	0.36	61.68	7423.97	1.05	0.83	35.20	2417.72	0.34

Green Roofs Assum 0.700



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	50000	1.148	2.870	0.287	0.28696	0.25
	52500	1.205	3.013	0.301	0.30131	0.25
	55000	1.263	3.157	0.316	0.31566	0.25
	57500	1.320	3.300	0.330	0.33	0.25
	60000	1.377	3.444	0.344	0.34435	0.25
	62500	1.435	3.587	0.359	0.3587	0.25
	65000	1.492	3.730	0.373	0.37305	0.25
	67500	1.550	3.874	0.387	0.3874	0.25
	70000	1.607	4.017	0.402	0.40174	0.25
	72500	1.664	4.161	0.416	0.41609	0.25
	75000	1.722	4.304	0.430	0.43044	0.25
	77500	1.779	4.448	0.445	0.44479	0.25
	80000	1.837	4.591	0.459	0.45914	0.25
	82500	1.894	4.735	0.473	0.47348	0.25
	85000	1.951	4.878	0.488	0.48783	0.25

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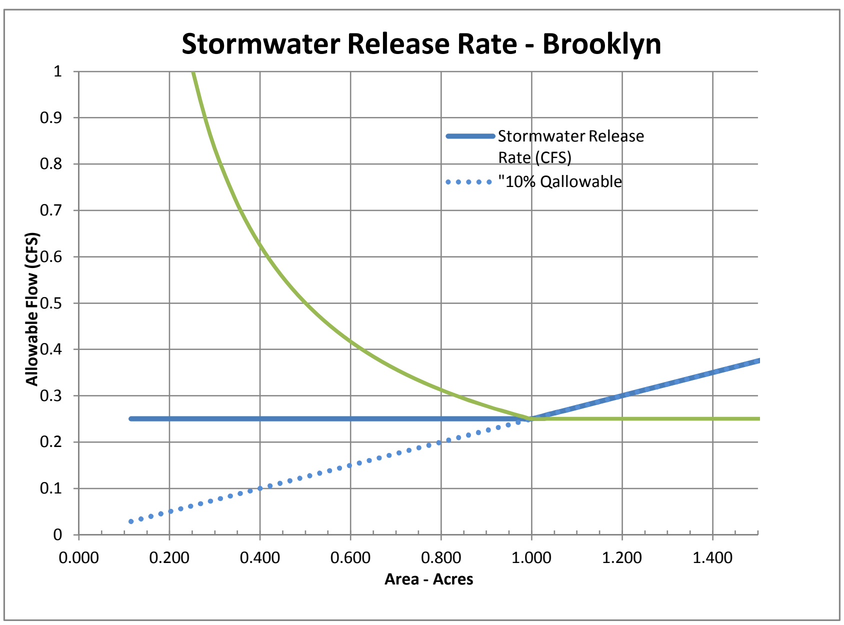

Appendix B

MAINTENANCE OF STORMWATER INFRASTRUCTURE PRACTICES

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Villanova University Department of Civil and Environmental Engineering

Prepared for: Natural Resources Defense Council

November 2011

Table of Contents

I. Introduction

Like many older urban areas in the United States, New York City faces challenges associated with a combined sewer system. Urban development, population growth, and aging sanitary infrastructure have pushed these combined sewer systems beyond their capacity causing frequent combined sewage overflows (CSOs) during wet weather. These CSO events result in more than 27 billion gallons of raw sewage and polluted stormwater being discharged in the New York Harbor each year. CSO events can occur as often as 70 times per year at some CSO outfalls throughout New York City (Riverkeeper, 2011).

Tools for combating CSOs consist of both gray and green infrastructure practices. Gray infrastructure tools include wastewater treatment plant improvements, increases in combined sewer storage capacity, and distributed underground extended detention. Green infrastructure tools are more focused on runoff source control, and include both structural and nonstructural stormwater best management practices (BMPs). It is recognized that all CSO reduction practices will require a significant upfront investment, but an aspect possibility being overlooked when considering CSO solutions is the maintenance burden essential to sustain performance and to prevent failure of these practices.

This report focuses specifically on underground stormwater detention systems as a CSO reduction tool. The goal of this report is to explore existing literature that addresses maintenance issues associated with underground systems. Both case studies and published maintenance guidance are examined and summarized. Recommendations are made while addressing comparisons to green infrastructure practices.

II. Gray versus Green Infrastructure

Green infrastructure practices can potentially generate a more valuable array of environmental, economic, and social benefits than traditional stormwater peak flow reduction practices like underground detention systems without infiltration. In contrast to gray infrastructure, green infrastructure practices have the ability to restore natural hydrologic processes that include infiltration and evapo-transpiration. In a combined sewer system, these processes act to remove total stormwater volume, while detention practices simply detain and delay stormwater runoff from reaching a downstream wastewater treatment plant. Vegetated green infrastructure practices also help shade and insulate buildings, block winter winds, and create an evaporative cooling effect. Both reduced energy use at wastewater treatment plants and energy savings from reductions in building heating and cooling result in a decrease in green house gas (GHG) emissions and other pollutant emissions, as well as cost savings at wastewater treatment plants and power plants. Additional green infrastructure benefits not presented by gray infrastructure include recreation opportunities, enhanced community aesthetics, heat stress reduction by evaporative cooling, air quality improvements through plant respiration, and the promotion of community environmental awareness (Flynn, 2011). In effort to place a monetary value on these benefits at a city scale, equivalent gray and green infrastructure CSO plans were evaluated by Raucher (2009) for the City of Philadelphia, Pennsylvania. The results of this study predict the monetary value of environmental and social benefits to be 23 times more for a green infrastructure plan than for an equivalent gray infrastructure plan over a 40 year period (Raucher, 2009).

III. Case Studies

Sydney, Australia

Few detailed maintenance studies have been undertaken for underground stormwater detention systems. The studies that do exist contain more qualitative than quantitative assessments of practice performance and maintenance needs. Most recent studies are focused on infiltration practices and are undertaken in more suburban environments. Perhaps the best example of underground detention facilities without infiltration implemented across an urban area is in Sydney, Australia. Since 1991, municipalities in Sydney have required all redevelopment properties serviced by existing drainage systems to provide on-site stormwater detention (OSD). Due to the ultra-urban development of Sydney and its municipalities, OSD systems in these areas largely consist of underground storage structures without infiltration (O'Loughlin et al., 1995).

OSD policy was originally developed by the Upper Parramatta River Catchment Trust (UPRCT), which was formed in 1989 to control flooding in a 110 square kilometer catchment that spans four municipalities. Since the introduction of OSD regulation, the UPRCT has lead two field studies to evaluate design, construction, and maintenance issues with OSD systems. These field studies qualitatively assess and identify the most commonly encountered problems with Sydney OSD systems. For the first study, over 150 OSD systems built between 1991 and 1994 were inspected (Upper Parramatta River Catchment Trust, 2005). About 90% of these systems were found to have design or construction faults which impaired their efficiency (O'Loughlin et al., 1995). Many systems lacked sufficient storage volume. Drowned outlets, skewed inlets, and unapproved construction materials resulted in unreliable discharge control. Less than half of the 150 OSD systems surveyed had screens to capture sediment and debris. Those systems with screening were often found to have screens that were poorly fabricated, corroding, and too small in relation to the discharge orifice. Odor problems were identified due to decomposing organic matter in unvented underground detention systems. Additionally, the walls of some underground systems were found to be structurally deficient (Upper Parramatta River Catchment Trust, 2005).

The second field study focused on OSD systems built from 1994 to 2004. Although an improvement was observed from the systems constructed prior to this period, further deficiencies were identifies in this second generation of OSD systems. Drowned outlets that retarded discharge were common. Screens were now more widely seen, but improper placement was observed to allow floating debris to bypass and obstruct the discharge orifice. Insufficient and poorly designed conveyance systems allowed for flows to by-pass the storage systems. The most concerning finding with regard to longevity of underground detention systems was the difficulty of access for inspection and maintenance. Common access issues found were heavy concrete lids, jammed grates, inaccessible access points, and deep underground storage structures without safe access (Upper Parramatta River Catchment Trust, 2005). Overall, it was observed that despite improvements in engineering design and construction, underground detention systems cannot perform property without routine maintenance. This is concerning with regard to the performance of the region’s stormwater infrastructure as a whole, as very few underground systems in Sydney receive any maintenance at all (Still and Bewsher, 1995).

Maryland, USA

While the results of the studies by Upper Parramatta River Catchment Trust (2005) show performance and maintenance of underground stormwater facilities without infiltration in urban areas, a study was conducted across the State of Maryland by Lindsey (1992) with an expansive scope that includes both infiltration practices and subsurface practices without infiltration. Lindsey reports on the results of field inspections of 258 stormwater facilities across four Maryland counties. These counties (Baltimore, Carroll, Cecil, and Harford) illustrate different development patterns that range from rural to suburban to urban. Facilities inspected include dry basins, wet basins, vegetated swales, infiltration basins, infiltration trenches, dry wells, and underground detention. Qualitative assessments of all facilities were made based upon these field inspections. Data describing maintenance schedules and the age of the facilities at time of inspection is unknown for this study (Lindsey, 1992). A summary of field inspection results is shown in *Table 1*. Analysis has been undertaken to isolate performance and maintenance needs of subsurface infiltration facilities (infiltration trenches and dry wells) and underground detention facilities without infiltration.

Table 1. Analysis of stormwater facility field inspection results (Lindsey, 1992)

	All Facilities[1]		**Subsurface Infiltration**[2]		**Underground Detention**[3]	
	#	%	#	%	#	%
Facilities inspected	258	100%	47	100%	31	100%
Functioning as designed	164	64%	33	70%	24	77%
Water quantity controlled as designed	182	71%	34	72%	26	84%
Enforcement action needed	71	28%	13	28%	9	29%
Maintenance action needed	177	69%	21	45%	15	48%
Inappropriate water ponding	70	27%	9	19%	5	16%
Clogging of facility	62	24%	13	28%	6	19%
Excessive sediment or debris	122	47%	22	47%	12	39%
Water bypassing facility	25	10%	11	23%	1	3%
Sediment entering facility	141	55%	24	51%	19	61%
Sediment/debris removal needed	125	48%	21	45%	18	58%
Inlet or outlet clogged	48	19%	8	17%	6	19%

Notes:

1. Includes dry basins, wet basins, vegetated swales, infiltration basins, infiltration trenches, dry wells, and underground detention.

2. Includes infiltration trenches and dry wells.

3. Underground detention systems without infiltration.

Analysis shows that maintenance action is needed for almost half (48%) of all underground detention facilities inspected, which is better than the average of all of the inspected facilities.

Despite this designation, enforcement action, which is indicative of more severe maintenance issues, is needed for 29% of the underground facilities inspected. This is worse than the overall average for all of the facilities inspected.

The major maintenance issue for most stormwater management facilities, including underground detention, is the accumulation of sediment and debris. Of the underground detention facilities examined by Lindsey (1992), 61% were found to have sediment entering the facility and 58% were in need of sediment and debris removal. These results are worse than the average of both all inspected facilities and all subsurface infiltration facilities (Lindsey, 1992). These results suggest that underground detention facilities without infiltration may be more susceptible to sediment and debris accumulation. This highlights the need for frequent and scheduled maintenance inspections because accumulation in these practices may not otherwise be observable.

Pennsylvania, USA

Ongoing monitoring and research at the Villanova University Stormwater Research and Demonstration Park has confirmed the importance of proper design, construction, and maintenance for all stormwater BMPs. Publications by Welker et al. (2006), Emerson and Traver (2008), and Emerson et al. (2010) assess performance and maintenance implications of both subsurface and aboveground infiltration BMPs. Site investigations in Maryland by Lindsey (1992) showed that on average approximately half of infiltration BMPs fail due to sediment buildup, improper design, improper location, and lack of maintenance (Lindsey, 1992).

A study was conducted at Villanova University by Emerson et al. (2010) to examine how a subsurface stormwater infiltration trench with an artificially accelerated aging process would perform over time. This practice was significantly undersized and designed to capture stormwater runoff from a busy parking deck, which results in an excessively high loading rate for both stormwater runoff volume and sediment. The practice receives no pretreatment and maintenance access is not provided for the six foot deep stone infiltration bed. Monitoring results over the first three years of operation show a rapid decrease in the subsurface infiltration trench's ability to infiltrate stormwater. This study demonstrates the importance of pre-treatment, proper siting, and adequate maintenance access for subsurface infiltration practices (Emerson et al., 2010).

Other cases have been studied where green infrastructure practices have been found to be resilient despite a lack of maintenance. In a study by Emerson and Traver (2008), two infiltration stormwater BMPs at Villanova University were continuously monitored without significant maintenance of their infiltration surfaces. One practice is a pervious concrete site with a subsurface infiltration basin. The majority of the runoff from this site is received from the roofs four-story dormitory buildings, which discharge directly to the subsurface basin. This subsurface infiltration BMP was monitored over a two year period. The other practice monitored for this study was a bioinfiltration traffic island, which received runoff from a 0.52 hectare watershed with 35% of the drainage area as directly connected impervious. Riprap aprons at inflow points provide pretreatment of all directly connected impervious drainage area. This infiltration BMP was monitored over a 4 year period. Despite no significant maintenance, results show no discernible decline in performance for both practices over the period of record examined (Emerson and Traver, 2008).

Yet another monitoring study at Villanova University by Welker et al. (2006) yielded a similar assessment of subsurface infiltration practices. For this study, an 85 to 100 year old subsurface infiltration pit on the Villanova University Campus was studied. Like the subsurface infiltration practice in the study by Emerson and Traver (2008), this site received the majority of its inflow from the roofs of four-story campus buildings. Despite no known maintenance over the life of the practice, this pits maintained excellent infiltration capacity (Welker et al., 2006). The results of these three studies show that infiltration practices can maintain performance with limited maintenance if they are designed to treat stormwater runoff without high sediment loads, such as roof areas, or designed with proper pre-treatment.

Historic Green Infrastructure

While green infrastructure practices may be a relatively new approach to reduce CSO events, green infrastructure practices have been used for centuries for the conveyance of stormwater runoff, microclimate mitigation, and the enhancement of urban aesthetics. Green roofs have been common in Norway since the Middle Ages. In rural areas, sod roofs were almost universal in the beginning of the 18^{th} century. This green infrastructure practice was used as a means of thermally insulating buildings from the Norwegian climate. Some of these 18^{th} century green roofs are still functioning today as a testament to the potential longevity of this practice. In France, rooftop gardens still thrive at a Benedictine abbey constructed in the 13^{th} century. The use of green roof technology has been well established in Germany since the 1960s. Today, Germany boasts more green roofs than any other nation (Yasinian, 2011). The oldest known green roofs in the United States are located at Rockefeller Center in Midtown Manhattan. These five roof gardens were constructed between 1933 and 1936 (Greenroofs.com, 2011). With their lavish design, they continue to enhance New York City views while reducing stormwater runoff to the combined sewer system.

Infiltration green infrastructure practices have also been around for centuries. Notable are the rain gardens in the City of Isfahan, Iran, which were constructed in the 16th century and are still functioning today. The urban streets of Isfahan are lined with sunken gardens containing dense trees and shrubs. For hundreds of years, these rain gardens have infiltrated and conveyed stormwater and provided climate mitigation through evapo-transpiration and shade. Like green infrastructure practices in urban areas today, these ancient green infrastructure infiltration practices couple environmental function and aesthetic beauty while providing health and social benefits to the citizens of Isfahan. The longevity of these rain gardens may be attributed to the city's dedication to maintain these practices. Routine maintenance keeps the rain gardens free of debris and standing water. This maintenance is necessary to preserve the quality of the precious water resources of Isfahan as these rain gardens drain directly to the City's main canals and the Zayandeh River (Wark, 2011).

More recently, infiltration green infrastructure practices have evolved to adapt to land development patterns shaped by the automobile. This facilitated the invention of porous asphalt pavement in the 1970s. Porous pavements can provide stormwater volume reduction through subsurface infiltration. With proper construction as well as routine and adequate maintenance, these infiltration green infrastructure practices have been observed to be highly effective. Two examples of the longevity of porous asphalt pavement practices with infiltration are the parking lots at the Morris Arboretum of the University of Pennsylvania in Philadelphia and the parking lot at the Siemens Medical Systems Corporate Campus in Malvern, Pennsylvania. Constructed in the early 1980s, both of these practices continue to perform effectively more than 25 years after their installation (Adams, 2003).

IV. Underground Detention Maintenance Guidance and Protocols

Some municipalities offer guidance documents and protocols with respect to maintenance of underground stormwater detention practices. The following section of this report summarizes some of the underground detention maintenance issues, schedules, and protocols from selected municipal manuals and handbooks. Further information on underground stormwater detention system maintenance is available from the Upper Parramatta River Catchment Trust (2005), the Stormwater Services Division of the City of Durham (2008), the Engineering and Public Works Department of Knox County Tennessee (2011), and the Virginia Department of Conservation and Recreation (2009).

Underground detention systems consist of a number of components, each with different potential maintenances issues. Typical underground detention system components include control structures, detention chambers, vaults or pipes, inlets, outfalls, screening, and bypass structures. Control structures may be the most critical component to the stormwater management performance of these systems. A minimum control structure low flow orifice diameter of one (1) inch (25 millimeters) is consistent across all municipal manuals reviewed for this report. Detention control structures are to be fitted with screening or trash racks to prevent orifice blockage, retain trash and debris, and to create static conditions around orifices to achieve predictable discharge rates (Upper Parramatta River Catchment Trust, 2005). The *Knox County Stormwater Management Manual* recommends low flow orifices be protected by a vertical stand pipe with 0.5 inch orifices or slots that are protected by wire cloth and a stone filtering jacket (Engineering and Public Works Department of Knox County Tennessee, 2008).

In addition to proper design and construction practices, underground detention control structures must be routinely maintained to provide the expected stormwater management performance. The most common control structure maintenance issue is blockage by trash, sediment, and debris. This may be addressed with routine inspection and cleaning. To allow for routine maintenance, underground detention systems must be designed with adequate access to their control structures. As per the Upper Parramatta River Catchment Trust's *On-site Stormwater Detention Handbook,* minimum internal dimensions around control structures for maintenance are 600 mm by 600 mm (approximately 2 ft by 2 ft) for structures up to 600 mm (2 ft) deep and 900 mm by 900 mm (approximately 3 ft by 3ft) for structures greater than 600 mm deep (Upper Parramatta River Catchment Trust, 2005).

More severe control structure maintenance issues consist of degraded structural integrity and insufficient debris management. Major structural integrity issues may require complete replacement. Less severe structural issues such as cracks, spalled areas, and rust may be mitigated using typical construction materials such as grouts, bonding agents, sealants, and paints. Insufficient debris management may be a result of environmental factors, improper design, or a combination of issues. This issue can be recognized by standing water for a period of longer than three days, and may require the installation of screening, trash racks, or other pretreatment practices to resolve (Stormwater Services Division, City of Durham, 2008).

Chambers, vaults, or pipes which provide extended detention for underground systems may also build up trash, sediment, and debris without routine cleaning. Accumulation may reduce available stormwater storage volume and thus decrease performance of these detention systems. In addition, debris and standing water due to lack of routine maintenance may promote mosquito breeding in underground structures. Routine maintenance consisting of sediment and debris removal may require specialized pumping equipment for some detention systems. Inspection and maintenance staff could also be required to have confined-space training to satisfy Occupational

Safety and Health Administration (OSHA) safety requirements (Virginia Department of Conservation and Recreation, 2009). Other potential maintenance issues with underground storage components include leaking and misaligned joints, separated joints, and crushed, collapsed, or rusted pipe sections. Progressive infiltration of soil into underground systems may result in cave-ins which could damage utilities as well as aboveground features such as parking and travel surfaces (Stormwater Services Division, City of Durham, 2008).

Inlets, outfalls, screening, and bypass structures are additional critical components to the performance of underground stormwater detention systems that require routine inspection and maintenance. Periodic inspections can identify any blockages, erosion, or structural issues with these system components. Routine maintenance is necessary to keep these components in good working condition. This reinforces the need for adequate maintenance access to all system components. Maintenance will include the removal of trash, sediment, and debris along with mitigation of more significant maintenance issues as they arise.

Because underground stormwater detention systems are likely to be inconspicuous and easily neglected, a maintenance schedule must be established and followed to ensure proper performance and to prevent system failure. One suggested maintenance schedule for underground stormwater detention systems is as follows:

1. Monthly or as needed cleaning and removal of sediment, trash, and debris.
2. Semi-annual inspection of inlet and outlet structures.
3. Annual inspection of sediment accumulation in the facility.
4. As needed inspection after several storm events or an extreme event.

This maintenance schedule is referenced from the *Knox County Stormwater Management Manual* (Engineering and Public Works Department of Knox County Tennessee, 2011). Other municipalities recommend inspection frequency based on land use. For example the Upper Parramatta River Catchment Trust (2005) recommends inspection every six months for residential land uses and inspection every three months for commercial land uses. This illustrates the point that maintenance is a function of the quality of the stormwater flow received by the system. The other integral component to following a proper maintenance schedule is the establishment of maintenance responsibilities and a maintenance budget. While most above-ground green infrastructure practices may be maintained by property owners, residents, or landscaping contractors, many underground systems require commercial cleaning companies with specialized equipment (Upper Parramatta River Catchment Trust, 2005).

V. Summary and Recommendations

The previous sections of this report examine case studies and published maintenance guidance for underground stormwater detention systems. In Sydney, it was observed that improvements in engineering design and construction cannot overcome a lack of routine maintenance (Upper Parramatta River Catchment Trust, 2005). Results of the Maryland case study suggest that underground detention systems without infiltration may be more susceptible to sediment and debris accumulation than aboveground practices (Lindsey, 1992). Studies at Villanova University show the important relationship between runoff quality from contributing drainage areas and the performance of underground infiltration systems. Practices that received building roof runoff without high sediment loads were observed to maintain performance with limited maintenance (Emerson and Traver, 2008). In New York City, only 20 percent of stormwater runoff is from roof areas. The remaining 60 percent is mostly from roads and sidewalks that will yield high sediment loads (Plumb and Seggos, 2008). This indicates that underground stormwater detention systems alone would not be the preferable CSO mitigation tool for New York City. It is recommended that stormwater flows to underground detention systems receive pre-treatment to improve practice performance and lessen maintenance needs.

The review of several municipalities' maintenance guidance and protocol documents demonstrates the range of maintenance issues associated with underground stormwater detention systems and highlights the need for frequent and scheduled maintenance inspections. Accumulation of trash, sediment, and debris is identified as the most common maintenance issue for all underground detention system components. This issue can be addressed with routine inspection and cleaning. One major obstacle to routine maintenance is a lack of access to these underground systems. To allow for routine maintenance, underground detention systems must be designed with adequate access to all system components. This should include access for vehicles and specialized equipment that may be required for system cleaning and repair. Because underground stormwater detention systems are likely to be out of sight and possibly out of mind, providing access alone cannot ensure these systems will receive the maintenance they need. Consequently, a detailed maintenance schedule must be established and followed to preserve system performance and to prevent system failure.

Inspection is just as important as maintenance for both gray and green infrastructure practices. Inspection cost may be as little as 5 to 10 percent of the total inspection plus maintenance cost for these systems. Like underground stormwater detention systems, green infrastructure practices need to be inspected. The frequency of inspection will depend upon the sediment loading and land practices contributing to the practice. Maintenance can be unique between practices, therefore property owners and maintenance contractors must be properly trained and understand the function of these practices (Hunt and Lord, 2005).

Deferred maintenance of both gray and green infrastructure practices can increase cost and negatively affect receiving sewer systems and downstream water bodies. Most maintenance problems are less costly to correct when caught early. The *Virginia Stormwater Management Handbook* separates maintenance into two categories: routine maintenance and structural maintenance. Structural maintenance is typically more costly and requires an enhanced level of expertise than routine maintenance (Virginia Department of Conservation and Recreation, 2009). Typically underground stormwater detention systems will have more components which may require structural maintenance than green infrastructure practices. While both will require routine maintenance, it could be concluded that underground detention will require more frequent structural maintenance compared to green infrastructure, in addition to a similar level of routine maintenance. In some cases, underground stormwater detention maintenance may be a more costly alternative.

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Attachment 3

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Re: **<u>NYC DEP's Proposed Amendments to Chapter 31 of Title 15 of the Rules Governing House/Site Connections to the Sewer System (a.k.a. "NYC Stormwater Rule")</u>**

Dear Mr. Shamoon,

On behalf of the undersigned members of the New York City Department of Environmental Protection's Green Infrastructure Steering Committee, we are submitting these comments on the proposed NYC Stormwater Rule. DEP convened the Committee pursuant to the NYC Green Infrastructure Plan. It is comprised of representatives selected by DEP from the private sector, nonprofit organizations, and educational institutions. While we have varied perspectives, we all support the content of this letter and share a common goal of widespread implementation of green infrastructure to cost-effectively reduce combined sewer overflows (CSOs), clean up local waterways, and improve the health and livability of New York City neighborhoods. Many of our organizations will be submitting their own comments individually as well.

We applaud the tremendous strides the Bloomberg Administration has taken over the last several years, with the support and encouragement of New York State, to advance the use of green infrastructure as a core strategy for CSO control. All of the members of the Committee agree that an approach that maximizes the use of green infrastructure represents a cost-effective and environmentally-preferable approach to traditional stormwater management, and a significant departure from DEP's past approach. We consider the city's Green Infrastructure Plan, which gave rise to the proposed Rule, to be an important step towards bringing New York City in line with the stormwater management practices of other leading cities.

In the Green Infrastructure Plan, DEP proposed targets for implementing, on both public and private property, decentralized stormwater management approaches that retain runoff -- through infiltration, evapotranspiration, or rainwater harvesting -- or delay its release into the sewer system.[1] The former set of approaches comprise what U.S. EPA, NYS DEC, and others refer to as "green infrastructure," because they rely on soils (or other lightweight growth media), vegetation, and other techniques that mimic the way nature handles stormwater, treating it as a resource rather than a waste. The Green Infrastructure Plan recognizes that these "retention" methods are more effective at reducing CSOs and, by creating more urban green space and reducing potable water demand, yield a wide range of sustainability benefits. Therefore, we strongly encourage DEP to implement its CSO and stormwater management programs in a way that maximizes the use of these approaches.

[1] The Green Infrastructure Plan's citywide targets are now proposed to be incorporated into a consent order with the state; today we also submitted to the state Department of Environmental Conservation a comment letter on the proposed consent order.

DEP's draft stormwater performance standard and accompanying technical guidelines (the proposed "Rule") will be a critical component of the success of the Green Infrastructure Plan, which relies on the application of a new performance standard to redevelopment projects to realize most of the CSO reductions attributed to green infrastructure. Therefore, it is critical that the Rule itself be structured to promote the use of retention methods wherever feasible.

We are concerned that, in numerous respects, the proposed Rule does not fully embody the visionary goals of the proposed CSO Order and the Green Infrastructure Plan. We urge the city to improve upon the current draft. Most significantly:

> 1. The proposed Rule is primarily oriented towards stormwater detention and delayed release, rather than stormwater retention, even though the Green Infrastructure Plan states that detention is only 60% as effective as retention. We encourage NYC DEP to revise the proposed Rule so that it directly drives the use of green infrastructure -- including not only infiltration, but also evapotranspiration and rainwater harvesting -- as the principal means of compliance wherever feasible. Even where infiltration may not be feasible, methods such as green roofs and analogous lined bioretention facilities at the ground level can effectively reduce runoff volumes by retaining runoff in the pore space of the soil for subsequent evapostranspiration, and that rainwater harvesting techniques can also be applied.
>
> 2. The proposed Rule remains very vague about what green infrastructure designs will be sufficient to achieve a given amount of "credit" toward compliance with the performance standard, and does not give sufficient credit for the full functionality of green infrastructure techniques. (For example, the current draft of the Technical Guidelines assumes 70% of rainfall will run off from a green roof, which is not consistent with current research or experience, but rather significantly understates the effectiveness of a green roof.)

These two issues lead us to be concerned that developers will often find a "gray" approach, based on detention and delayed release, to be the path of least resistance for permit approval, and that investments in green infrastructure may not be duly rewarded towards achieving compliance with the DEP's performance standard.

In light of these concerns, we urge DEP to improve the proposed Rule to ensure that it maximizes the use of retention methods wherever feasible.

Thank you for considering these comments, and for all of DEP's work to advance green infrastructure. We look forward to continuing to engage with DEP as the city moves ahead with implementation of its exciting green infrastructure initiatives.

Sincerely,

Kevin Bone
Center for Sustainable Design - Cooper Union

Michael Brotchner
Sustainable South Bronx

Susannah Drake
dland studio

Stuart Gaffin
Center for Climate Systems Research – Columbia

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Shino Tanikawa
NYC Soil and Water Conservation District

Herschel Weiss
Ashokan Water Services

Kate Zidar
S.W.I.M. Coalition

cc: Commissioner Carter Strickland, NYC DEP
David Bragdon, Director, NYC Mayor's Office of Long-Term Planning and Sustainability

Attachment 4

NYC
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December 21, 2011

Lawrence M. Levine
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Dear Mr. Levine:

I appreciate our meeting with you and Dr. Travers last week. We agree with you on many of the points you raised at the meeting and in your follow-up email, and we are working to incorporate as many of your suggestions as we think are appropriate at this time. More importantly, we are looking forward to collaborating with NRDC and other stakeholders over the long term to make this rule and the green infrastructure program as effective as possible through period reviews and incremental improvements as we gain experience with the program.

In the City's draft Amended Consent Order with the New York State Department of Conservation we commit to ten watershed-specific Long Term Control Plans (LTCP) and one citywide LTCP. In your December 19, 2011, email you request that DEP commit to mandated "look-backs" of the stormwater performance standard as a component of the LTCPs. As you know, the Green Infrastructure Program and the LTCPs are designed to be iterative. We will be working closely with the green infrastructure steering committee throughout the year and will be performing internal reviews of the rule, all of which will be reflected in the annual reports that will account for progress toward achieving our goals in each watershed, including rates of development and adoption of the performance standard. We will use those annual reports as an opportunity to reflect on challenges in implementing the rule and potential amendments to the rule moving forward.

Your recommendation to accelerate a peer review group is well taken. Just a year ago, DEP's commitment to immediately form a Green Infrastructure Citizen's Group and Steering Committee, both launched in early 2011, was accompanied by a commitment to form "a panel of independent, qualified experts" to review green infrastructure designs (letter from Commissioner Cas Holloway, November 12, 2010). At that time we envisioned creating that group at the "end of a three to five year start-up period," but so much has happened in the first year of the NYC Green Infrastructure Plan that we believe it would be beneficial to gather a group of technical experts in green infrastructure, hydrology, and drainage sooner than that timeframe. A strong foundation in defensible, replicable results, complemented by rigorous peer review, will make our program even more effective. We will be sure to reach out to you and other important stakeholders to create a panel that is robust in stormwater expertise.

We appreciate the time that you and your staff have committed to the Green Infrastructure Citizen's Group and the Steering Committee. Please do not hesitate to reach out to me if you have any more questions.

Very truly yours,

Carter H. Strickland, Jr.

c: Chris Hawkins, Chief of Staff, DEP
Kathryn Garcia, Deputy Commissioner for Operations, DEP
Robin Levine, General Counsel, DEP
Angela Licata, Deputy Commissioner for Sustainability, DEP
James Roberts, Deputy Commissioner for Water and Sewer Operations, DEP
Julie Stein, Director, Bureau of Environmental Planning and Analysis, DEP
James Garin, Director, Bureau of Water and Sewer Operations, DEP
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Attachment 5

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Tree and impervious cover change in U.S. cities

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ABSTRACT

Paired aerial photographs were interpreted to assess recent changes in tree, impervious and other cover types in 20 U.S. cities as well as urban land within the conterminous United States. National results indicate that tree cover in urban areas of the United States is on the decline at a rate of about 7900 ha/yr or 4.0 million trees per year. Tree cover in 17 of the 20 analyzed cities had statistically significant declines in tree cover, while 16 cities had statistically significant increases in impervious cover. Only one city (Syracuse, NY) had a statistically significant increase in tree cover. City tree cover was reduced, on average, by about 0.27 percent/yr, while impervious surfaces increased at an average rate of about 0.31 percent/yr. As tree cover provides a simple means to assess the magnitude of the overall urban forest resource, monitoring of tree cover changes is important to understand how tree cover and various environmental benefits derived from the trees may be changing. Photo-interpretation of digital aerial images can provide a simple and timely means to assess urban tree cover change to help cities monitor progress in sustaining desired urban tree cover levels.

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Introduction

Tree cover in cities is constantly changing due to various natural and anthropogenic forces. Natural forces for change include natural regeneration, tree growth and tree mortality from insects and diseases or old age. Anthropogenic factors that influence tree cover include tree planting and tree mortality or removal from either direct or indirect human actions such as development and air pollution (Nowak, 1993). The combination of these factors through time determines existing and future tree cover levels.

An important question for city managers is how their local tree cover is currently changing as present-day benefits derived from urban forests are related to the amount of tree cover in cities. As many urban forest ecosystem services are directly related to the amount of healthy and functioning leaves, tree cover becomes a simple measure of the extent of the urban forest and consequently the magnitude of services provided by the forest. To help sustain tree cover in cities, various city programs are planting large numbers of trees (e.g., City of New York, 2011; City of Los Angeles, 2011), protecting existing trees (e.g., Town of Chapel Hill, 2011; City of Pasadena, 2011) and developing tree canopy goals (e.g., City of Seattle, 2011; Maryland Department of Natural Resources, 2011).

Though tree cover in cities is constantly changing, limited studies have investigated how overall tree cover in cities has or is changing. Nowak (1993) illustrated through an analysis of historical imagery and documents that the tree cover in Oakland, CA, has increased from a presettlement tree cover of approximately 2 percent in 1850s to 19 percent in 1991. Land cover maps have been used to quantify how various cover classes have changed through time, but assessments of tree cover change within cities are limited (e.g., Zhou et al., 2008). In Seattle, tree cover was estimated to change from 22.5 percent in 2002 to 22.9 percent in 2007 by comparing digital land cover maps developed from 0.6 m resolution imagery (Parlin, 2009). However, the accuracy of the map classification is unknown and comparing cover maps to estimate change can lead to false changes due to misclassification of cover types on either map.

Various land cover change analyses have been conducted using satellite-based approaches. Moderate Resolution Imaging Spectroradiometer (MODIS) data (250-m) and Landsat data (30-m) have and are being used to estimate changes in land cover and impervious surface cover (e.g., Yang et al., 2003; Lunetta et al., 2006; U.S. EPA, 2011). MODIS data (500-m) also has the ability to estimate change in percent tree cover across the globe (Hansen et al., 2003; Schwarz et al., 2006). These satellite-based approaches have limitations based on image resolution and inaccuracies of image classifications. Photo-interpretation of high resolution images to detect cover changes has the ability to overcome these limitations, but lacks the ability to develop detailed comprehensive cover change maps.

Trees and impervious surfaces provide numerous ecosystem services and values to a community, but also have various economic or environmental costs. Trees provide various benefits associated

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with air and water quality, building energy conservation, cooler air temperatures, reductions in ultraviolet radiation, and many other environmental and social benefits (e.g., Dwyer et al., 1992; Kuo and Sullivan, 2001; Westphal, 2003; Wolf, 2003; Nowak and Dwyer, 2007). Costs associated with trees are both economic (e.g., planting and maintenance and increased building energy costs) and environmental (e.g., pollen and volatile organic compound emissions) (Nowak and Dwyer, 2007).

Likewise, impervious cover plays an important role in the landscape, particularly in urban areas. These surfaces, such as roads, buildings, sidewalks, and parking lots, facilitate transportation and provide shelter, but also can negatively impact the environment. Increased impervious surfaces enhance local temperatures and heat islands (Oke, 1989; Heisler and Brazel, 2010), which consequently affects building energy use, human comfort and health, ozone production, and pollutant emissions in cities. In addition, impervious surfaces significantly affect urban hydrology (e.g., stream flow and water quality) (e.g., U.S. EPA, 1983; National Research Council, 2008).

As development occurs in forests, tree cover will decrease to make space for buildings and other impervious surfaces. In non-forest regions, tree cover can increase due to urbanization (unpublished data). Thus, urbanization as a process will alter regional tree cover. As tree cover changes in cities, so will the associated ecosystem services and their effects on environmental quality and human health. Unfortunately, within existing cities, rates and direction of change in tree and impervious cover are largely unknown. This paper investigates tree and impervious cover change in urban areas and select cities across the United States using a simple and repeatable measure that can be used worldwide where paired multi-year digital aerial imagery exists. The objective of this paper is to determine the current direction and rate of tree and impervious cover change in U.S. cities to help guide cities in sustaining desired tree cover levels and associated ecosystem services.

Methods

To determine the percent tree/shrub cover (hereafter referred to as tree cover or canopy) and impervious cover change in cities in the United States, 20 cities from across the nation were selected (Table 1). Some cities were selected based on existing projects (Syracuse, NY; Baltimore, MD; Spokane, WA). Other cities were selected by picking major cities scattered throughout the conterminous United States where paired imagery could be obtained. Two cities were specifically selected to determine the effect of recent suspected tree cover change: (1) New Orleans, LA (effect of 2005 Hurricane Katrina), and (2) Detroit, MI (effect of recent infestation of emerald ash borer (*Agrilus planipennis*)). For each city, paired digital aerial photographs were obtained for the most recent date possible and imagery as close to 5 yr prior to the most current date as possible.

In 18 of the 20 cities, 1000 random points were laid and interpreted across the city to provide a maximum standard error of 1.6 percent if all points are classified (Lindgren and McElrath, 1969). In two cities, more points were laid and interpreted (Baltimore: 2500 points; Spokane, WA: 2000 points). City geographic boundaries were determined using census incorporated or designated places boundaries (U.S. Census Bureau, 2007). Each point was laid in the same geographic position on both sets of temporal images in the city, and paired image interpretation was conducted (i.e., interpreter classified each point pair by contrasting and classifying the image points in sequence). In cases of misregistration of the image or point, the interpreter corrected the point location to ensure the exact same location was interpreted. For example, sometimes the points would shift position slightly between images due to issues of image misregistration. In these cases, the interpreter moved the point on the most recent image back to the position on the oldest image to make the interpretation of change at the same point on both images.

In some cases, not all of the points could be classified. Non-classification occurred when one of the images were missing part of the city area (incomplete imagery) or had cloud cover. All cities had greater than 97.2 percent of the points interpreted. As some cities have substantial amounts of water within their city boundary (Table 1), cover estimates were only based on points that were not classified as water in both years. That is, permanent water points were deleted from the sample so that cover estimates were based on city land area, not city total area.

For the photo-interpretation, trained photo interpreters with experience interpreting leaf-off and leaf-on imagery classified each point as to either: trees/shrubs (woody vegetation), grass

Table 1
Resolution and year of imagery for 20 analyzed cities. Percent of city area classified as water in both years (%Water) was removed from analysis so that cover estimates could be based on land area. Human population density change (#/ha) between year 1 and year 2 is based on U.S. Census estimates (1).

City	Year 1	Res.[a] (m)	Leaf on/off	Year 2	Res.[a] (m)	Leaf on/off	%interp[b]	%Water	*n*	Change (#/ha)
Albuquerque, NM	2006	0.15	Off	2009	1	On	100	0.2	998	0.6
Atlanta, GA	2005	2	On	2009	1	On	99.5	0.4	991	1.7
Baltimore, MD	2001	1	On	2005	1	On	99.9	12.6	2184	−0.2
Boston, MA	2003	1	On	2008	1	On	99.9	13.6	863	2.3
Chicago, IL	2005	2	On	2009	1	On	100	0.8	992	0.5
Denver, CO	2005	1	On	2009	1	On	100	1.6	984	1.2
Detroit, MI	2005	1	On	2009	1	On	99.9	0.3	996	−0.3
Houston, TX	2004	1	On	2009	1	On	99.5	1.6	979	1.4
Kansas City, MO	2003	1	On	2009	1	On	100	1.5	985	0.4
Los Angeles, CA	2005	1	On	2009	1	On	100	0.2	998	0.3
Miami, FL	2003	1	On	2009	0.3	On	100	9.3	907	6.3
Minneapolis, MN	2003	1	On	2008	1	On	98.9	7.1	919	0.3
Nashville, TN	2003	0.15	Off	2008	0.15	Off	100	0.7	993	0.3
New Orleans, LA	2005	2	On	2009	1	On	97.2	38.4	563	−2.1
New York, NY	2004	0.15	On	2009	1	On	98.1	2.9	953	2.8
Pittsburgh, PA	2004	1	On	2008	1	On	99.5	4.8	947	−0.6
Portland, OR	2005	1	On	2009	1	On	100	1.6	984	1.0
Spokane, WA	2002	0.15	On	2007	0.15	On	100	1.0	1980	0.3
Syracuse, NY	2003	0.3	Off	2009	0.3	Off	99.6	2.0	976	−0.7
Tacoma, WA	2001	0.15	On	2005	0.15	On	100	8.6	914	−0.1

[a] Image (pixel) resolution.
[b] Percent of original points (land and water) that were able to be classified on both images. *n* – sample size – number of points not classified as permanent water points (classified as water in both years).

or herbaceous cover, bare soil, water, impervious (buildings), impervious (roads), or impervious (other). For the analysis of Albuquerque, NM, only, an eighth class of scrub/shrub was added due to the different vegetation cover morphology of that region. This class was included in the tree/shrub cover classification, but the scrub/shrub class results were also reported separately. Within Syracuse, which was one of the first cities analyzed, impervious other and impervious road categories were combined by the interpreter as was the grass/herbaceous and soil categories. In subsequent city analyses these categories were separated.

In interpreting change from aerial imagery, image parallax (tall objects appearing to lean on the image) and seasonal changes can appear to cause changes, but in fact are not actual changes. In these cases the interpreter could use judgment to determine if actual change did occur. In cases of tall object parallax, the interpreter's classification was based on the oldest image and if there was no change, both dates of imagery were classified the same. For example, tall objects (e.g., buildings and trees) may lean to the left in the first image, but lean to the right in the second image and a point may land on the object in the first image, but miss the object in the second image. The point classification would appear to change class, but no actual change would have occurred. Also agricultural fields can change cover class depending on time of year (herbaceous cover vs. bare soil depending upon time of imagery). These types of seasonal changes were classified as no change and classified as herbaceous cover. By conducting paired-point image analysis, the interpreter can correct these false changes to no change in the analysis. A five-percent random sample of points was reinterpreted by another photo-interpreter to check for classification accuracy. Overall, the two interpreters were in agreement on 97 percent of the classifications.

Within each city, the percentage of each cover class (p) was calculated as the number of sample points (x) hitting the cover attribute divided by the total number of interpretable sample points (n) within the area of analysis ($p = x/n$). The standard error of the estimate (SE) was calculated as $SE = \sqrt{p \times (1-p)/n}$ (Lindgren and McElrath, 1969). This method has been used to assess canopy cover in many cities (e.g., Nowak et al., 1996).

If changes in cover classes were observed at any point on the image then it is known that cover classes are changing within the city (i.e., no statistical test is needed to determine if change is greater than zero). However, as a cover class can both gain and lose cover through time and space, the McNemar test (Sokal and Rohlf, 2003) was used to determine if the net change in cover was different from zero (alpha levels 0.90 and 0.95). Pearson product moment correlation was used to test for a relationship between change in percent tree cover and change in population density among the 18 cities.

As the overall time frame of change in cover varied among cities from between 3 and 6 yr, change results were annualized for comparative purposes among cities. Results were combined with city area and population data from the year of the oldest photo date (U.S. Census Bureau, 2011) to determine actual tree and impervious cover change (ha) and cover change per capita in each city. Results of percent change were reported as absolute change (percent of city area that changed = cover change/city area) and relative change (percent of existing cover class that changed = cover change/original cover area). For example, a city with 30 percent tree cover that changed to 20 percent tree cover would have a 10 percent absolute change, but a 33 percent relative change.

As the 20 analyzed cities are not a truly random sample, an analysis of change in tree and impervious cover in urban areas across the conterminous United States was conducted using Google Earth® (Google, 2011) imagery to determine the relative magnitude of net change in urban tree and impervious cover. Urban land was defined based on population density as delimited using the U.S. Census Bureau's (2007) definition: all territory, population, and housing units located within urbanized areas or urban clusters. Urbanized area and urban cluster boundaries encompass densely settled territories, which are described by one of the following:

- one or more block groups or census blocks with a population density of at least 386.1 people/km^2 (1000 people/mile^2),
- surrounding census blocks with a minimum population density of 193.1 people/km^2 (500 people/mile^2), or
- less densely settled blocks that form enclaves or indentations, or are used to connect discontinuous areas.

In the conterminous United States, 1000 points randomly located within urban land were interpreted based on paired imagery from Google using the images with the most recent date and the next oldest interpretable imagery with the goal of trying to get the second set of imagery about 5 yr apart from the first set. Imagery date along with cover class was recorded for each point. This type of analysis of change with Google imagery has varying date issues that were not encountered with the paired city imagery, but does give a general indication of direction and magnitude of change nationally. Analysis of Google imagery was similar to the city imagery in terms of non-interpretable images and adjusting for misregistered images. However, Google imagery could also not be interpreted in some locations due to poor image resolution. Overall, 97 percent of the points could be interpreted using Google imagery.

Results

Of the 20 cities analyzed, tree cover ranged from 53.9 percent in Atlanta to 9.6 percent in Denver; building impervious cover ranged from 27.1 percent in Chicago to 4.8 percent in Kansas City; road and other impervious cover ranged from 36.2 percent in Miami to 12.3 percent in Nashville; and total impervious cover varied from 61.1 percent in New York City to 17.7 percent in Nashville (Table 2). Two cover classes – tree/shrub and bare soil generally exhibited a reduction in percent cover, while the other land classes generally exhibited an increase in cover.

Change in tree cover during the varying periods of analysis ranged from reduction in percent tree cover of −9.6 in New Orleans to an increase in percent tree cover of 1.0 in Syracuse (Table 3). Nineteen of the 20 cities analyzed showed a reduction in tree cover, 17 of those cities had a statistically significant net reduction. Average change was calculated for all 20 cities and for 18 cities – excluding the two cities (New Orleans and Detroit) that were targeted due to an expected loss in tree cover. Percent tree cover dropped on average by 1.1 percent during the varying periods of analysis (1.5 percent for 20 city average) with the greatest decreases in percent tree cover in New Orleans (−9.6 percent), Houston (−3.0 percent) and Albuquerque (−2.7 percent). The relative reduction in tree cover was as high as −29.2 percent in New Orleans, but averaged −3.8 percent (−5.0 percent for 20 city average).

Cities with the greatest annual loss in tree cover were New Orleans (average of −1120 ha/yr), Houston (−890 ha/yr) and Albuquerque (−420 ha/yr) (Table 3). Tree cover losses per capita were greatest in New Orleans (−24.6 m^2/person/yr), Albuquerque (−8.3 m^2/person/yr) and Nashville (−5.3 m^2/person/yr) with an average loss of −1.9 m^2/person/yr (−3.0 m^2/person/yr for 20 city average). Average annual loss in percent tree cover was −0.27 percent/yr (−0.37 percent/yr for 20 city average). Relative annual loss in tree cover was −0.90 percent/yr (−1.29 percent/yr for 20 city average). Loss of tree cover was slightly correlated to increased population density in the 18 cities (Pearson product moment correlation coefficient (r) = −0.31).

Table 2
Change of percent of city land area occupied by various cover classes in 20 U.S. cities.

City	1st year cover class	2nd year cover class							1st year	
		Grass/herb[a]	Tree/shrub	Imp. bldg[b]	Imp. road[c]	Imp. other[d]	Water	Soil	Total	SE
Albuquerque, NM (2006–2009)[e]	Grass/herb	8.8	0.1	0.1	0.0	0.1	0.0	0.0	9.1	0.9
	Tree/shrub	0.4	38.0	0.0	0.0	0.4	0.0	2.0	40.8	1.6
	Imp. bldg	0.1	0.0	11.9	0.0	0.0	0.0	0.0	12.0	1.0
	Imp. road	0.0	0.0	0.0	9.4	0.0	0.0	0.0	9.4	0.9
	Imp. other	0.0	0.0	0.0	0.0	13.9	0.0	0.0	13.9	1.1
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.4	0.0	0.5	0.3	0.5	0.0	13.0	14.7	1.1
	2nd year total	9.7	38.1	12.5	9.7	14.9	0.0	15.0		
	2nd year SE	0.9	1.5	1.0	0.9	1.1	0.0	1.1		
	Net (2006–2009)	0.6	−2.7	0.5	0.3	1.0	0.0	0.3		
Atlanta, GA (2005–2009)	Grass/herb	15.1	0.4	0.1	0.0	0.3	0.0	0.6	16.5	1.2
	Tree/shrub	1.0	51.6	0.4	0.1	0.3	0.0	0.5	53.9	1.6
	Imp. bldg	0.0	0.0	9.6	0.0	0.1	0.0	0.1	9.8	0.9
	Imp. road	0.0	0.0	0.0	7.4	0.0	0.0	0.0	7.4	0.8
	Imp. other	0.0	0.0	0.1	0.0	9.2	0.0	0.0	9.3	0.9
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	1.3	0.1	0.2	0.2	0.2	0.0	1.1	3.1	0.6
	2nd year total	17.5	52.1	10.4	7.7	10.1	0.0	2.3		
	2nd year SE	1.2	1.6	1.0	0.8	1.0	0.0	0.5		
	Net (2005–2009)	0.9	−1.8	0.6	0.3	0.8	0.0	−0.8		
Baltimore, MD (2001–2005)	Grass/herb	22.2	0.1	0.2	0.0	0.7	0.0	0.3	23.5	0.9
	Tree/shrub	0.9	28.4	0.4	0.1	0.5	0.0	0.1	30.4	1.0
	Imp. bldg	0.0	0.0	15.3	0.0	0.0	0.0	0.3	15.6	0.8
	Imp. road	0.0	0.0	0.0	10.9	0.0	0.0	0.0	11.0	0.7
	Imp. other	0.0	0.0	0.0	0.0	16.8	0.0	0.2	17.1	0.8
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.1	0.0	0.3	0.0	0.3	0.0	1.6	2.3	0.3
	2nd year total	23.2	28.5	16.3	11.0	18.5	0.0	2.5		
	2nd year SE	0.9	1.0	0.8	0.7	0.8	0.0	0.3		
	Net (2001–2005)	−0.4	−1.9	0.7	0.0	1.3	0.0	0.2		
Boston, MA (2003–2008)	Grass/herb	17.8	0.5	0.1	0.0	0.6	0.0	0.1	19.1	1.3
	Tree/shrub	0.6	27.1	0.6	0.2	0.1	0.0	0.2	28.9	1.5
	Imp. bldg	0.1	0.0	16.5	0.0	0.1	0.0	0.0	16.7	1.3
	Imp. road	0.0	0.0	0.0	12.5	0.0	0.0	0.0	12.5	1.1
	Imp. other	0.2	0.2	0.0	0.1	18.4	0.0	0.0	19.0	1.3
	Water	0.1	0.0	0.0	0.0	0.0	0.0	0.7	0.8	0.3
	Soil	0.5	0.1	0.1	0.1	0.5	0.0	1.7	3.0	0.6
	2nd year total	19.4	27.9	17.3	13.0	19.7	0.0	2.8		
	2nd year SE	1.3	1.5	1.3	1.1	1.4	0.0	0.6		
	Net (2003–2008)	0.2	−0.9	0.6	0.5	0.7	−0.8	−0.2		
Chicago, IL (2005–2009)	Grass/herb	20.0	0.0	0.0	0.0	0.3	0.1	0.4	20.8	1.3
	Tree/shrub	0.3	18.0	0.1	0.0	0.0	0.0	0.1	18.5	1.2
	Imp. bldg	0.4	0.0	26.5	0.0	0.1	0.0	0.1	27.1	1.4
	Imp. road	0.0	0.0	0.0	12.1	0.0	0.0	0.0	12.1	1.0
	Imp. other	0.0	0.0	0.2	0.0	19.1	0.0	0.0	19.3	1.3
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.0	0.0	0.0	0.0	0.1	0.1	2.0	2.2	0.5
	2nd year total	20.7	18.0	26.8	12.1	19.6	0.2	2.6		
	2nd year SE	1.3	1.2	1.4	1.0	1.3	0.1	0.5		
	Net (2005–2009)	−0.1	−0.5	−0.3	0.0	0.3	0.2	0.4		
Denver, CO (2005–2009)	Grass/herb	41.1	0.0	0.1	0.0	0.3	0.0	0.9	42.4	1.6
	Tree/shrub	0.1	9.6	0.1	0.0	0.1	0.0	0.0	9.9	1.0
	Imp. bldg	0.0	0.0	12.8	0.0	0.0	0.0	0.1	12.9	1.1
	Imp. road	0.0	0.0	0.1	12.5	0.0	0.0	0.0	12.6	1.1
	Imp. other	0.2	0.0	0.2	0.1	13.9	0.0	0.1	14.5	1.1
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.8	0.0	0.1	0.1	1.0	0.2	5.5	7.7	0.9
	2nd year total	42.2	9.6	13.4	12.7	15.3	0.2	6.6		
	2nd year SE	1.6	0.9	1.1	1.1	1.1	0.1	0.8		
	Net (2005–2009)	−0.2	−0.3	0.5	0.1	0.8	0.2	−1.1		
Detroit, MI (2005–2009)	Grass/herb	27.9	0.1	0.0	0.0	0.2	0.0	0.3	28.5	1.4
	Tree/shrub	0.1	22.3	0.1	0.2	0.4	0.0	0.1	23.2	1.3
	Imp. bldg	0.1	0.0	17.1	0.0	0.0	0.0	0.0	17.2	1.2
	Imp. road	0.0	0.0	0.0	14.7	0.0	0.0	0.0	14.7	1.1

Table 2 (*Continued*)

City	1st year cover class	2nd year cover class							1st year	
		Grass/herb[a]	Tree/shrub	Imp. bldg[b]	Imp. road[c]	Imp. other[d]	Water	Soil	Total	SE
	Imp. other	0.0	0.0	0.1	0.0	14.5	0.0	0.0	14.6	1.1
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.2	0.1	0.1	0.0	0.3	0.0	1.2	1.9	0.4
	2nd year total	28.3	22.5	17.4	14.9	15.4	0.0	1.6		
	2nd year SE	1.4	1.3	1.2	1.1	1.1	0.0	0.4		
	Net (2005–2009)	−0.2	−0.7	0.2	0.2	0.8	0.0	−0.3		
Houston, TX (2004–2009)	Grass/herb	28.7	0.0	0.5	0.0	0.5	0.2	0.2	30.1	1.5
	Tree/shrub	1.4	27.4	0.3	0.1	0.2	0.1	0.8	30.3	1.5
	Imp. bldg	0.0	0.0	13.5	0.0	0.0	0.0	0.2	13.7	1.1
	Imp. road	0.0	0.0	0.0	12.0	0.0	0.0	0.0	12.0	1.0
	Imp. other	0.1	0.0	0.1	0.0	11.8	0.0	0.1	12.2	1.0
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.4	0.0	0.0	0.0	0.1	0.0	1.2	1.7	0.4
	2nd year total	30.6	27.4	14.4	12.1	12.7	0.3	2.6		
	2nd year SE	1.5	1.4	1.1	1.0	1.1	0.2	0.5		
	Net (2004–2009)	0.5	−3.0	0.7	0.1	0.5	0.3	0.8		
Kansas City, MO (2003–2009)	Grass/herb	48.5	0.5	0.2	0.3	0.7	0.1	0.3	50.7	1.6
	Tree/shrub	1.1	27.5	0.0	0.1	0.0	0.0	0.5	29.2	1.4
	Imp. bldg	0.0	0.0	4.6	0.0	0.2	0.0	0.0	4.8	0.7
	Imp. road	0.0	0.0	0.0	6.3	0.0	0.0	0.0	6.3	0.8
	Imp. other	0.0	0.0	0.2	0.1	6.8	0.0	0.0	7.1	0.8
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.2	0.0	0.0	0.0	0.7	0.0	1.0	1.9	0.4
	2nd year total	49.8	28.0	5.0	6.8	8.4	0.1	1.8		
	2nd year SE	1.6	1.4	0.7	0.8	0.9	0.1	0.4		
	Net (2003–2009)	−0.8	−1.2	0.2	0.5	1.3	0.1	−0.1		
Los Angeles, CA (2005–2009)	Grass/herb	21.0	0.0	0.3	0.0	0.2	0.0	0.3	21.8	1.3
	Tree/shrub	0.4	20.6	0.2	0.0	0.3	0.0	0.0	21.5	1.3
	Imp. bldg	0.0	0.0	21.0	0.0	0.2	0.0	0.0	21.2	1.3
	Imp. road	0.0	0.0	0.0	14.7	0.0	0.0	0.0	14.7	1.1
	Imp. other	0.0	0.0	0.4	0.0	15.8	0.0	0.1	16.3	1.2
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.3	0.0	0.5	0.2	0.2	0.0	3.1	4.3	0.6
	2nd year total	21.7	20.6	22.4	14.9	16.7	0.0	3.5		
	2nd year SE	1.3	1.3	1.3	1.1	1.2	0.0	0.6		
	Net (2005–2009)	−0.1	−0.9	1.2	0.2	0.4	0.0	−0.8		
Miami, FL (2003–2009)	Grass/herb	14.2	0.2	0.1	0.1	0.6	0.0	0.1	15.3	1.2
	Tree/shrub	1.1	21.2	0.4	0.2	0.1	0.1	0.1	23.3	1.4
	Imp. bldg	0.3	0.0	23.5	0.0	0.0	0.0	0.1	23.9	1.4
	Imp. road	0.0	0.0	0.0	18.0	0.0	0.0	0.0	18.0	1.3
	Imp. other	0.2	0.2	0.6	0.0	17.0	0.0	0.1	18.1	1.3
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.0	0.0	0.2	0.0	0.2	0.0	1.0	1.4	0.4
	2nd year total	15.9	21.6	24.8	18.3	17.9	0.1	1.4		
	2nd year SE	1.2	1.4	1.4	1.3	1.3	0.1	0.4		
	Net (2003–2009)	0.6	−1.7	0.9	0.3	−0.2	0.1	0.0		
Minneapolis, MN (2003–2008)	Grass/herb	18.6	0.2	0.0	0.0	0.3	0.0	0.4	19.6	1.3
	Tree/shrub	1.0	33.7	0.1	0.2	0.1	0.0	0.0	35.1	1.6
	Imp. bldg	0.0	0.0	14.4	0.0	0.1	0.0	0.1	14.6	1.2
	Imp. road	0.0	0.1	0.0	12.3	0.0	0.0	0.0	12.4	1.1
	Imp. other	0.0	0.0	0.3	0.0	15.6	0.0	0.0	15.9	1.2
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.2	0.0	0.1	0.0	0.1	0.2	1.7	2.4	0.5
	2nd year total	19.8	34.1	14.9	12.5	16.2	0.2	2.3		
	2nd year SE	1.3	1.6	1.2	1.1	1.2	0.2	0.5		
	Net (2003–2008)	0.2	−1.1	0.3	0.1	0.3	0.2	−0.1		
Nashville, TN (2003–2008)	Grass/herb	28.3	0.4	0.1	0.1	0.0	0.0	0.3	29.2	1.4
	Tree/shrub	0.7	49.4	0.1	0.2	0.1	0.0	0.5	51.1	1.6
	Imp. bldg	0.0	0.0	5.4	0.0	0.0	0.0	0.0	5.4	0.7
	Imp. road	0.0	0.0	0.0	5.6	0.0	0.0	0.0	5.6	0.7
	Imp. other	0.0	0.0	0.0	0.0	6.7	0.0	0.0	6.7	0.8
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.4	0.0	0.2	0.0	0.3	0.1	0.9	1.9	0.4
	2nd year total	29.4	49.8	5.8	5.9	7.2	0.1	1.7		

Table 2 (*Continued*)

City	1st year cover class	2nd year cover class							1st year	
		Grass/herb[a]	Tree/shrub	Imp. bldg[b]	Imp. road[c]	Imp. other[d]	Water	Soil	Total	SE
	2nd year SE	1.4	1.6	0.7	0.8	0.8	0.1	0.4		
	Net (2003–2008)	0.2	−1.2	0.4	0.3	0.4	0.1	−0.2		
New Orleans, LA (2005–2009)	Grass/herb	22.7	0.0	0.0	0.0	0.2	0.4	0.7	24.0	1.8
	Tree/shrub	6.6	23.3	0.0	0.9	1.1	0.4	0.7	32.9	2.0
	Imp. bldg	1.4	0.0	14.6	0.0	0.4	0.0	0.4	16.7	1.6
	Imp. road	0.0	0.0	0.0	15.5	0.0	0.0	0.0	15.5	1.5
	Imp. other	0.2	0.0	0.0	0.0	9.1	0.0	0.0	9.2	1.2
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.2	0.0	0.0	0.0	0.2	0.0	1.4	1.8	0.6
	2nd year total	31.1	23.3	14.6	16.3	10.8	0.7	3.2		
	2nd year SE	2.0	1.8	1.5	1.6	1.3	0.4	0.7		
	Net (2005–2009)	7.1	−9.6	−2.1	0.9	1.6	0.7	1.4		
New York, NY (2004–2009)	Grass/herb	14.9	0.1	0.2	0.0	0.6	0.1	0.6	16.6	1.2
	Tree/shrub	1.2	19.3	0.0	0.2	0.2	0.0	0.0	20.9	1.3
	Imp. bldg	0.0	0.0	24.4	0.0	0.1	0.0	0.0	24.6	1.4
	Imp. road	0.0	0.0	0.0	16.1	0.0	0.0	0.0	16.1	1.2
	Imp. other	0.0	0.3	0.2	0.1	18.5	0.0	0.0	19.1	1.3
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
	Soil	0.5	0.0	0.3	0.0	0.1	0.0	1.8	2.7	0.5
	2nd year total	16.6	19.7	25.2	16.4	19.5	0.1	2.5		
	2nd year SE	1.2	1.3	1.4	1.2	1.3	0.1	0.5		
	Net (2004–2009)	0.0	−1.2	0.6	0.3	0.4	0.0	−0.2		
Pittsburgh, PA (2004–2008)	Grass/herb	16.9	0.0	0.0	0.0	0.1	0.0	0.1	17.1	1.2
	Tree/shrub	0.2	41.6	0.1	0.0	0.0	0.0	0.0	41.9	1.6
	Imp. bldg	0.0	0.0	14.7	0.0	0.1	0.0	0.1	14.9	1.2
	Imp. road	0.0	0.0	0.0	13.3	0.0	0.0	0.1	13.4	1.1
	Imp. other	0.0	0.0	0.1	0.0	11.6	0.0	0.0	11.7	1.0
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.1	0.0	0.0	0.0	0.0	0.0	0.8	1.0	0.3
	2nd year total	17.2	41.6	14.9	13.3	11.8	0.0	1.2		
	2nd year SE	1.2	1.6	1.2	1.1	1.0	0.0	0.3		
	Net (2004–2008)	0.1	−0.3	0.0	−0.1	0.1	0.0	0.2		
Portland, OR (2005–2009)	Grass/herb	21.4	0.3	0.3	0.1	0.3	0.0	0.2	22.7	1.3
	Tree/shrub	0.7	30.4	0.1	0.0	0.3	0.0	0.0	31.5	1.5
	Imp. bldg	0.2	0.1	14.4	0.0	0.0	0.0	0.0	14.7	1.1
	Imp. road	0.0	0.0	0.0	12.5	0.0	0.0	0.0	12.5	1.1
	Imp. other	0.0	0.1	0.1	0.0	15.8	0.0	0.0	16.0	1.2
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	0.6	0.0	0.2	0.1	0.5	0.0	1.2	2.6	0.5
	2nd year total	23.0	30.9	15.1	12.7	16.9	0.0	1.4		
	2nd year SE	1.3	1.5	1.1	1.1	1.2	0.0	0.4		
	Net (2005–2009)	0.3	−0.6	0.4	0.2	0.9	0.0	−1.2		
Spokane, WA (2002–2007)	Grass/herb	24.0	0.7	0.2	0.1	0.4	0.0	1.7	27.1	1.0
	Tree/shrub	0.5	20.6	0.2	0.0	0.1	0.0	1.1	22.4	0.9
	Imp. bldg	0.0	0.0	12.0	0.0	0.1	0.0	0.0	12.1	0.7
	Imp. road	0.0	0.0	0.0	11.1	0.0	0.0	0.1	11.1	0.7
	Imp. other	0.1	0.0	0.0	0.0	10.5	0.0	0.1	10.6	0.7
	Water	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1
	Soil	1.3	0.5	0.5	0.2	0.7	0.0	13.6	16.7	0.8
	2nd year total	25.9	21.8	12.8	11.4	11.6	0.0	16.5		
	2nd year SE	1.0	0.9	0.8	0.7	0.7	0.0	0.8		
	Net (2002–2007)	−1.2	−0.6	0.8	0.3	1.0	−0.1	−0.2		
Syracuse, NY (2003–2009)[f]	Grass/herb	21.7	1.6	0.1	0.6	na	0.0	na	24.1	1.4
	Tree/shrub	0.5	25.0	0.1	0.3	na	0.0	na	25.9	1.4
	Imp. bldg	0.7	0.0	18.9	0.1	na	0.0	na	19.7	1.3
	Imp. road	0.6	0.3	0.2	29.2	na	0.0	na	30.3	1.5
	Imp. other	na	na	na	na	na	0.0	na	na	na
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	na	na	na	na	na	0.0	na	na	na
	2nd year total	23.6	26.9	19.3	30.2	na	0.0	na		
	2nd year SE	1.4	1.4	1.3	1.5	na	0.0	na		
	Net (2003–2009)	−0.5	1.0	−0.4	−0.1	na	0.0	na		
Tacoma, WA (2001–2005)	Grass/herb	24.8	1.2	0.1	0.1	0.8	0.0	0.1	27.1	1.5
	Tree/shrub	1.8	21.3	0.1	0.0	0.8	0.0	0.4	24.4	1.4

Table 2 (*Continued*)

City	1st year cover class	2nd year cover class							1st year	
		Grass/herb[a]	Tree/shrub	Imp. bldg[b]	Imp. road[c]	Imp. other[d]	Water	Soil	Total	SE
	Imp. bldg	0.2	0.0	13.2	0.0	0.3	0.0	0.2	14.0	1.1
	Imp. road	0.0	0.0	0.0	12.5	0.0	0.0	0.0	12.5	1.1
	Imp. other	0.0	0.1	0.1	0.1	13.8	0.0	0.1	14.2	1.2
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Soil	1.3	0.3	0.3	0.1	2.0	0.3	3.4	7.8	0.9
	2nd year total	28.1	23.0	13.9	12.8	17.6	0.3	4.3		
	2nd year SE	1.5	1.4	1.1	1.1	1.3	0.2	0.7		
	Net (2001–2005)	1.0	−1.4	−0.1	0.3	3.4	0.3	−3.5		
Average 20 cities[g]	Grass/herb	23.0	0.3	0.1	0.0	0.4	0.0	0.4	24.3	na
	Tree/shrub	1.1	27.8	0.2	0.1	0.3	0.0	0.4	29.9	na
	Imp. bldg	0.2	0.0	15.2	0.0	0.1	0.0	0.1	15.6	na
	Imp. road	0.0	0.0	0.0	12.1	0.0	0.0	0.0	12.1	na
	Imp. other	0.1	0.1	0.1	0.0	13.6	0.0	0.0	13.9	na
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	na
	Soil	0.5	0.1	0.2	0.1	0.4	0.1	3.0	4.3	na
	2nd year total	24.7	28.2	15.9	12.3	14.8	0.1	4.0		
	2nd year SE	na	na	na	na	na	na	na		
	Average net	0.5	−1.5	0.3	0.3	0.8	0.1	−0.3		
Average 18 cities[h]	Grass/herb	22.7	0.3	0.2	0.0	0.4	0.0	0.4	24.0	na
	Tree/shrub	0.8	28.4	0.2	0.1	0.2	0.0	0.4	30.0	na
	Imp. bldg	0.1	0.0	15.1	0.0	0.1	0.0	0.1	15.4	na
	Imp. road	0.0	0.0	0.0	11.7	0.0	0.0	0.0	11.7	na
	Imp. other	0.1	0.1	0.2	0.0	13.8	0.0	0.0	14.2	na
	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	na
	Soil	0.5	0.1	0.2	0.1	0.4	0.1	3.2	4.6	na
	2nd year total	24.2	28.8	15.9	12.0	15.0	0.1	4.2		
	2nd year SE	na	na	na	na	na	na	na		
	Average net	0.1	−1.1	0.4	0.2	0.8	0.0	−0.4		

SE – standard error. Net – net difference between the years (2nd year – 1st year).

[a] Grass and other herbaceous ground cover.

[b] Impervious cover occupied by buildings.

[c] Impervious cover occupied by roads.

[d] Other impervious cover (e.g., sidewalks, driveways, and parking lots).

[e] Scrub/shrub/chaparral was a cover class only measured in Albuquerque, NM, and is included in tree/shrub cover. This cover class occupied 31.6 percent of the city area in 2006 and dropped to 29.4 percent in 2009, a loss of 2.2 percent of the city area.

[f] Soil cover is included in grass and herbaceous cover; impervious other is included in impervious road.

[g] Results from Syracuse are not included in average of grass/herbaceous, impervious road, impervious other or soil (see table footnote f).

[h] Average result not including New Orleans or Detroit as these cities were specifically selected due to expected losses from hurricane and emerald ash borer damage respectively. Results from Syracuse are not included in average of grass/herbaceous, impervious road, impervious other or soil (see table footnote f).

Most of the loss of tree cover converted to grass/herbaceous cover (47 percent), followed by conversions to impervious cover (29 percent) and bare soil (23 percent) (Table 2). Likewise, new cover most often converted from grass/herbaceous cover (68 percent), followed by impervious cover (17 percent) and bare soil (14 percent). Only one city (Syracuse) exhibited an overall increase in tree cover, with most of this increase coming from grass/herbaceous cover.

Change in percent impervious cover during the varying periods of analysis ranged from an increase of 3.6 percent in Tacoma to a decrease in percent impervious cover of −0.5 in Syracuse (Table 3). Seventeen of the 20 cities analyzed showed an increase in net impervious cover, 16 of those cities had a statistically significant increase. Four cities exhibited small changes in net impervious cover that were not statistically significant from zero (Syracuse, Chicago, Pittsburgh, New Orleans). Percent impervious cover increased on average by 1.4 percent during the varying periods of analysis (1.3 percent for 20 city average) with the greatest increases in percent impervious cover in Tacoma (3.6 percent), Baltimore (2.1 percent) and Kansas City and Spokane (2.0 percent each). The relative increase in impervious cover was as high as 11.2 percent in Kansas City, but averaged 3.9 percent (3.7 percent for 20 city average).

Cities with the greatest annual increase in impervious cover were Los Angeles (average of 550 ha/yr), Houston (400 ha/yr) and Albuquerque (280 ha/yr) (Table 3). Impervious cover increases per capita were greatest in Tacoma (6.0 m^2/person/yr), Kansas City (5.9 m^2/person/yr) and Albuquerque (5.5 m^2/person/yr) with an average increase of 2.2 m^2/person/yr (2.1 m^2/person/yr for 20 city average). Average annual increase in percent impervious cover was 0.31 percent/yr (0.30 percent/yr for 20 city average). Relative annual increase in impervious cover was 0.87 percent/yr (0.82 percent/yr for 20 city average).

The analysis of the 20 cities shows a general loss in tree cover and increase in impervious cover in the mid to late 2000s. This overall trend of change was also exhibited in the results of national urban land cover change using Google Earth imagery. Of the 1000 random paired-points laid throughout the conterminous urban United States, 970 points were interpretable, with average length of time between points of 6.4 yr. The most recent imagery had an average year of 2009, but ranged between 2004 and 2011. The older paired image year averaged 2002 with a range of 1990–2006. Tree cover increases between images averaged 2.1 percent (SE = 0.5 percent) with average losses of −2.3 percent (SE = 0.5 percent) for an average net change in tree cover of −0.2 percent. Impervious cover increases between images averaged 3.2 percent (SE = 0.6 percent)

Table 3
Percent net and annualized net absolute and relative tree and impervious cover change in 20 U.S. cities. Absolute percent change is based on city land area between the years (percent of city land in year 1 minus percent of city land in year 2). Relative percent change is based on amount of cover in year 1 (percent of city in year 1 minus percent of city in year 2 divided by percent of city in year 1). Annualized change is percent change during time period on an annual basis. Per capita change estimates are based on population in the first year of analysis.

City	Net				Tree cover change		Impervious cover change		Annualized net			
	Absolute change		Relative change		ha/yr[c]	m^2/cap/yr[d]	ha/yr[c]	m^2/cap/yr[d]	Absolute change		Relative change	
	Tree[a]	Imp.[b]	Tree[a]	Imp.[b]					Tree[a]	Imp.[b]	Tree[a]	Imp.[b]
New Orleans, LA (2005–2009)	−9.6**	0.4	−29.2**	0.9	−1120	−24.6	40	0.9	−2.49	0.09	−8.27	0.21
Houston, TX (2004–2009)	−3.0**	1.3**	−9.8**	3.5**	−890	−4.3	400	1.9	−0.60	0.26	−2.03	0.69
Albuquerque, NM (2006–2009)	−2.7**	1.8**	−6.6**	5.1**	−420	−8.3	280	5.5	−0.91	0.60	−2.26	1.67
Baltimore, MD (2001–2005)	−1.9**	2.1**	−6.3**	4.7**	−100	−1.5	110	1.7	−0.48	0.51	−1.62	1.16
Atlanta, GA (2005–2009)	−1.8**	1.7**	−3.4**	6.5**	−150	−3.1	150	3.1	−0.46	0.43	−0.85	1.58
Miami, FL (2003–2009)	−1.7**	1.0*	−7.1**	1.7*	−30	−0.8	20	0.5	−0.28	0.16	−1.22	0.27
Tacoma, WA (2001–2005)	−1.4**	3.6**	−5.8**	8.9**	−50	−2.6	117	6.0	−0.36	0.89	−1.49	2.15
Kansas City, MO (2003–2009)	−1.2**	2.0**	−4.2**	11.2**	−160	−3.5	270	5.9	−0.20	0.34	−0.71	1.78
Nashville, TN (2003–2008)	−1.2**	1.1**	−2.4**	6.2**	−300	−5.3	270	4.8	−0.24	0.22	−0.48	1.21
New York, NY (2004–2009)	−1.2**	1.4**	−5.5**	2.3**	−180	−0.2	210	0.3	−0.23	0.27	−1.13	0.45
Minneapolis, MN (2003–2008)	−1.1**	0.8**	−3.1**	1.8**	−30	−0.8	20	0.5	−0.22	0.15	−0.63	0.35
Boston, MA (2003–2008)	−0.9*	1.7**	−3.2*	3.6**	−20	−0.3	40	0.7	−0.19	0.35	−0.65	0.71
Los Angeles, CA (2005–2009)	−0.9**	1.8**	−4.2**	3.4**	−270	−0.7	550	1.4	−0.23	0.45	−1.06	0.85
Detroit, MI (2005–2009)	−0.7**	1.2**	−3.0**	2.6**	−60	−0.7	110	1.2	−0.18	0.30	−0.77	0.64
Portland, OR (2005–2009)	−0.6	1.5**	−1.9	3.5**	−50	−0.9	130	2.4	−0.15	0.38	−0.49	0.87
Spokane, WA (2002–2007)	−0.6	2.0**	−2.5	5.8**	−20	−1.0	60	3.0	−0.11	0.39	−0.50	1.14
Chicago, IL (2005–2009)	−0.5**	0.0	−2.7**	0.0	−70	−0.2	0	0.0	−0.13	0.00	−0.69	0.00
Pittsburgh, PA (2004–2008)	−0.3*	0.0	−0.8*	0.0	−10	−0.3	0	0.0	−0.08	0.00	−0.19	0.00
Denver, CO (2005–2009)	−0.3*	1.4**	−3.1*	3.6**	−30	−0.5	140	2.5	−0.08	0.35	−0.78	0.88
Syracuse, NY (2003–2009)	1.0*	−0.5	4.0*	−1.0	10	0.7	−6	−0.4	0.17	−0.09	0.65	−0.17
20 city average	−1.5	1.3	−5.0	3.7		−3.0		2.1	−0.37	0.30	−1.29	0.82
18 city average[e]	−1.1	1.4	−3.8	3.9		−1.9		2.2	−0.27	0.31	−0.90	0.87

[a] Percent tree and shrub cover (including shrub/scrub/chaparral cover in Albuquerque, NM).
[b] Percent impervious surfaces (building, roads and other combined).
[c] Average annual change in hectares per year.
[d] Average annual change in square meters per capita per year.
[e] Average result not including New Orleans or Detroit as these cities were specifically selected due to expected losses from hurricane and emerald ash borer damage respectively.
* Change significantly different from zero at alpha = 0.90.
** Change significantly different from zero at alpha = 0.95.

with average losses of −0.4 percent (SE = 0.2 percent) for an average net change in impervious cover of +2.8 percent.

Discussion

While cities expend resources to plant millions of new trees, land development, storms, old age and other factors are reducing the number of older, established trees in cities. Though current planting campaigns may increase tree cover now and in the future, recent trends indicate that tree cover is decreasing in many U.S. cities. Tree cover is decreasing at a rate of about 0.27 percent of the city land area per year, which is equivalent to about 0.9 percent of the existing tree cover being lost annually.

The tree cover loss in the analyzed cities was higher than the average tree cover loss for urban land in the conterminous United States by a factor of about 6 (1.1 vs. 0.2 percent over the varying time frames). This difference is likely because these analyzed cities do not represent the entire urban area. The selected cities are relatively major cities with increased population densities and likely increased development pressures when compared with the average urban landscape, which includes many smaller, less densely populated areas. These city boundaries, which are often in forested regions, can also include non-urban lands that may have a high likelihood for development and therefore loss of tree cover and increased impervious cover. The change effects in these cities are likely more representative of change in major cities than the national urban change estimates.

Using the national tree cover loss estimate of 0.2 percent of urban land over about a 6 yr period, which equates to about 1/30 of a percent per year, a first order approximation of tree cover loss in urban areas of the conterminous United States is a loss rate of about 7900 ha of urban tree cover per year. Given an average tree density per unit of urban tree cover of approximately 508 trees/ha (average from Cumming et al., 2007; Nowak et al., 2007, in press-a, in press-b; Nowak and Greenfield, 2008; unpublished data), this loss equates to an annual net loss of about 4.0 million trees per year in urban areas of the conterminous United States. This estimate of number of trees lost may be excessive as much of canopy loss may be due to loss of mature trees that would have a lower tree density per unit canopy than the average urban forest, but further research is needed to understand the composition and size class distribution of the canopy loss. Although tree planting and natural regeneration are occurring in urban areas, net tree cover is on a general decline in urban areas of the United States. Tree canopy loss of mature trees, for whatever reason (storms, insects, development, old age), can create relatively large gaps in the canopy cover that will require new tree plantings or regeneration and time to fill.

It is apparent that tree planting and natural regeneration are insufficient to offset the current losses of established urban tree canopies. However, without various tree planting efforts in cities, tree cover loss would be higher. Efforts to facilitate more natural regeneration in cities (e.g., limits on mowing) may also be needed to sustain tree cover. Natural regeneration may not work in all locations (e.g., water limited areas) or produce desired tree species, but it can provide for relatively low cost tree/shrub establishment. Similarly, tree planting may not be appropriate in all cities (e.g., water limited areas) due to the resource costs of maintaining vegetation (e.g., water). Sustaining tree cover not only includes establishing new trees, but also limiting the loss of existing canopy, particularly large trees that provide substantial amounts of canopy per tree. Sustaining tree health and protection of healthy tree canopies from human removal (e.g., development) or natural mortality forces (e.g., insects and diseases) can also help sustain existing tree cover and associated environmental services.

Though the current trend is a decline in canopy cover, not all cities are losing tree cover. One of the 20 cities analyzed (Syracuse, NY) had an absolute increase in canopy cover of one percent, or 0.2 percent increase per year, with most of the tree cover increase occurring in grass/herbaceous areas. This increase in tree cover matches field data estimates of urban forest change in Syracuse (U.S. Forest Service, unpublished data) that shows that the number of trees (woody plants with stem diameter at 1.37 m greater than 2.54 cm) are increasing. This increase is dominated by European buckthorn (*Rhamnus cathartica* L.), an invasive small tree/shrub from Europe. Thus, the cover increase in Syracuse is most likely due to natural regeneration in concert with limited development or activities that would tend to reduce regeneration.

New Orleans, as expected, had a significant reduction in tree cover (−9.6 percent absolute reduction or −29.2 percent relative reduction), which is most likely due to the devastation of Hurricane Katrina in 2005 (e.g., Chapman et al., 2008). In contrast, the loss in tree cover due to the emerald ash borer in Detroit was lower than expected. Since 2002, this beetle has killed more than 30 million ash trees in Southeastern Michigan (US Forest Service et al., 2011). However, the loss of tree cover in Detroit (−0.18 percent absolute annual reduction or −0.77 percent relative annual reduction) was less than the average loss from the sampled cities (−0.27 percent absolute annual reduction or −0.90 percent relative annual reduction). This difference could be due to ash trees not comprising a major component of overall tree cover in Detroit and/or new trees being established through tree planting programs or natural regeneration that help offset the loss of ash and other trees.

Overall, most of the tree losses converted to grass/herbaceous cover (47 percent) or impervious cover (29 percent), while most of the gain of new tree cover also came from grass/herbaceous cover (68 percent) or impervious cover (17 percent). Some of the conversions from tree to impervious cover are due to development, but are also due to impervious cover being beneath trees. When trees are removed, the ground surface beneath the trees switches to the new cover class. Likewise, as trees cover ground surfaces, additional tree cover can tend to reduce impervious cover estimates when trees grow over the impervious surfaces.

Of the overall average increase in impervious cover, about 29 percent of that change was due to changes with loss of tree cover. That 29 percent of newly classified impervious cover is a combination of new development and exposure of existing impervious cover beneath trees. However, at least 71 percent of the impervious cover increase was due to new development. Some cities (i.e., Chicago, Pittsburgh) exhibited no net change in impervious cover during the analysis period, but did exhibit increases and decreases in impervious cover that offset each other. Syracuse exhibited a decrease in impervious cover, which may be, in part, due to the overall increase in tree cover. However, most of the changes in impervious cover in Syracuse occurred with grass/herbaceous cover. New Orleans also lost a substantial amount of building cover (2.1 percent absolute reduction), most likely due to damage from Hurricane Katrina (e.g., Kates et al., 2006).

A better understanding of how tree cover and tree populations are changing can aid managers in developing regeneration or canopy protection plans to sustain adequate tree cover through time and space. Photo-interpretation of paired digital images offers a relatively easy, quick and low-cost means to statistically assess changes among various cover types. To help in quantifying the cover types within an area, a free tool (i-Tree Canopy) is available (www.itreetools.org) that allows users to photo-interpret a city using Google images. This program automatically quantifies the percent cover and associated standard error for each cover class based on user interpretations. Cover data on a city can provide a baseline for developing management plans, setting tree cover goals, and for monitoring change through time. Future analyses on cover distribution or change by land use type or geographic region are needed to investigate patterns and causes of tree and impervious cover changes between and within cities.

The paired digital image analysis offers a relatively quick, easy and cost-effective means to assess cover change, but it does have some limitations. Though Google offers high-resolution imagery in many parts of the world, paired image analysis with Google images is limited by the varying dates among images and varying image resolution. In urban areas, many of the Google images are of sufficient resolution for accurate photo-interpretation and images are continually updated. Obtaining local digital images with known and consistent dates across an area of analysis can overcome the problems associated with varying dates across a study area. Sometimes paired city data also had different image resolution between years, but most images were 1 m or less. As image interpretation was paired, information from the higher resolution image could aid in interpreting the lower resolution image. Another limitation of the paired image approach is the ability of the interpreter to correctly classify sample points. Interpreter error can lead to inaccurate results, but proper training and testing can produce accurate results. Satellite cover maps also have inherent inaccuracies due to classification errors and can cost tens of thousands of dollars to produce a cover map for a city. The paired photo-interpretation method offers a more cost effective means to assess change, but does not produce a detailed map of cover attributes or cover change across a city.

The results of this study illustrate recent changes in tree and impervious cover in cities and urban areas that can be used to inform planners and policy makers. To determine whether similar trends occurred in the 1990s or early 2000s, and whether these trends will continue in the future, more paired image analyses can be conducted using older paired imagery or by comparing future imagery with contemporary images. More paired image analyses can help better determine both spatial and temporal patterns and rates of landscape cover change. Photo-interpreted data on cover in urban areas and elsewhere can provide an accurate means of assessing cover types and changes in cover through time to help managers and planners make informed decisions on how to better improve local landscapes and the environment.

Conclusion

Tree cover provides a simple means to assess the magnitude of the overall urban forest and its environmental effects. Despite various and likely limited tree planting and protection campaigns, tree cover tends to be on the decline in U.S. cities while impervious cover is on the increase. While these individual campaigns are helping to increase or reduce the loss of urban tree cover, more widespread, comprehensive and integrated programs that focus on sustaining overall tree canopy may be needed to help reverse the trend of declining tree cover in cities. Net tree cover change is the result of the combined influences of tree planting and natural regeneration, tree growth and tree mortality. Developing coordinated healthy tree canopy programs across various land ownerships can help sustain desired tree cover levels and better manage cover change. Monitoring of tree cover changes is essential to determine current trends and whether desired canopy levels or program effects are being attained. Photo-interpretation of digital aerial images can provide a simple and timely means to assess urban tree cover and how it is changing.

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